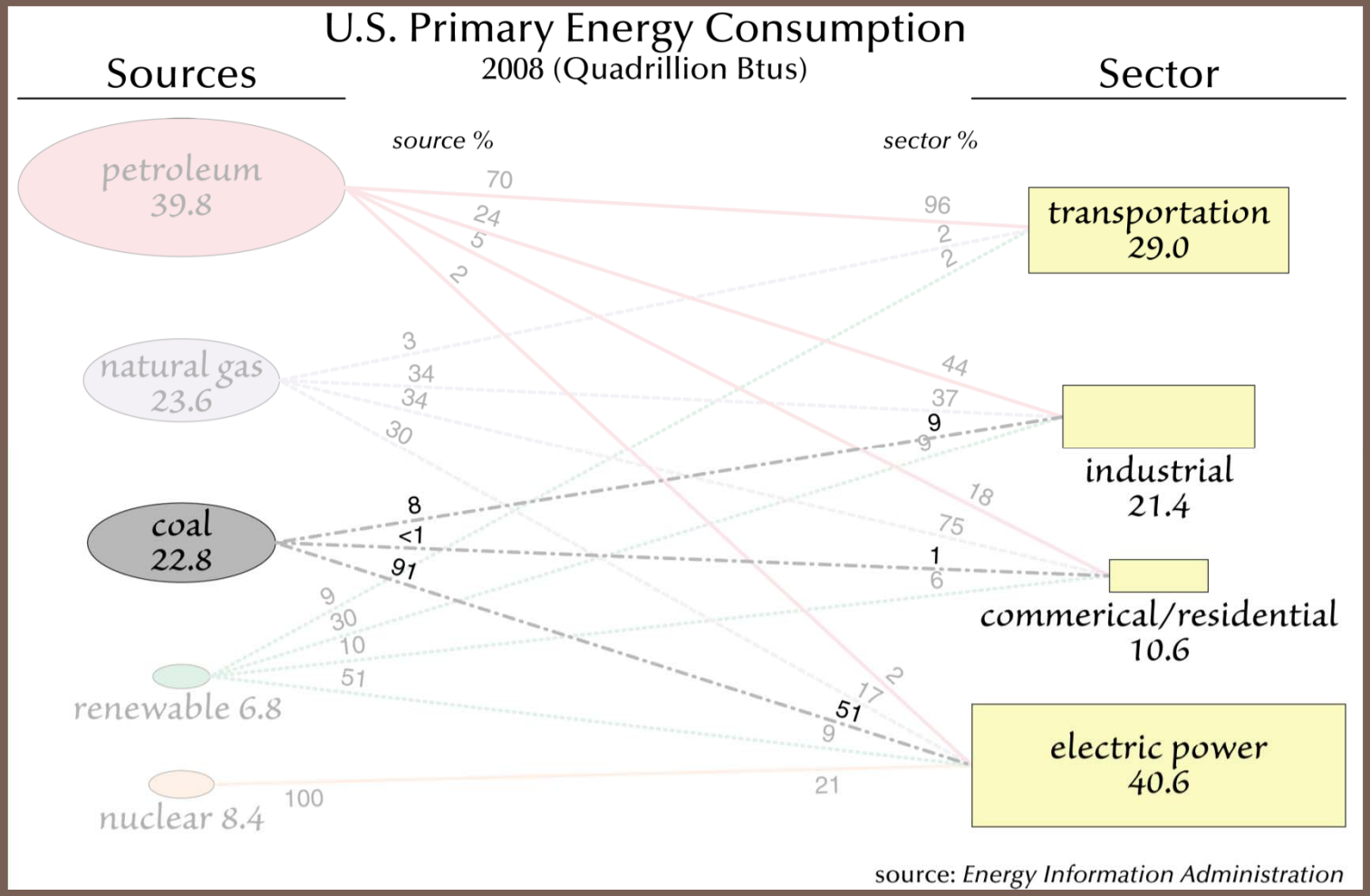
Coal and Electricity:

Kicking a Habit?

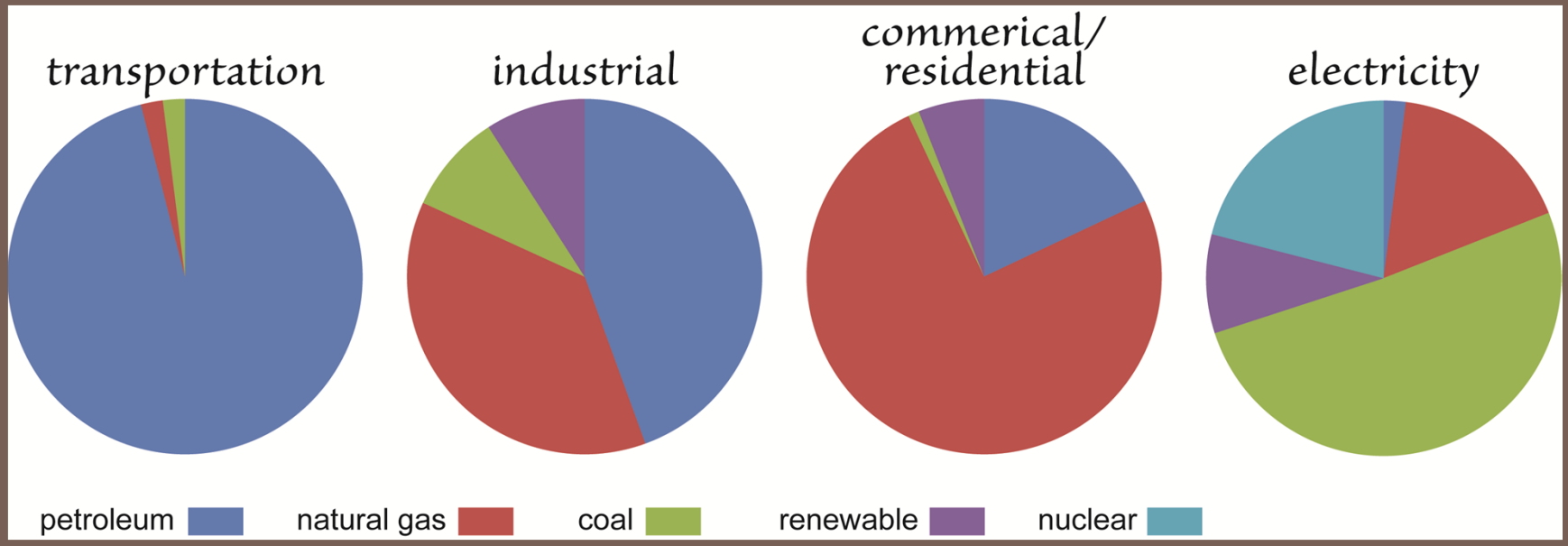
Coal and Electricity

U.S. Energy Sources/Sectors Mix



Coal and Electricity

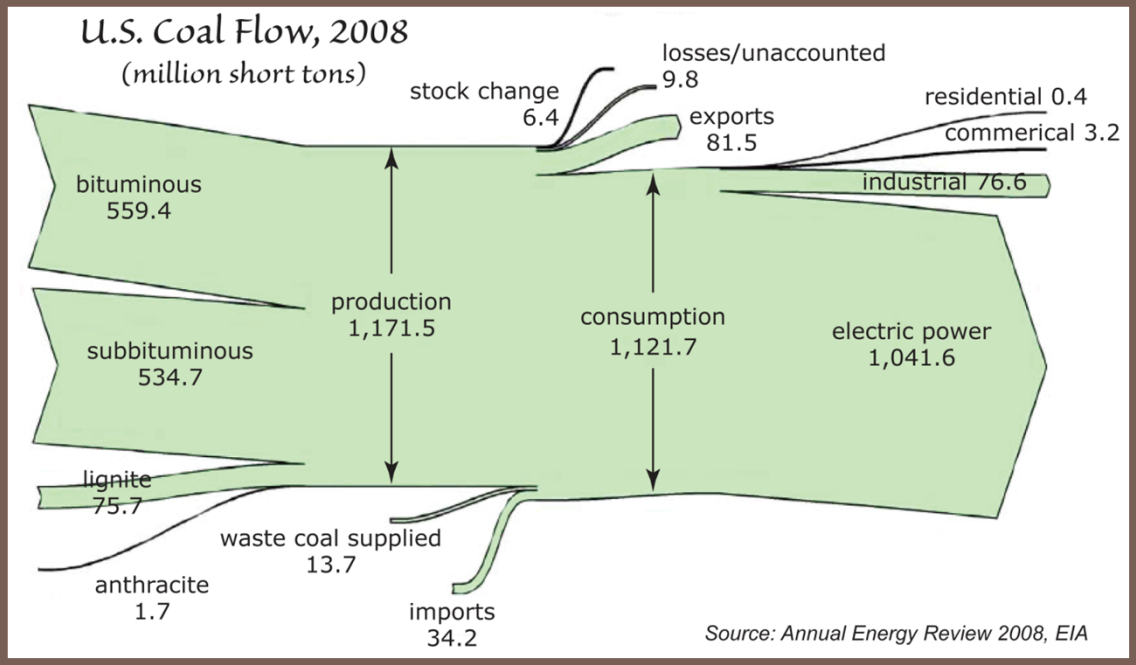
U.S. Coal Use by Sector



Coal and Electricity

U.S. Coal Use

- in 2008, total U.S. coal consumption was 1,172 million short tons
- electricity (1,042 million short tons) is greatest use
  - industrial is distant second (77 million short tons)
  - small amounts used for commercial (3.2) and residential (0.4)



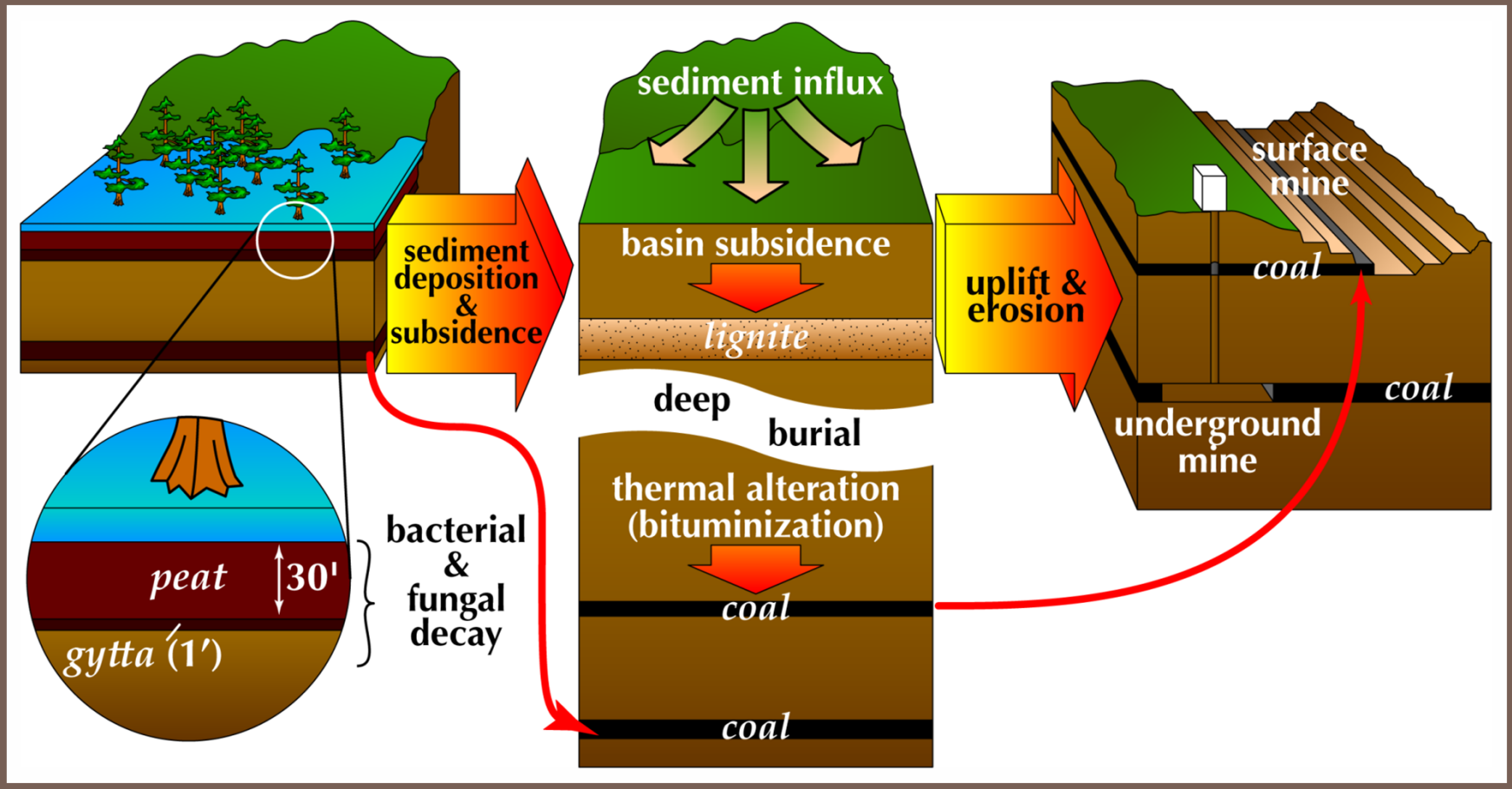
Coal and Electricity

What We Are Going to Discuss

- coal background
  - coal formation
  - coal production
- coal-fired power plants
- two environmental concerns about coal use
  - SO_x and NO_x emissions
  - carbon dioxide

Coal Geology

Formation



Coal Geology

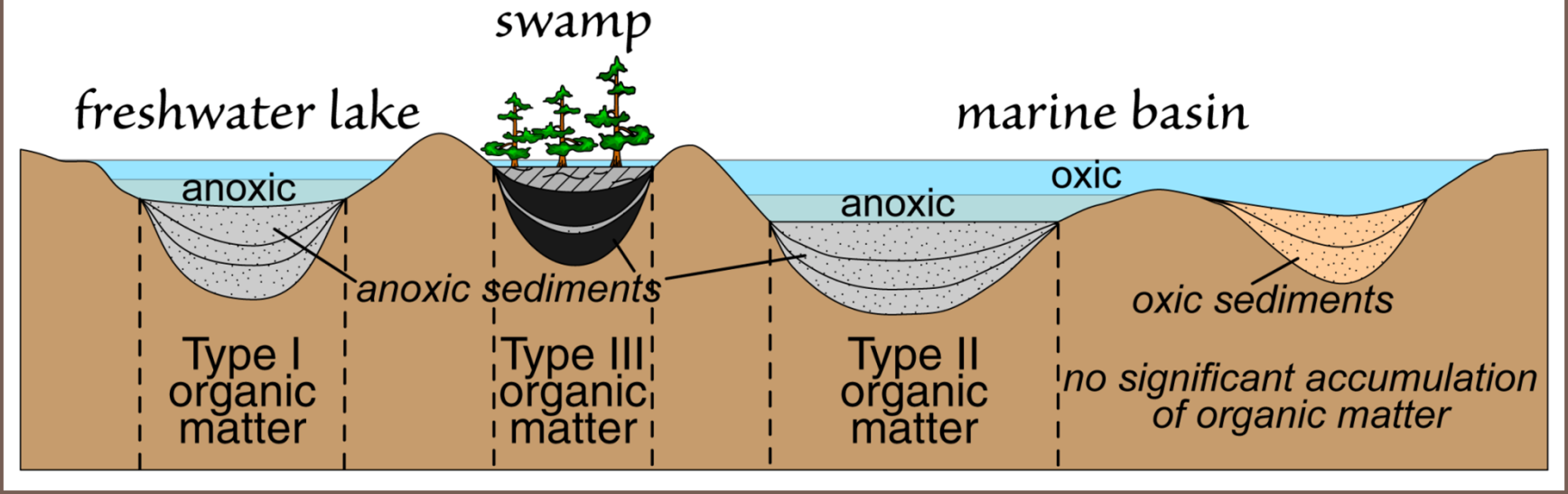
Formation

- coal is produced by alteration of organic matter:
  - organic decay
  - chemical changes due to increasing heat with depth
- preserved in sedimentary rocks
- four factors determine type of coal formed:
  - nature of living organisms accumulated
  - abundance of organic matter
  - maximum temperature organic matter exposed to
  - duration of maximum temperature

Coal Geology

Formation

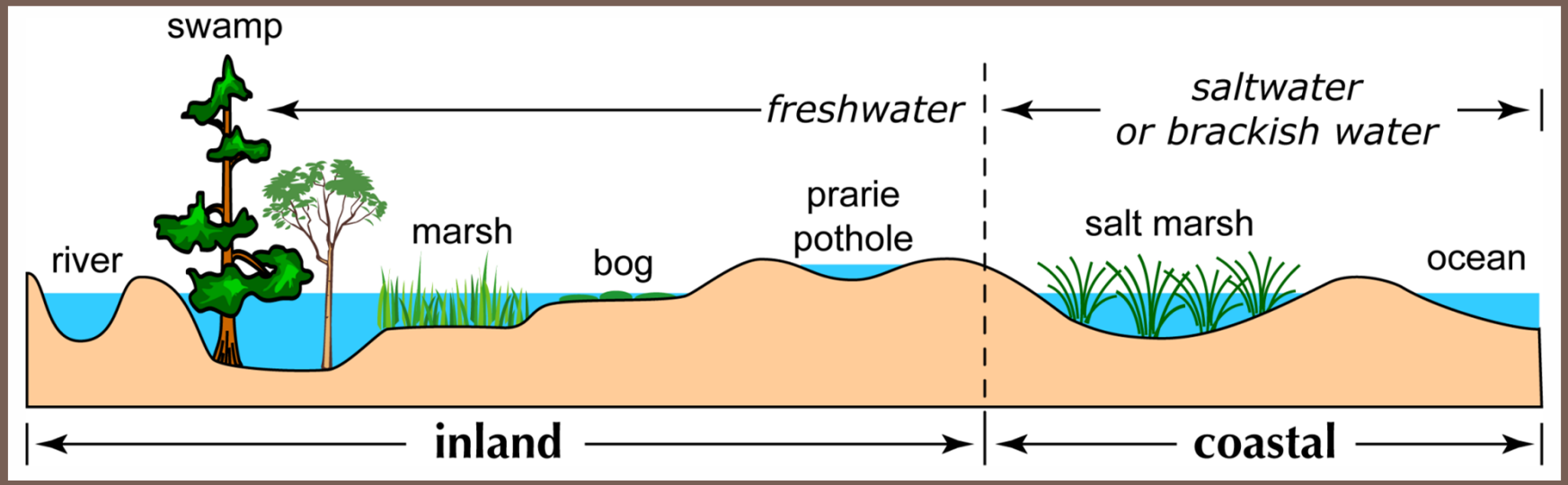
- three types of organic matter: Types I, II & III
  - each produces different fossil fuels
- must be preserved for subsequent burial
  - requires regions of low oxygen – no decay



Coal Geology

Formation

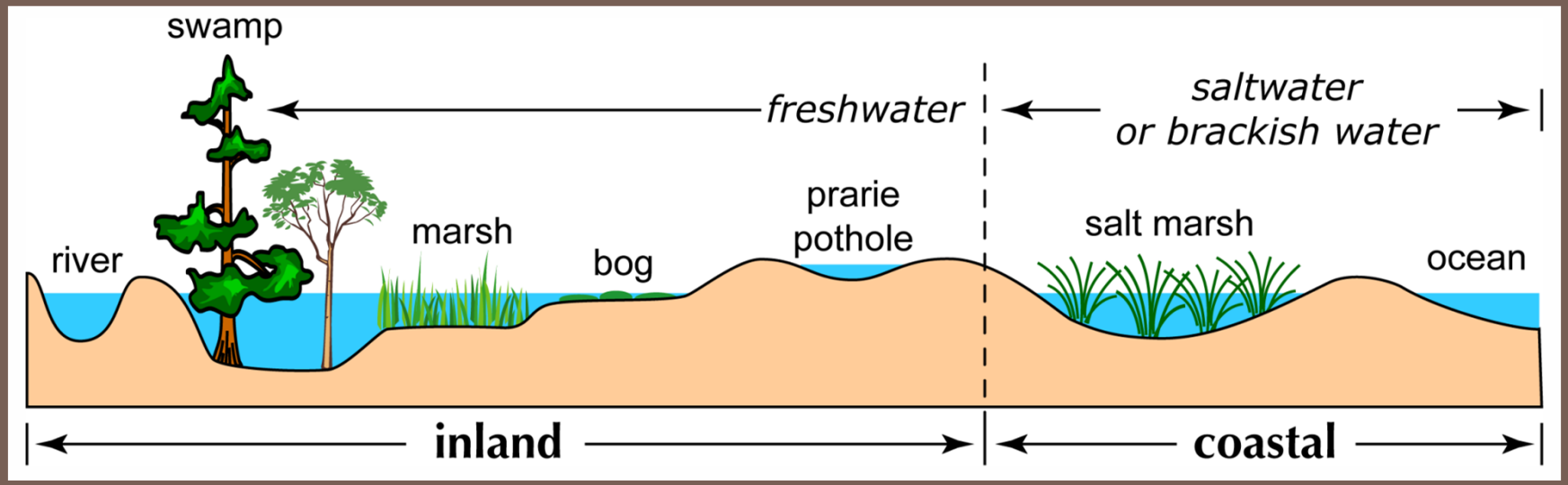
- wetlands: transition zones between land and water
  - water above, at or near surface, unique soils, vegetation adapted to wet conditions (hydrophytes), absence of flood-intolerant plants
- variable in character
  - water depth, dry/wet conditions, location, size, plant species



Coal Geology

Formation

- three primary types of inland wetlands
  - bog: mosses, shrubs, +/- sedges
  - marsh: grasses, reeds, rushes, +/- cattails
  - swamp: trees
- fossils in coal indicate swamps are where coal forms



Coal Geology

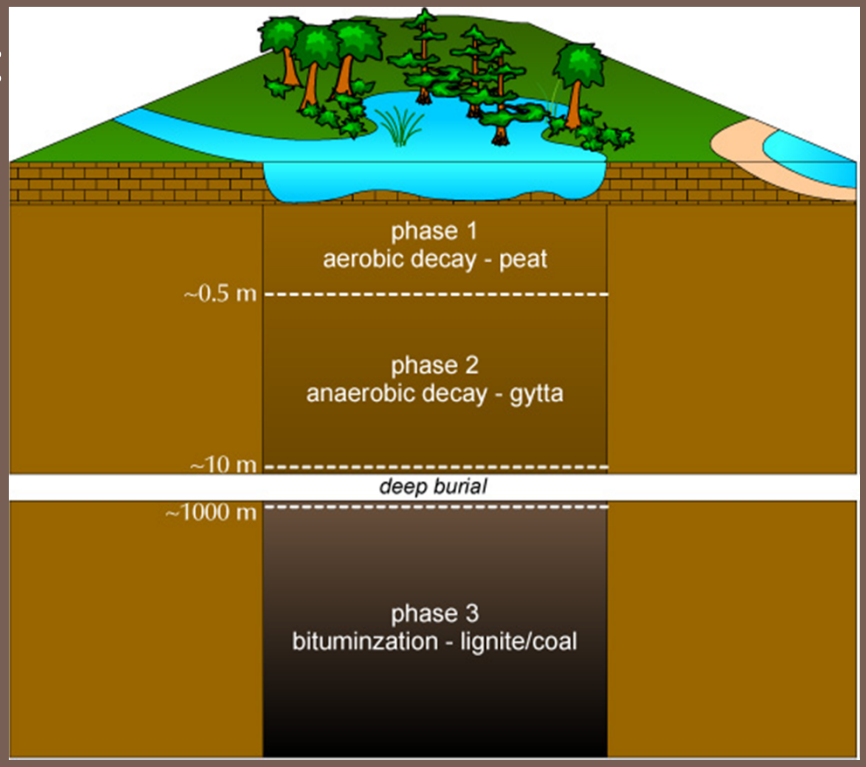
Coal Swamp

- coal swamp characteristics:
  - wetland with trees, i.e. a swamp
  - freshwater
  - stagnant water
  - high water levels
  - long period of stable conditions
  - accommodation space

Coal Geology

Coalification

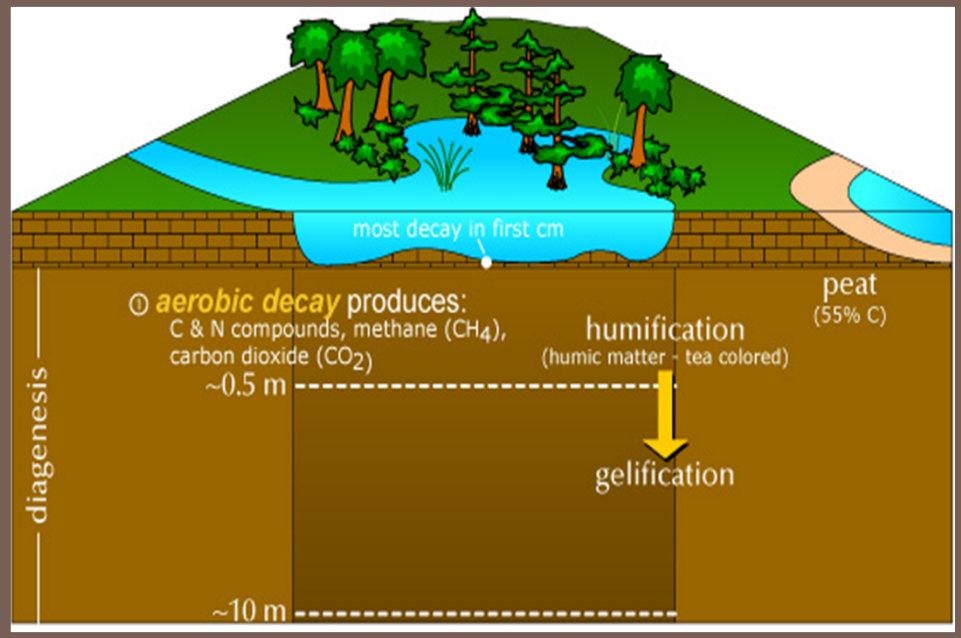
- three stages of coalification:
  - peat formation
  - partial decay by living organisms
    - aerobic/anaerobic
    - bacteria/fungi
  - thermal alteration (bituminization)



Coal Geology

Coalification – Aerobic Decay

- aerobic bacteria/fungi decompose accumulating organic material
- live on oxygen originally trapped in organic debris
  - peat is impermeable
- when oxygen consumed, bacteria/fungi die
  - aerobic decay ceases
  - not all organic matter gone



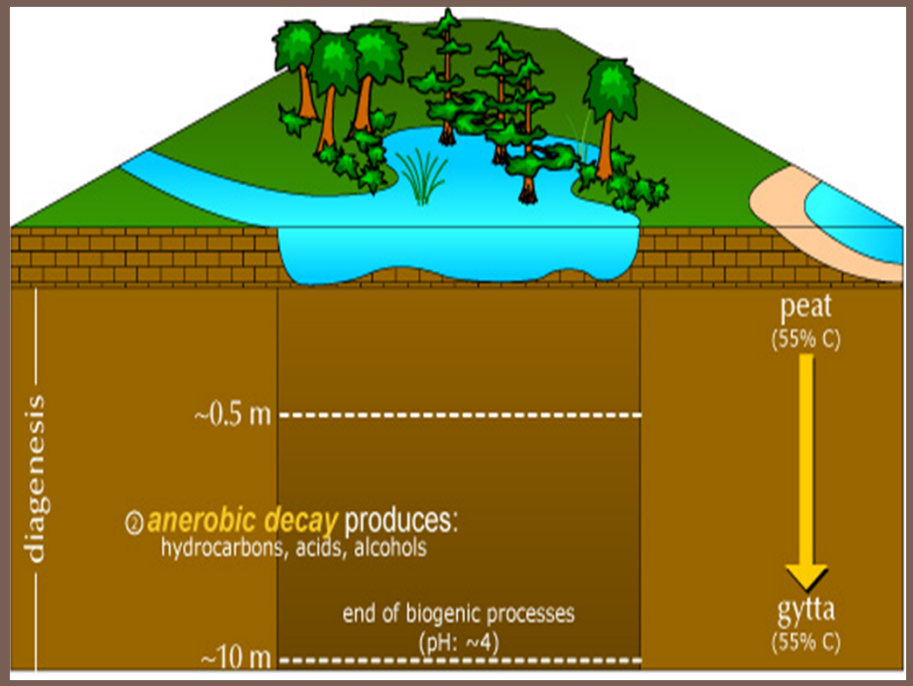
Coal Geology

Coalification – Peat

Coal Geology

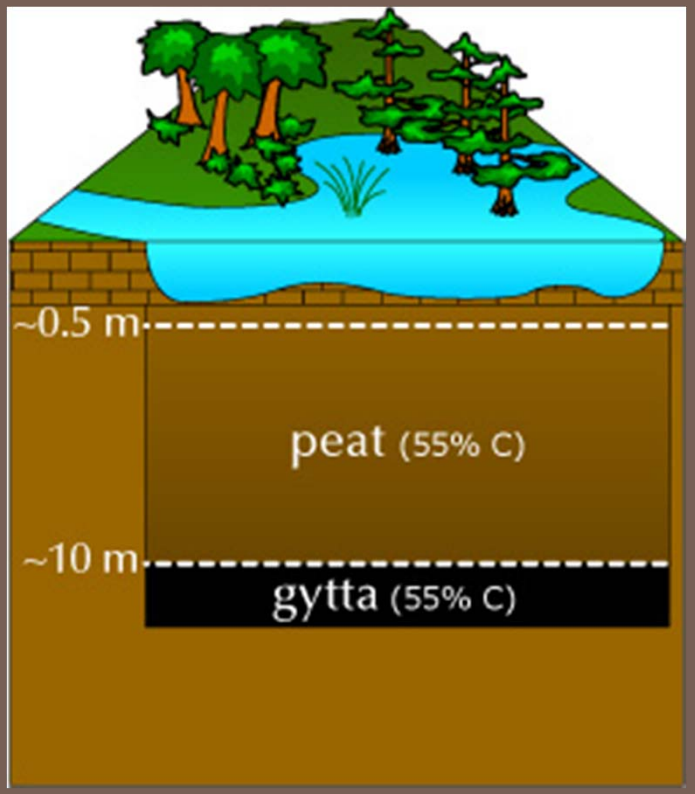
Coalification – Anaerobic Decay

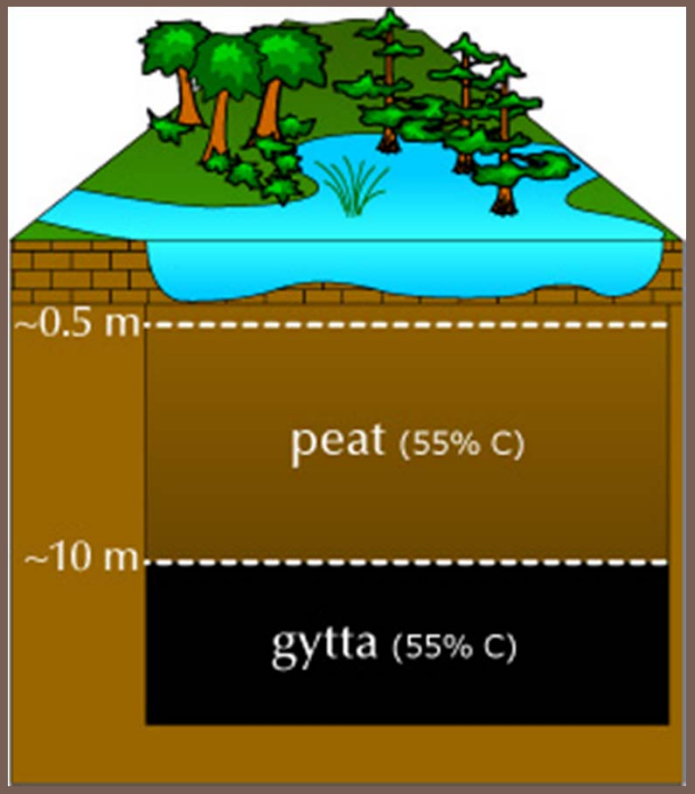
- anaerobic decay now becomes important
- produces acids
  - tannic produces swamp water's brownish tint
- raises pH of water
  - when pH falls below 4.5, bacteria die
- at this depth, biogenic processes cease



Coal Geology

Gytta

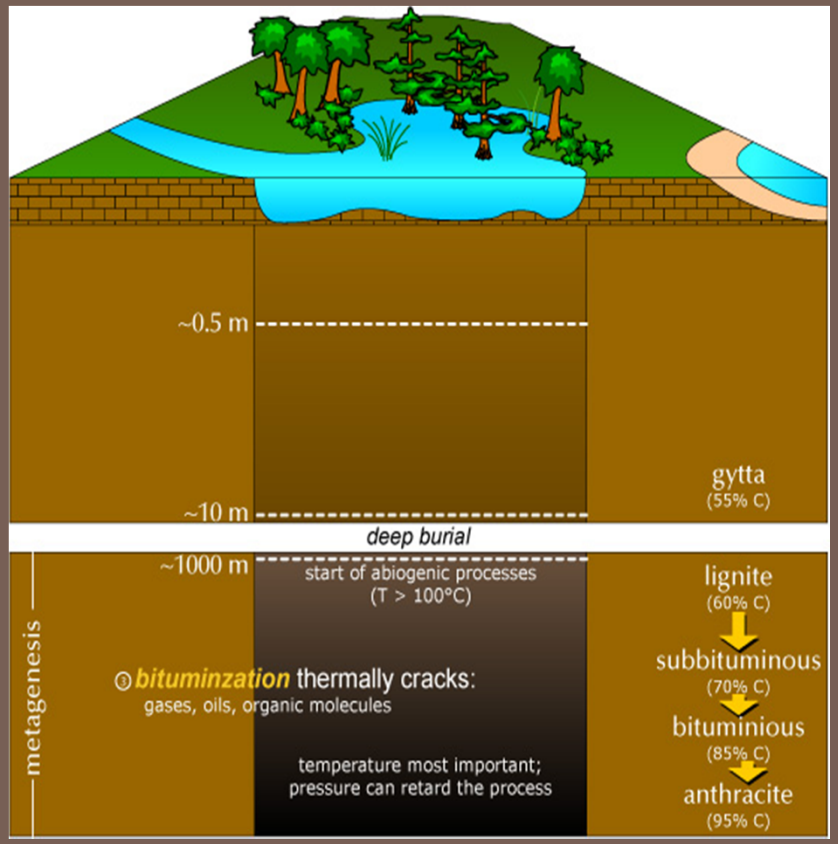




Coal Geology

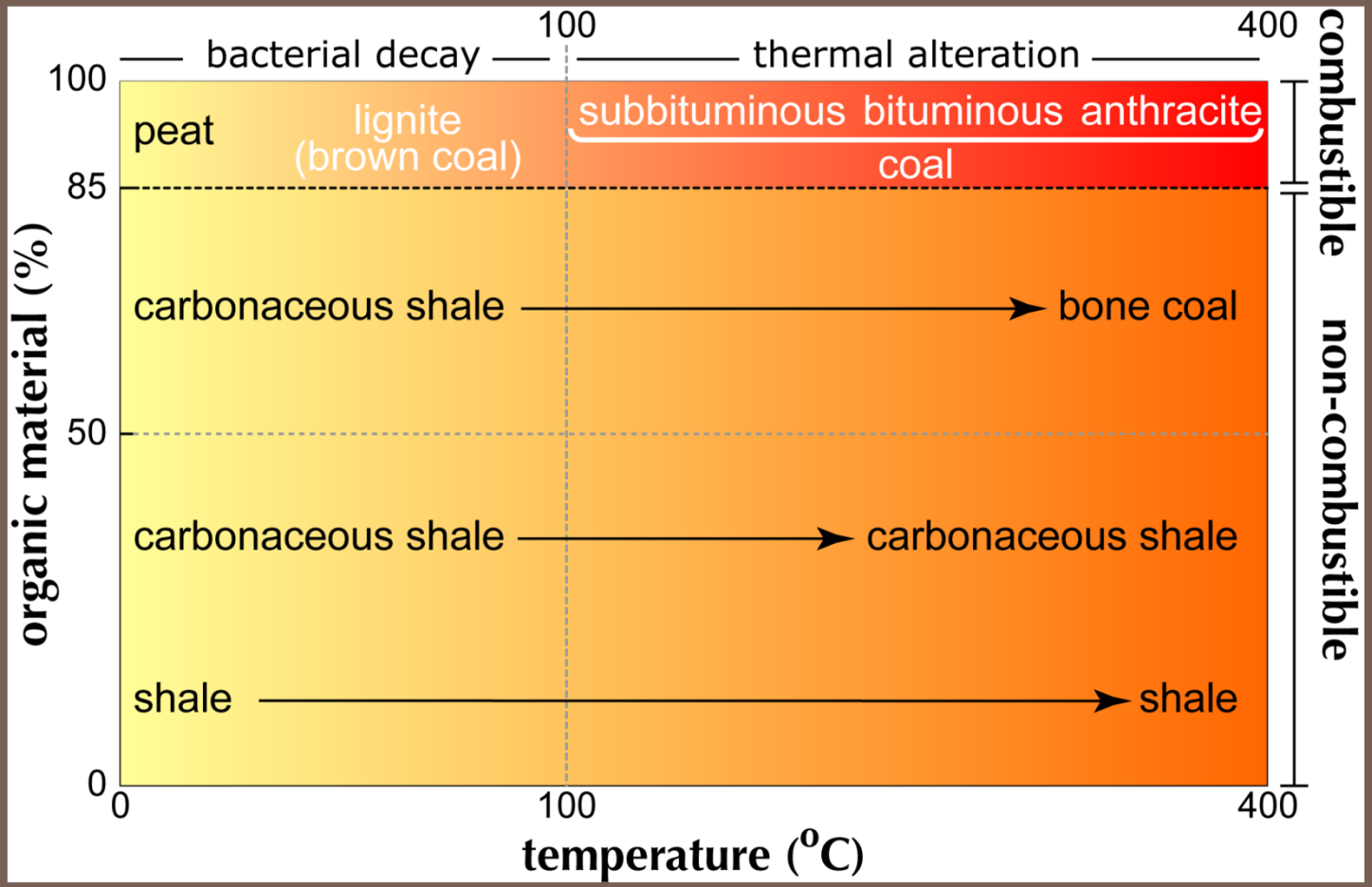
Bituminization

- as gytta buried under thousands of feet of sediment, temperature rises
- when temperature exceeds 100°C, bituminization occurs
  - moisture driven off
  - organic molecules cracked into smaller H-C-O molecules



Coal Geology

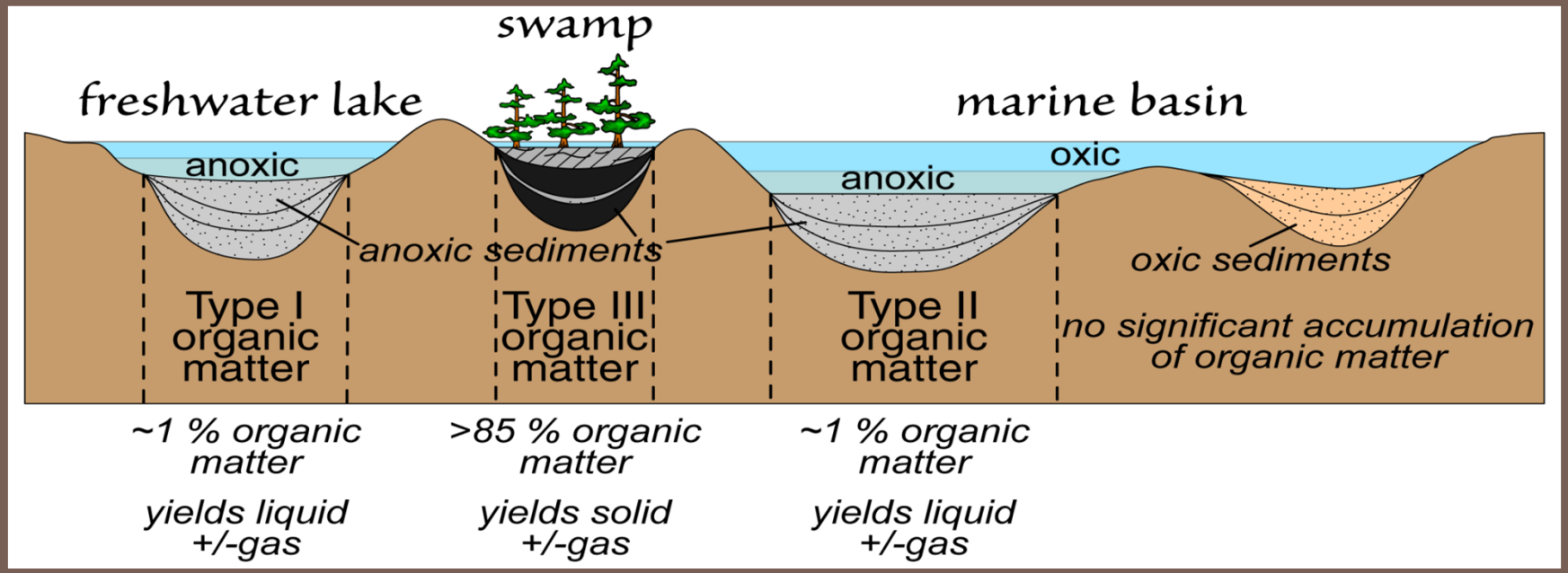
Organic Content



Coal Geology

Organic Content

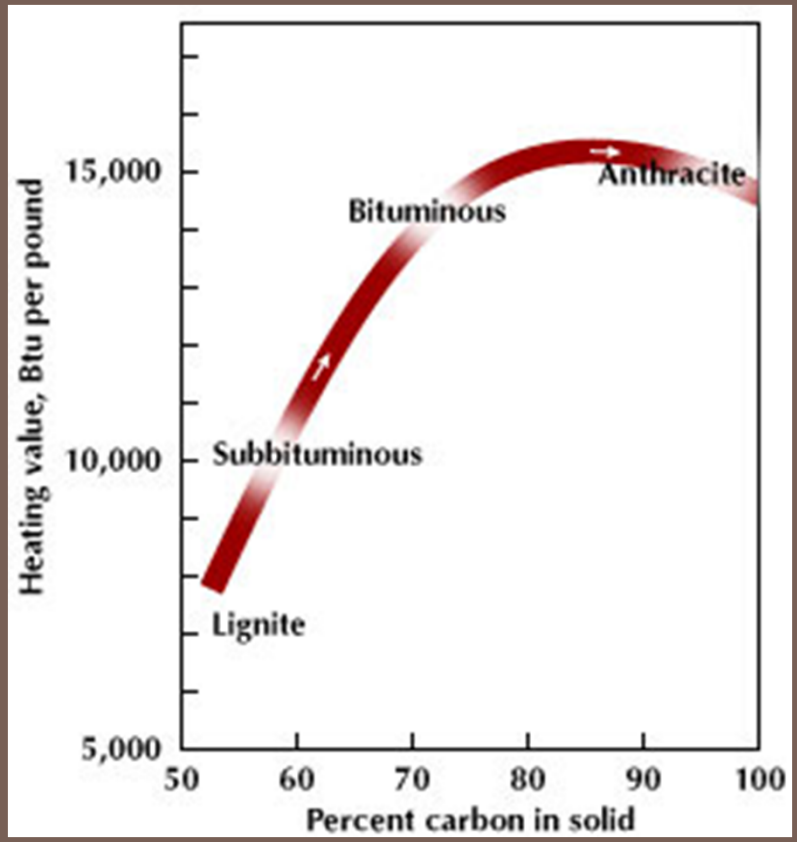
- major differences from petroleum formation
  - much higher organic content required
  - no movement of hydrocarbons
  - only solid +/- gas produced
  - cracking not as extensive, i.e. coal more C-rich and H-poor than petroleum



Coal Geology

Coal Classification

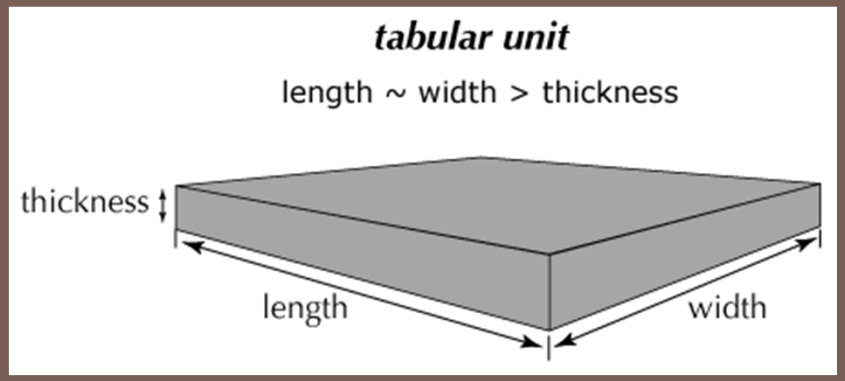
- coal classified in number of ways
  - rank: heat content
  - grade: ash content
  - use: electricity generation (steam) or iron/steel production (metallurgical)
  - physical nature: hard/soft
  - origin: humic (trees), sapropelic (spores, algae)

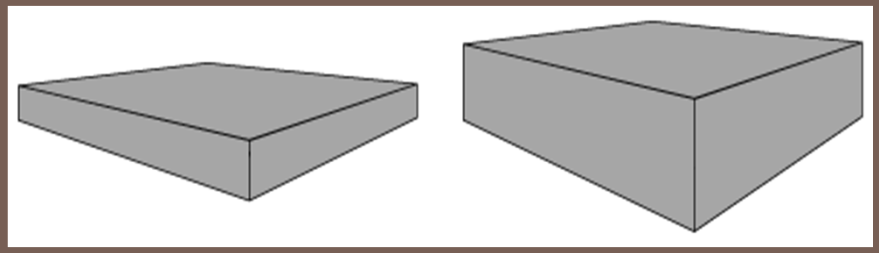


Coal Production

Mining

- coal is mined using surface and underground methods
- nature of coal mining is defined by how coal occurs:
  - tabular bodies known as *seams*
  - almost always horizontal or nearly horizontal

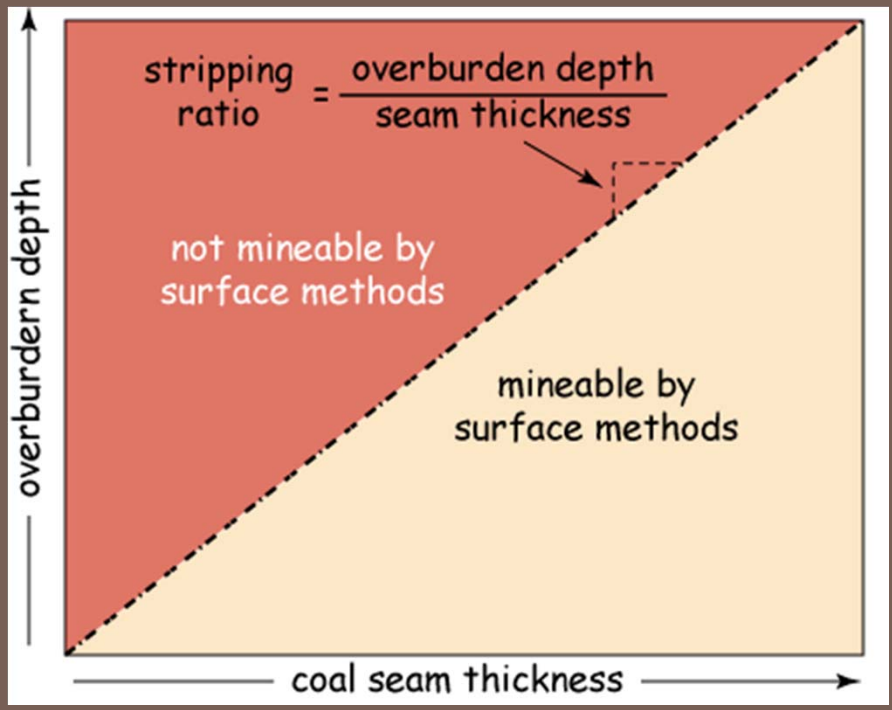




Coal Production

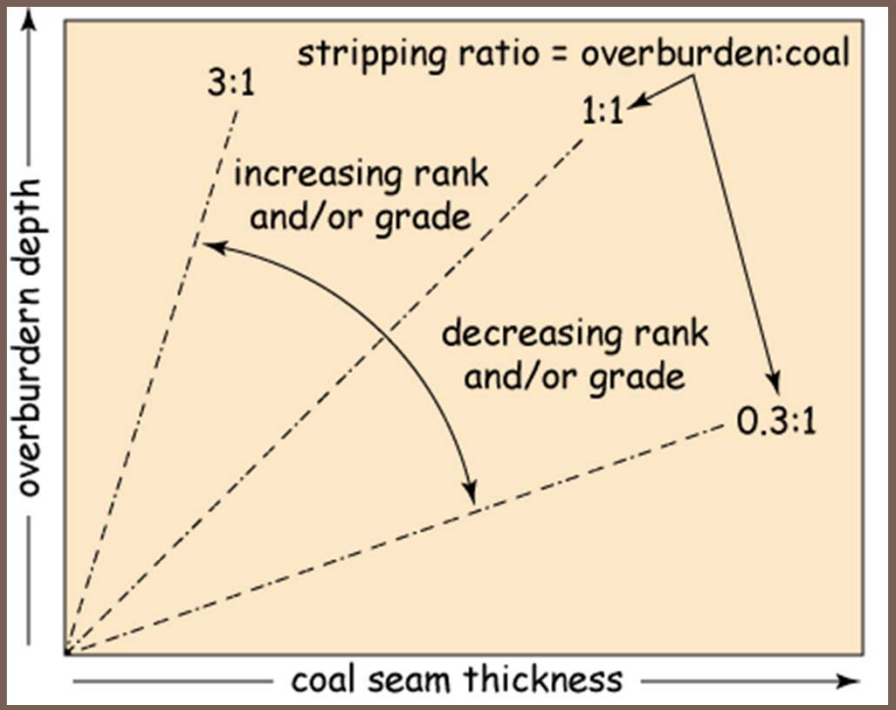
Surface vs. Underground Mining: Stripping Ratio

- material above seam is *overburden*
- how a coal seam can be mined is determined by its *stripping ratio*:
  - ratio of overburden removed to coal removed



Coal Production

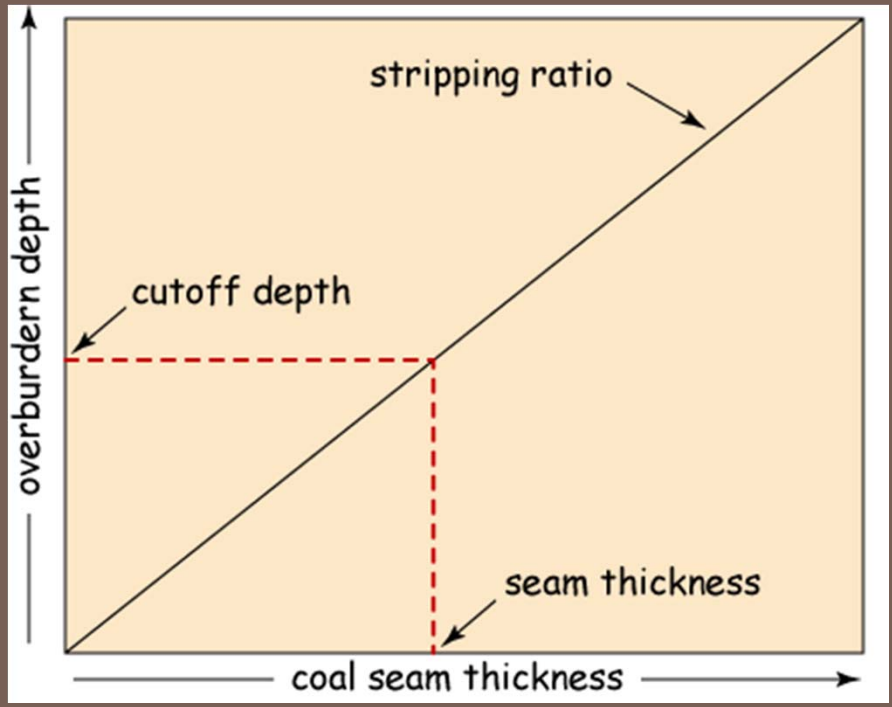
Surface vs. Underground Mining: Stripping Ratio



Coal Production

Surface vs. Underground Mining: Cutoff Depth

- obviously stripping ratio only works to a certain depth
- below this depth, i.e. *cutoff depth*, surface mining is not economical
  - depends on coal rank and quality
- for Wyoming coals, this is about 500 feet



Coal Production

Surface Mining

- steps:
  - remove overburden
  - extract coal
  - reclaim land
- advantages:
  - large production volumes
  - cheap
  - small labor force
  - highly mechanized

Coal Production

Surface Mining: Overburden Removal

- overburdern typically removed in one of three ways:
  - bucket wheel excavator
  - dragline
  - truck and shovel
- typically does not require drilling and blasting

Coal Production

Surface Mining: Coal Extraction

- once exposed the coal in a coal seam is almost always removed by truck and shovel operations
- involves:
  - drilling
  - blasting
  - loading
  - hauling

Coal Production

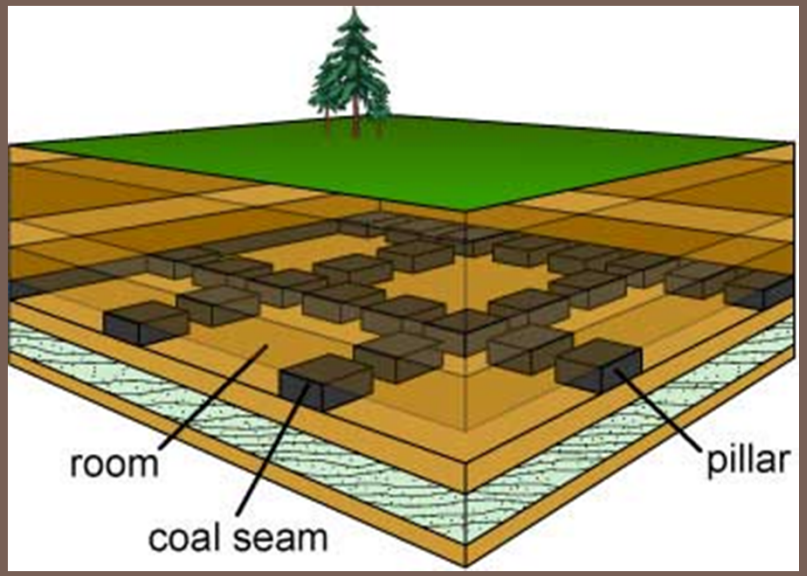
Underground Mining

- major factor is seams are generally horizontal or nearly so
- limited number of mining methods necessary:
  - room and pillar
  - longwall

Coal Production

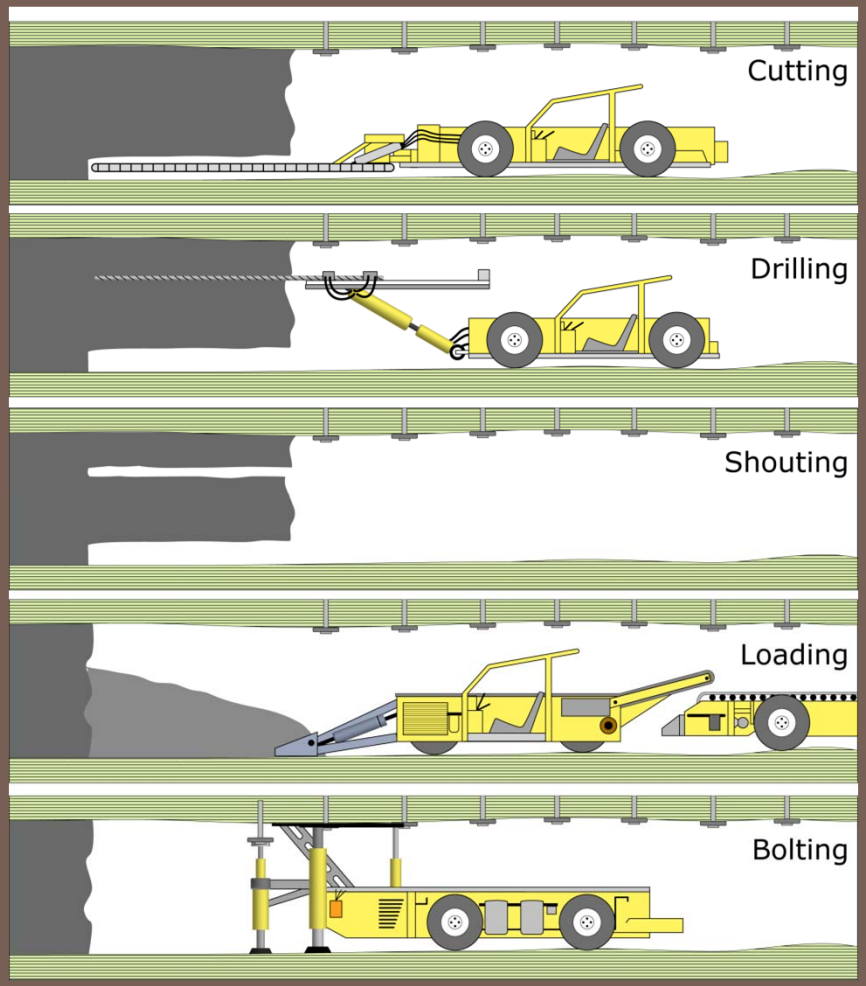
Underground Mining: Room & pillar

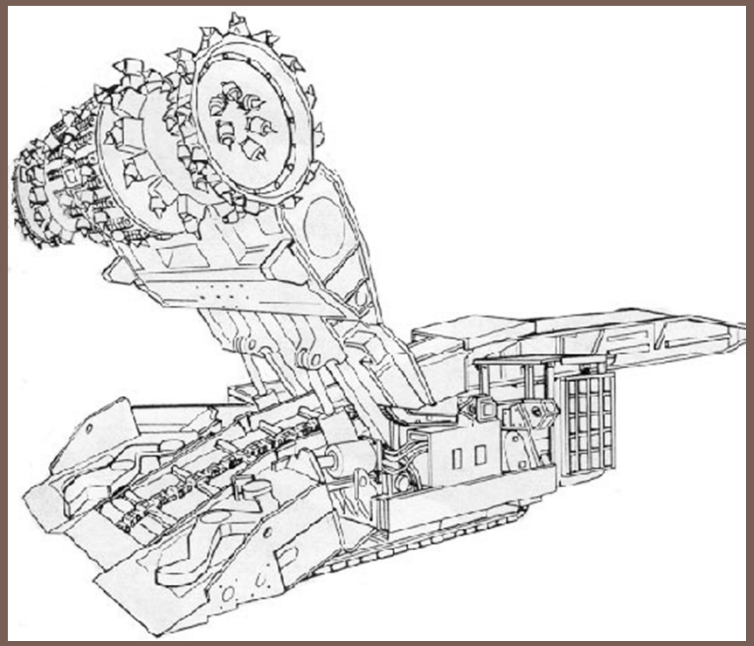
- room and pillar is older method
- cut series of openings to remove coal producing *rooms*
  - columns of coal are left to provide roof support, *pillars*
- labor intensive with smaller production volumes
  - nearly 50 % of coal left
  - retrieve some through retreat mining



Coal Production

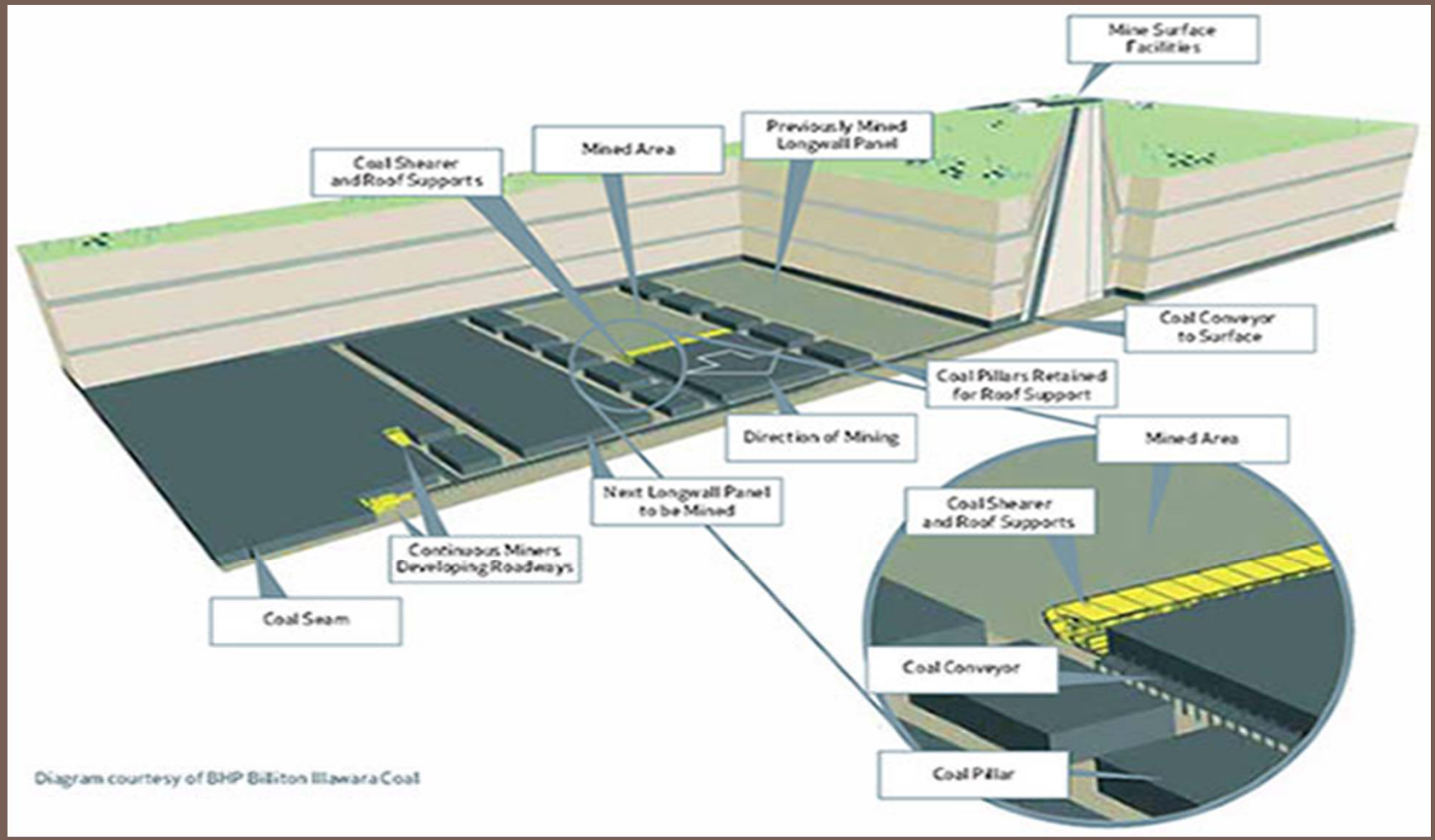
Underground Mining: Room & pillar





Coal Production

Underground Mining: Longwall

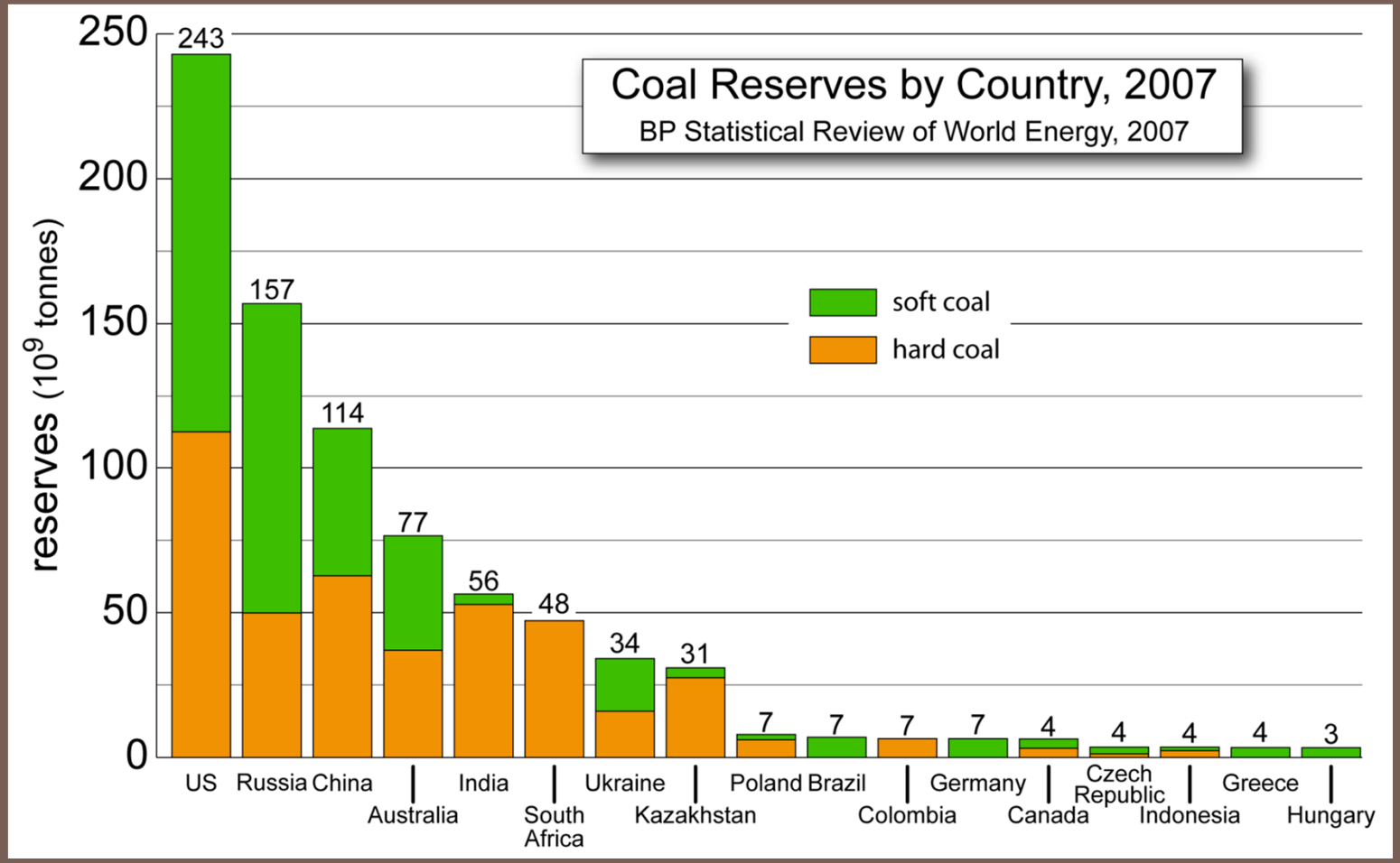


Coal Production

Underground Mining: Longwall

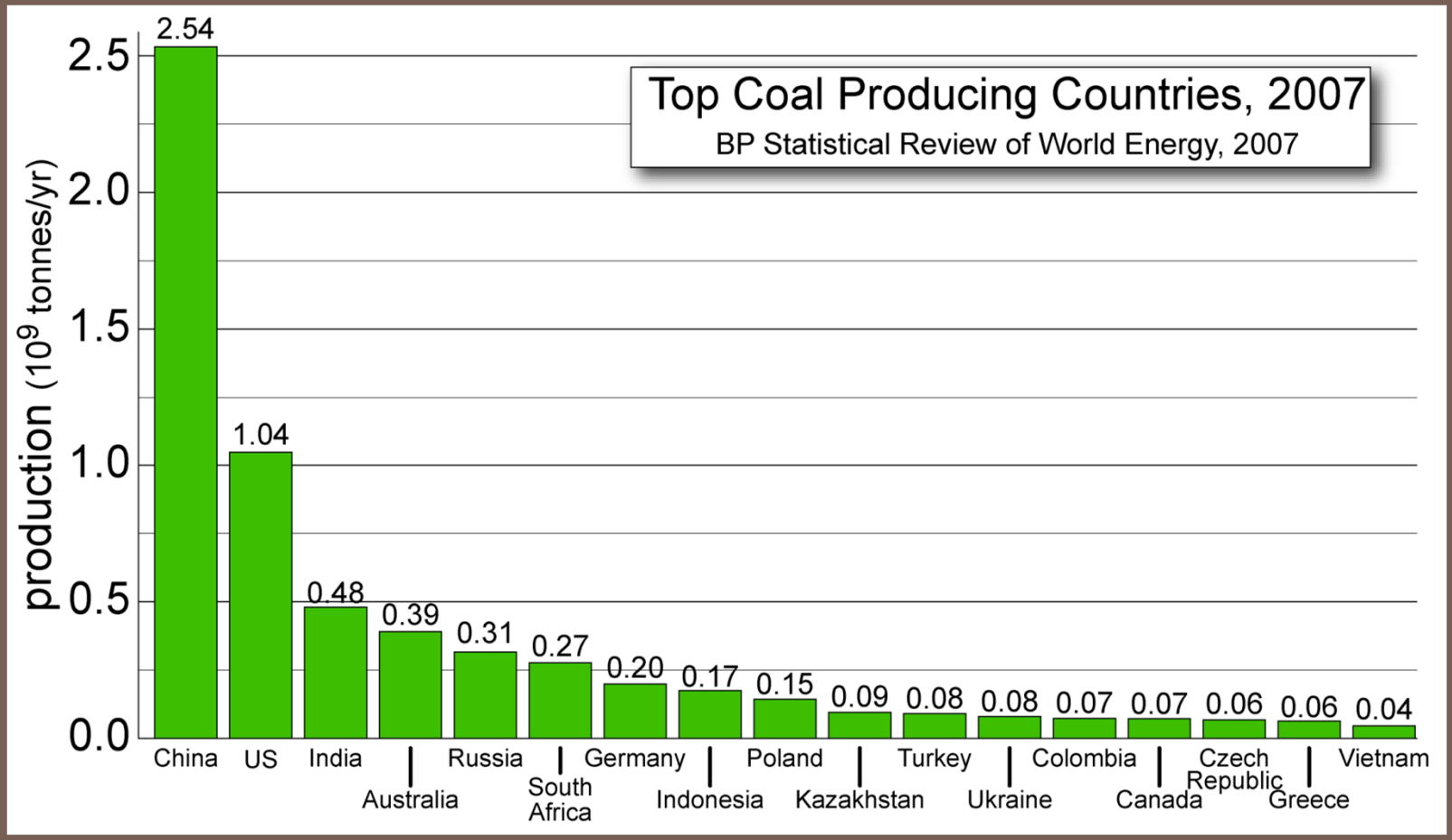
Global Coal

Reserves by Country



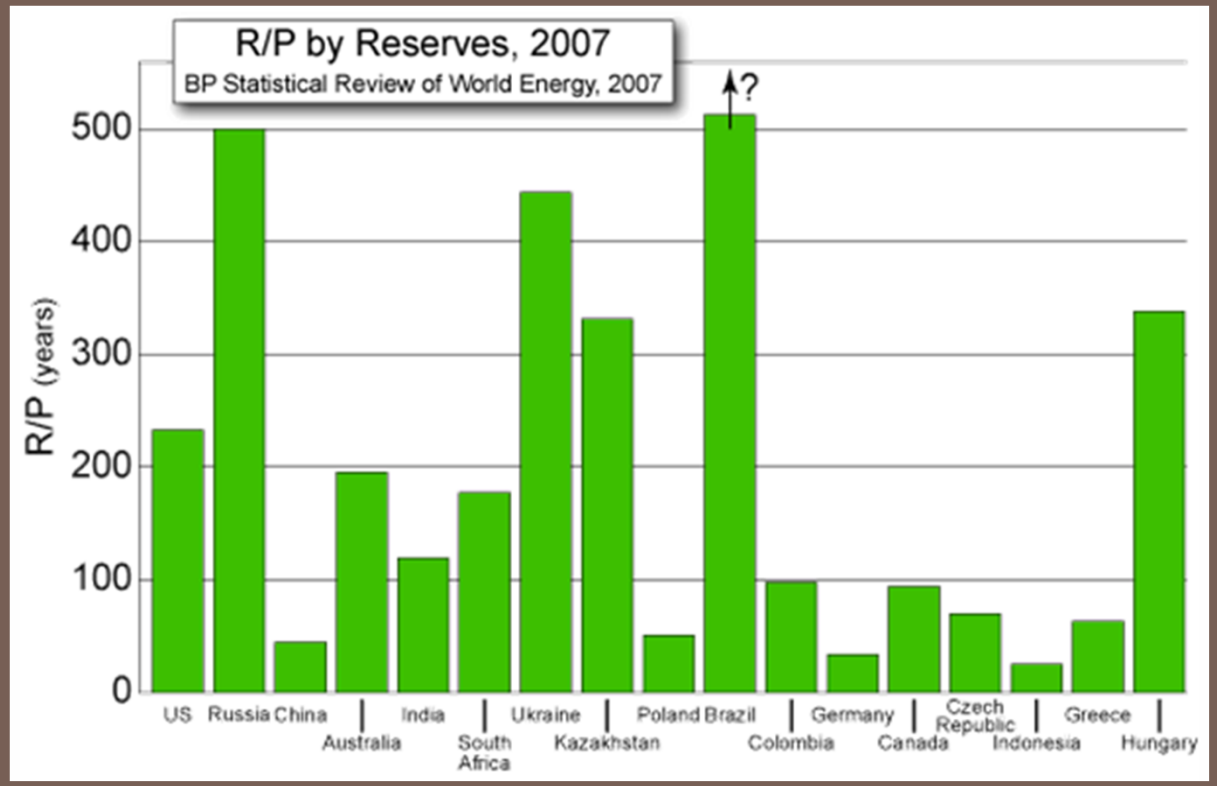
Global Coal

Production



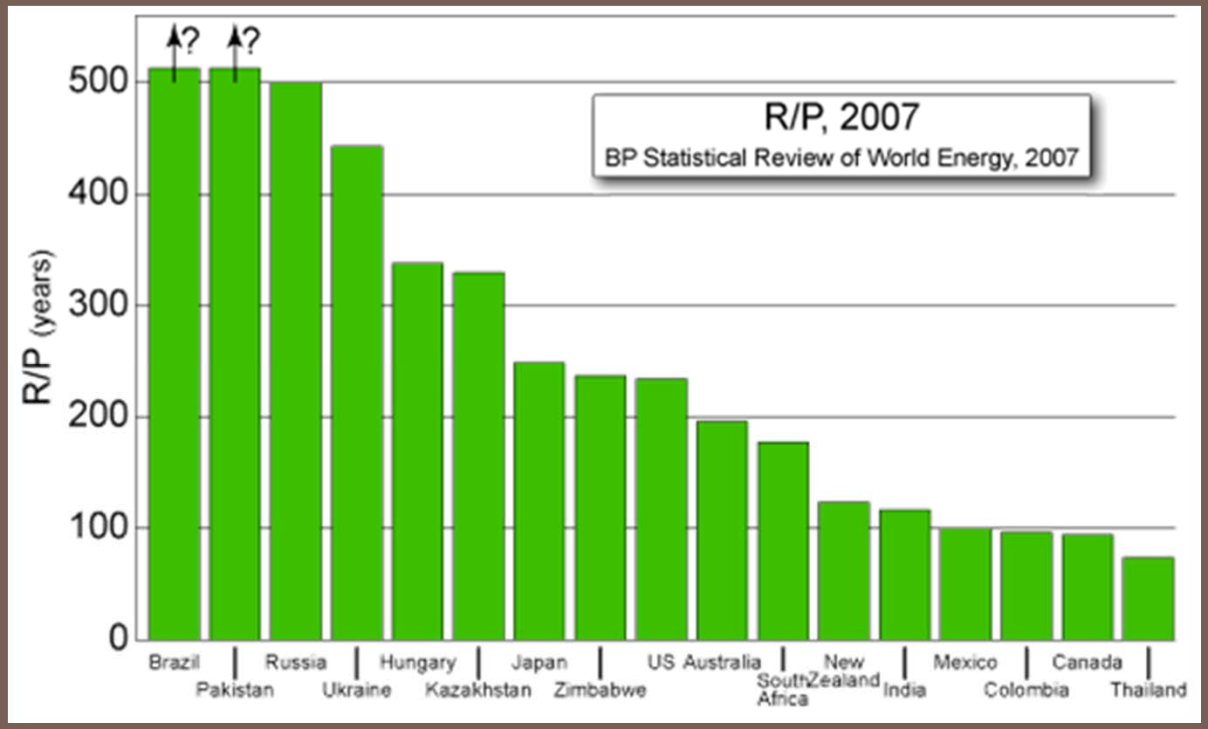
Global Coal

R/P – Arranged by Reserves



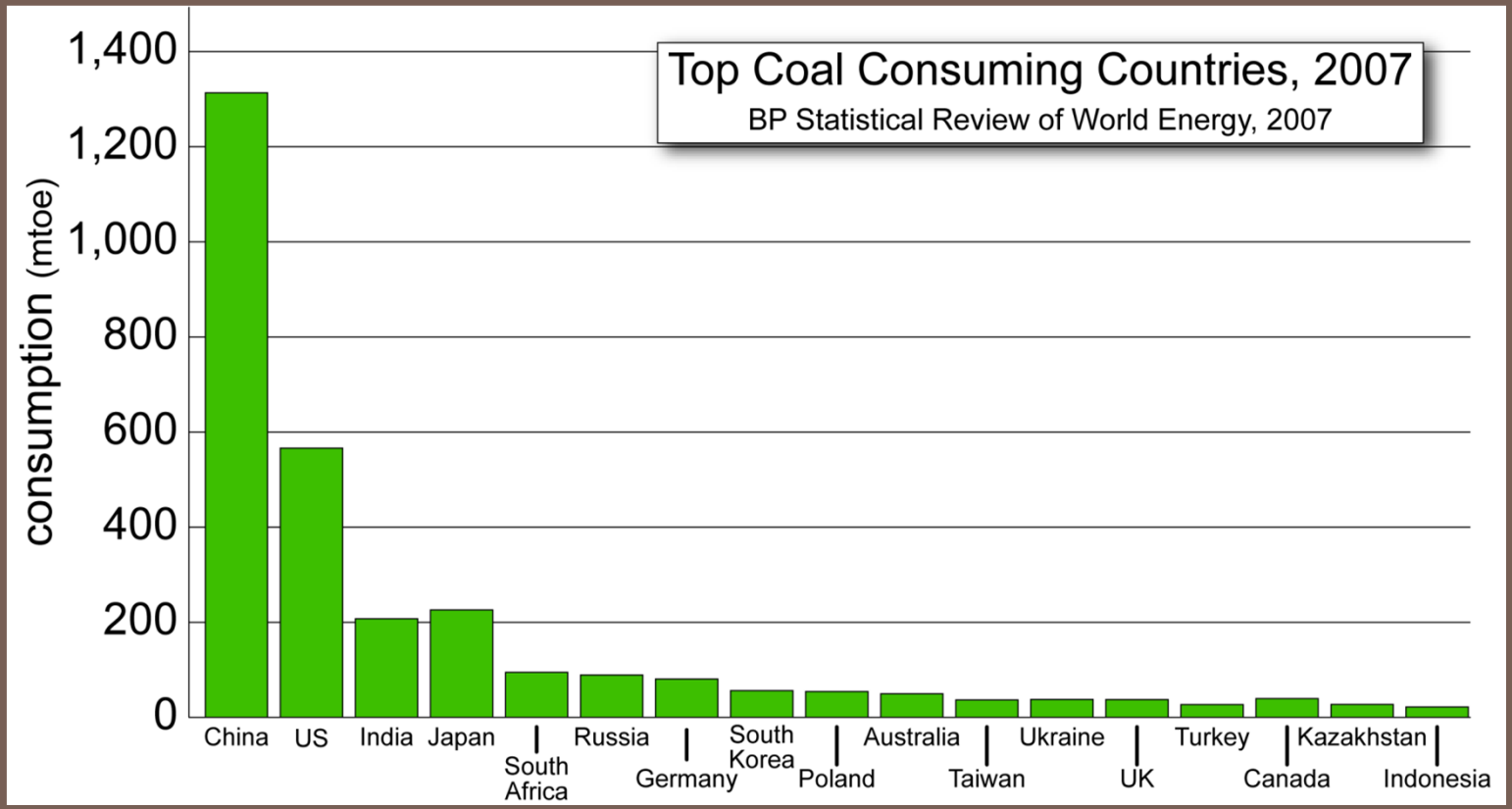
Global Coal

R/P – Arranged by Length



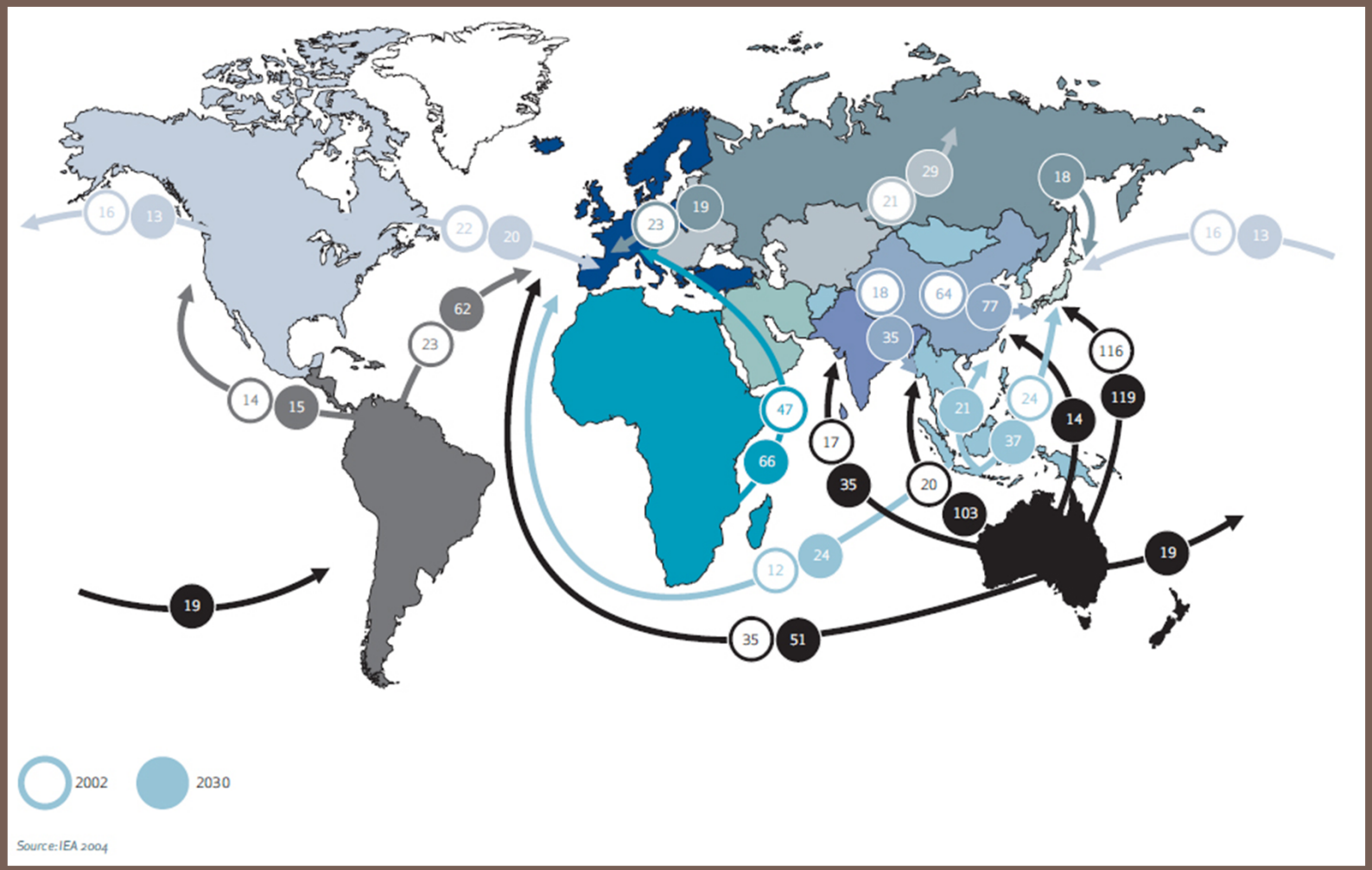
Global Coal

Consumption by Country



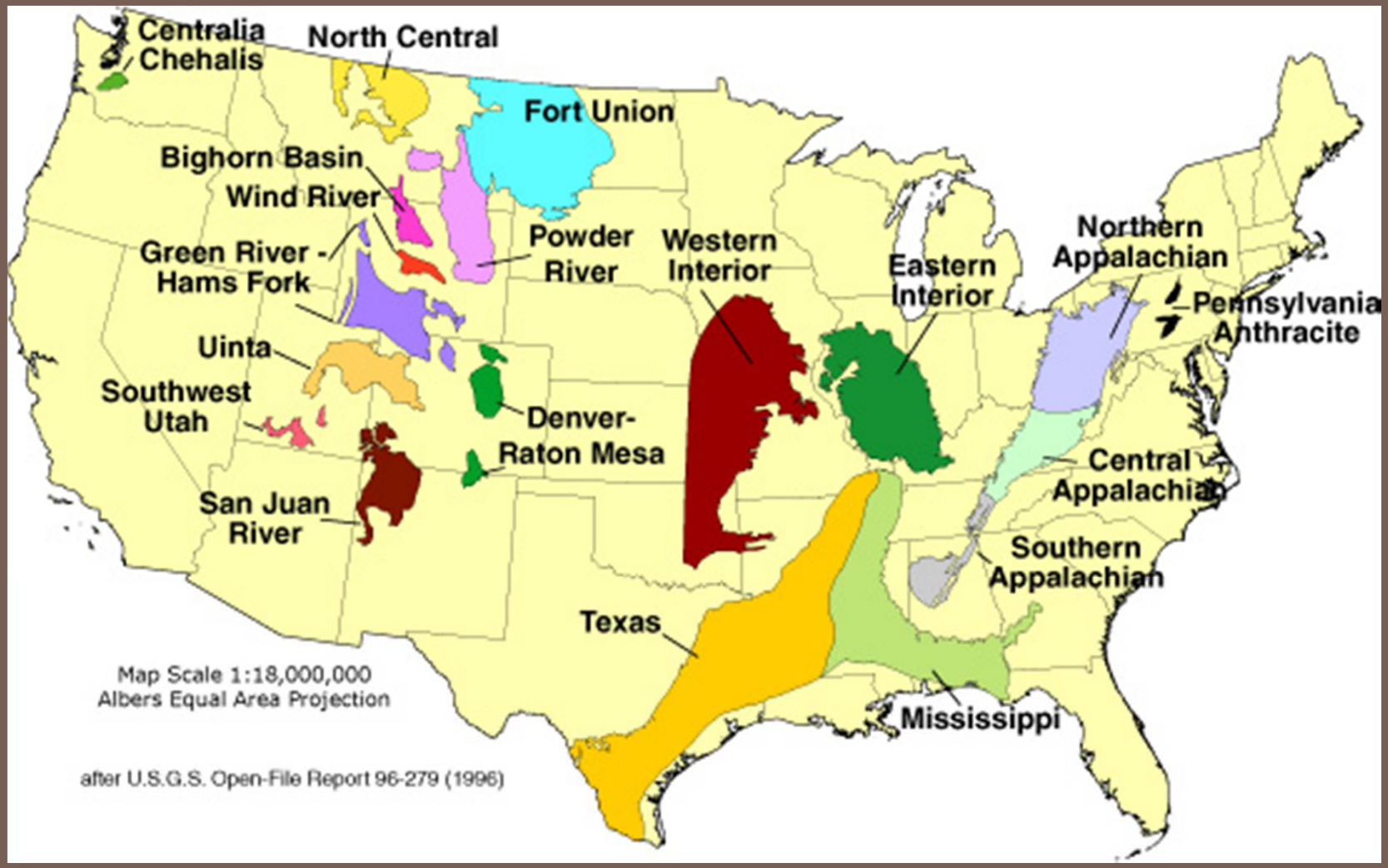
Global Coal

Trade



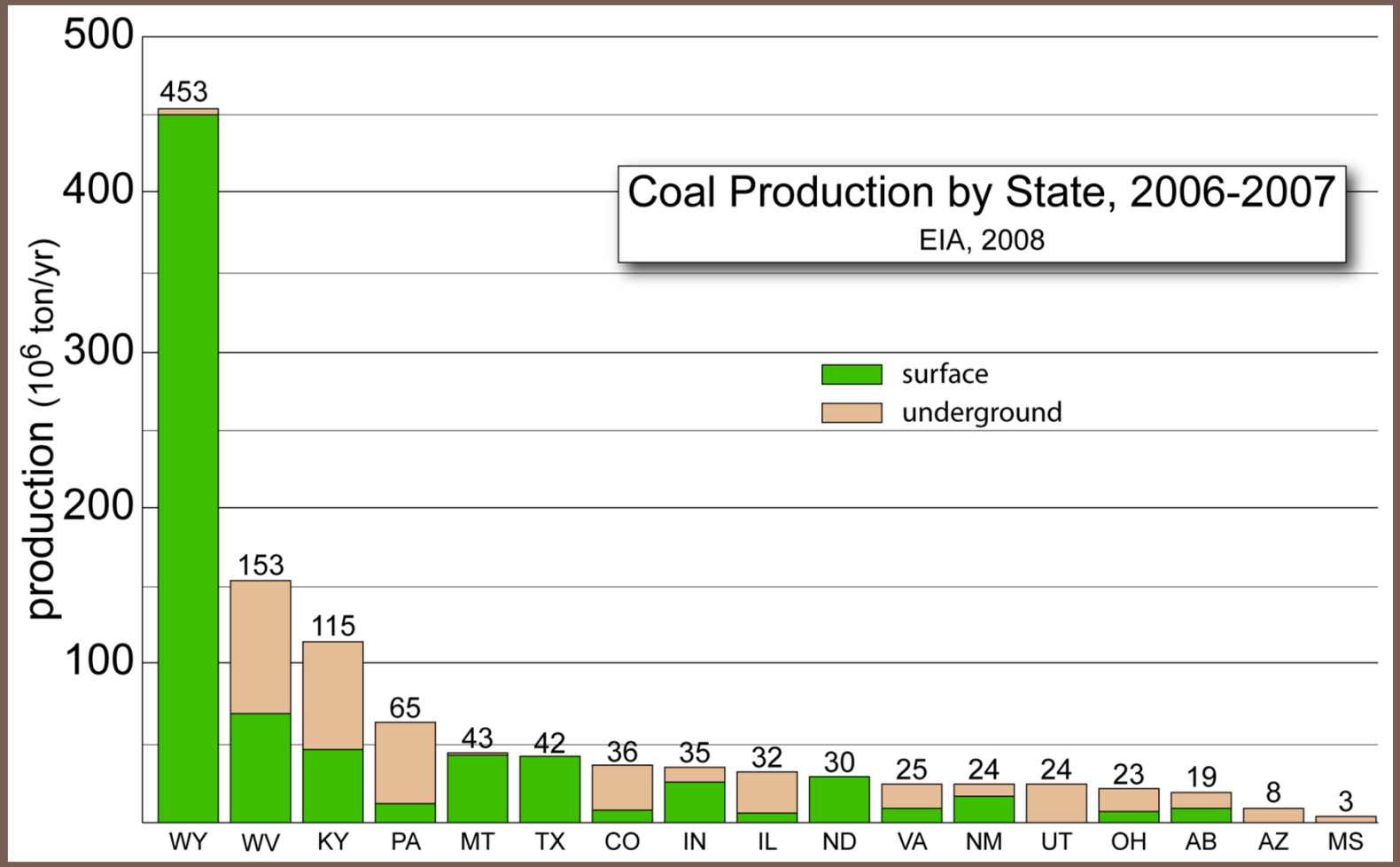
U.S. Coal

Coal Fields



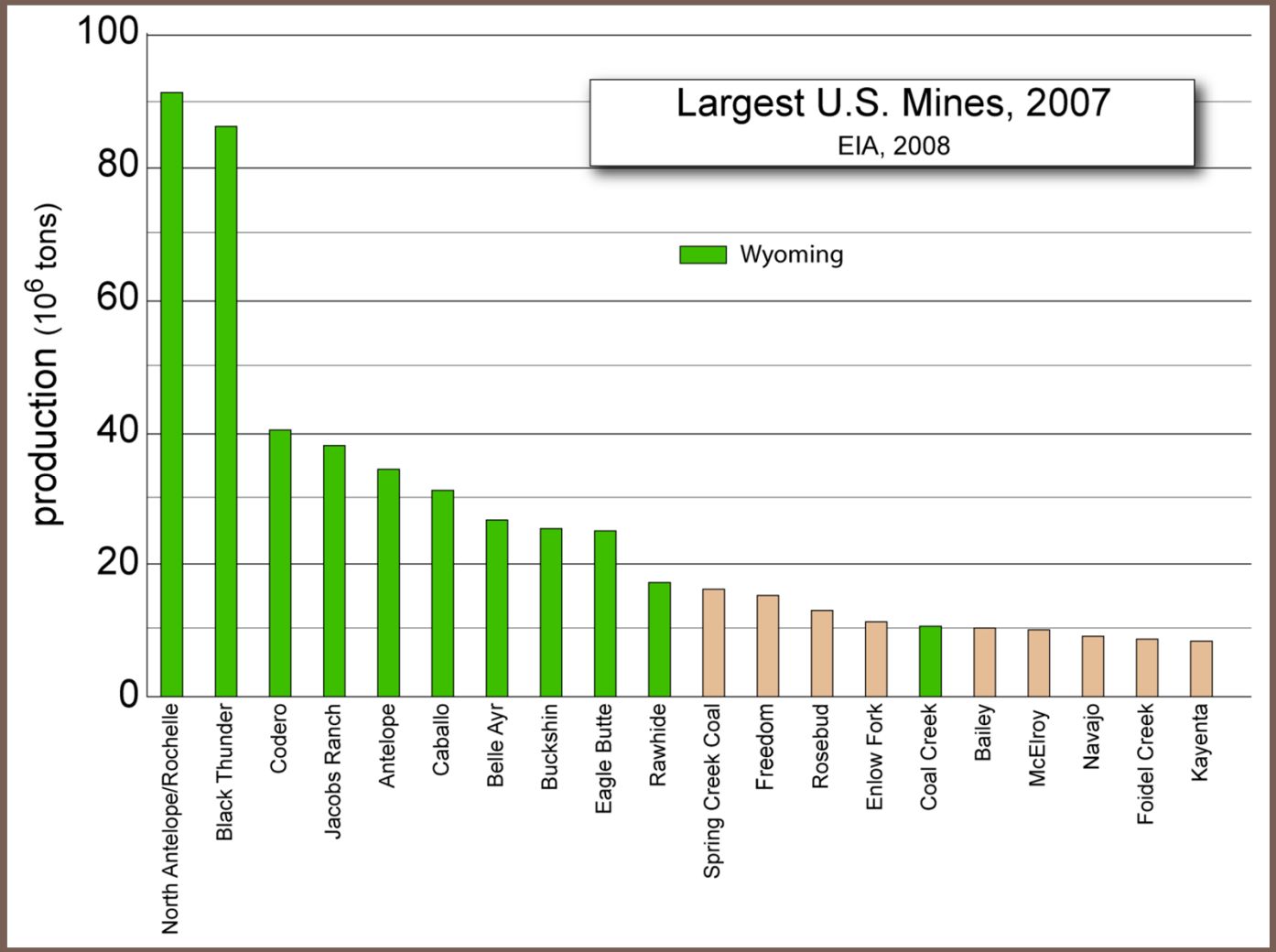
U.S. Coal

Production by State



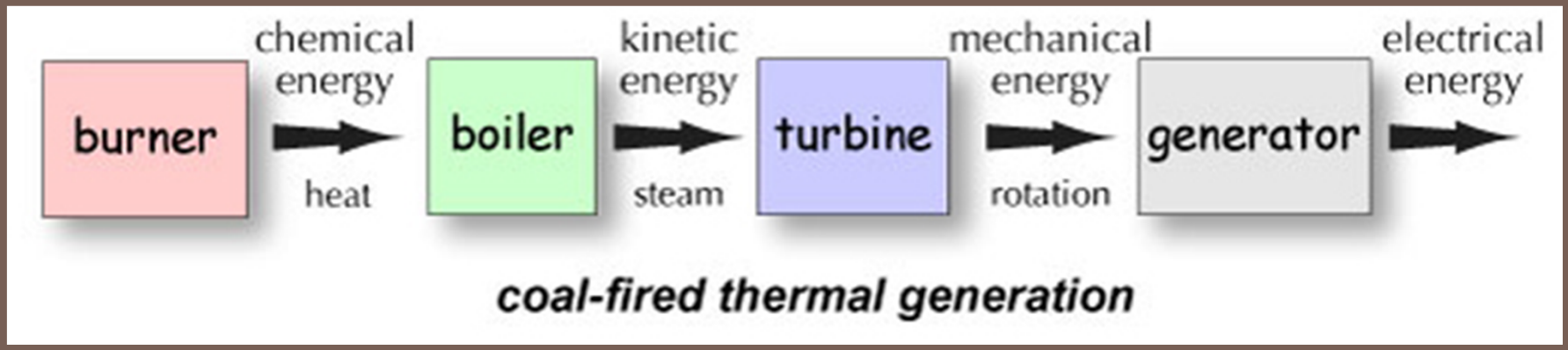
U.S. Coal

Largest Mines



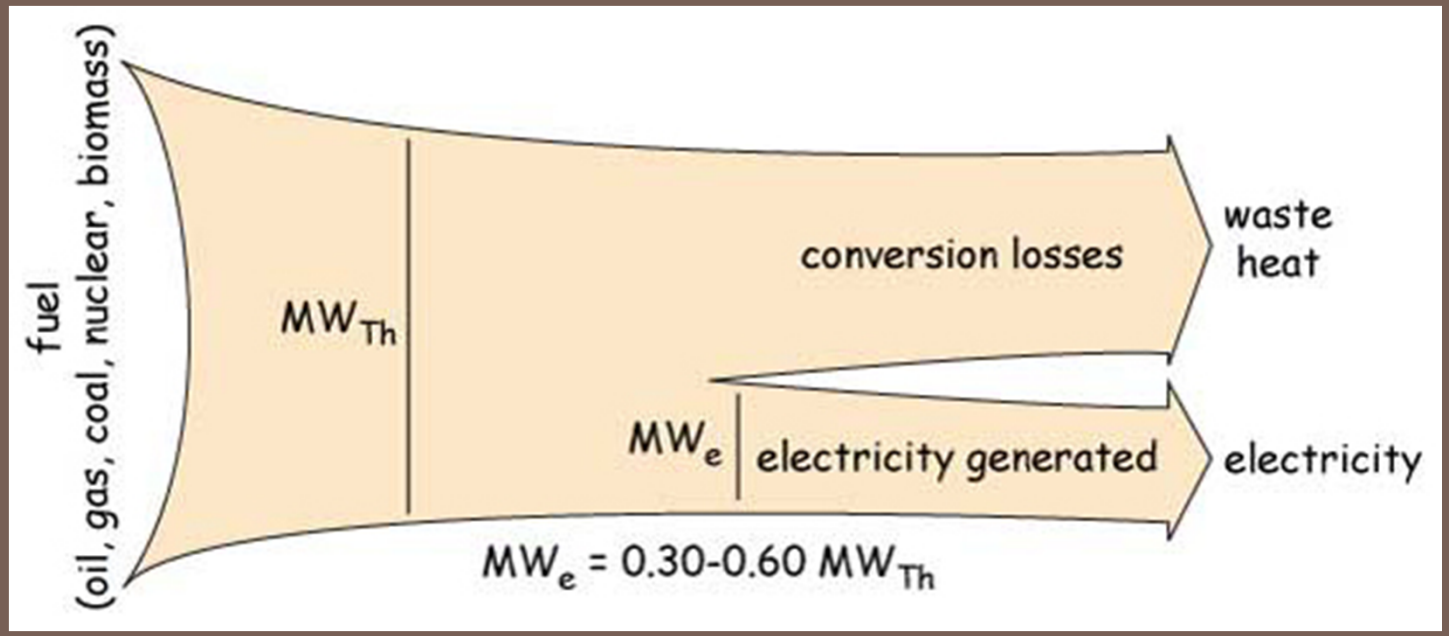
Coal-Fired Power Stations

Basic Process



Coal-Fired Power Stations

MW_e vs. MW_{Th}



$$MW_{Th} = \frac{MW_e}{efficiency}$$

Coal-Fired Power Stations

Types of Plants

- pulverized coal (PC): most common
- supercritical pulverized coal (SCPC)
- fluidized bed combustion (FBC)
  - atmospheric (AFBC)
  - pressurized (PFBC)
- integrated gasification combined cycle (IGCC)

Coal-fired Power Plants

Concerns

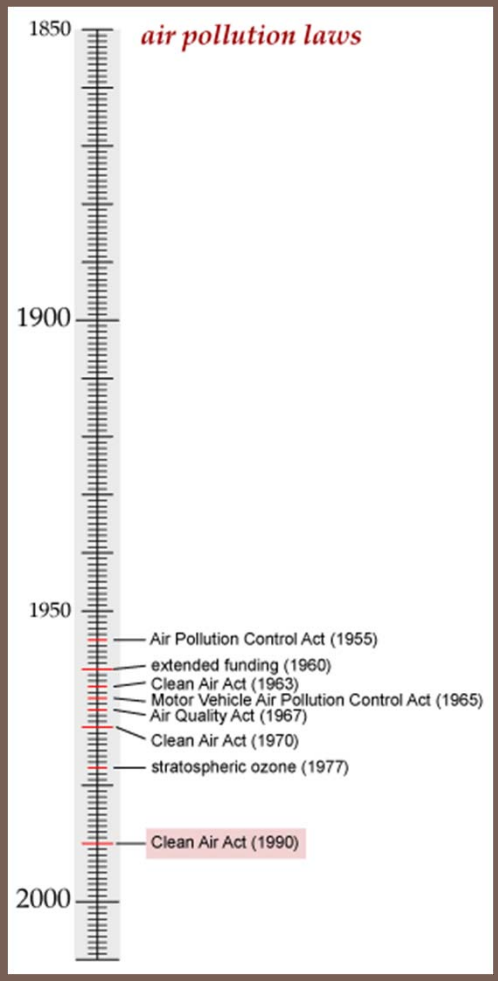
- acid precipitation
- greenhouse gases
- mercury
- heavy metals

Coal-fired Power Plants

Clean Air Act (CCA)

major clean air laws:

- Air Pollution Control Act of 1955
- Clean Air Act of 1963
- Clean Air Act of 1970
- Clean Air Act of 1990



Coal-fired Power Plants

Clean Air Act (CCA)

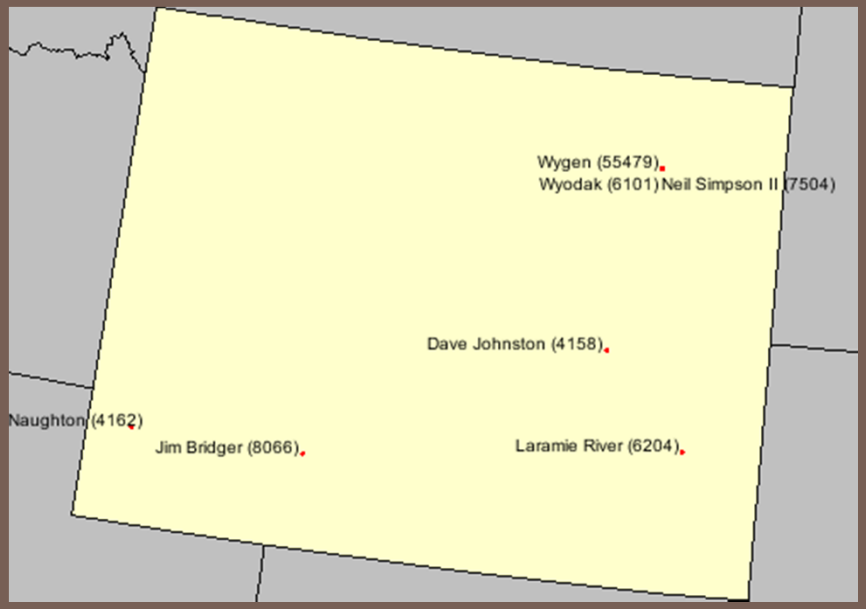
important provisions of the Clean Air Act of 1990 include:

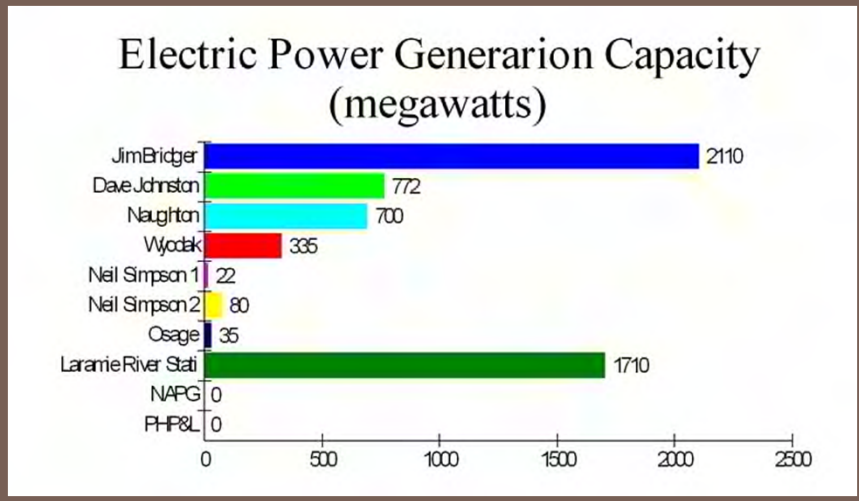
Air Pollution Control Act of 1955

- National Ambient Air Quality Standards (**NAAQS**)
- National Emissions Standards for Hazardous Air Pollutants
- maximum achievable control technology
- control of ozone-depleting chemicals
- asbestos management
- operating Permit Program

Coal-fired Power Plants

Wyoming, Coal and Electricity





Conclusions - Summary

- U.S. cannot easily end use of coal as energy source
  - cheap, abundant
  - very important for electricity generation
- problems:
  - acid precipitation
  - mercury emissions
  - heavy metal release
  - carbon dioxide release, “dirtiest” fossil fuel
- typical power plant releases lots of CO_2 per year
  - Jim Bridger: 2,100 MW, 15x010^6 tons/year