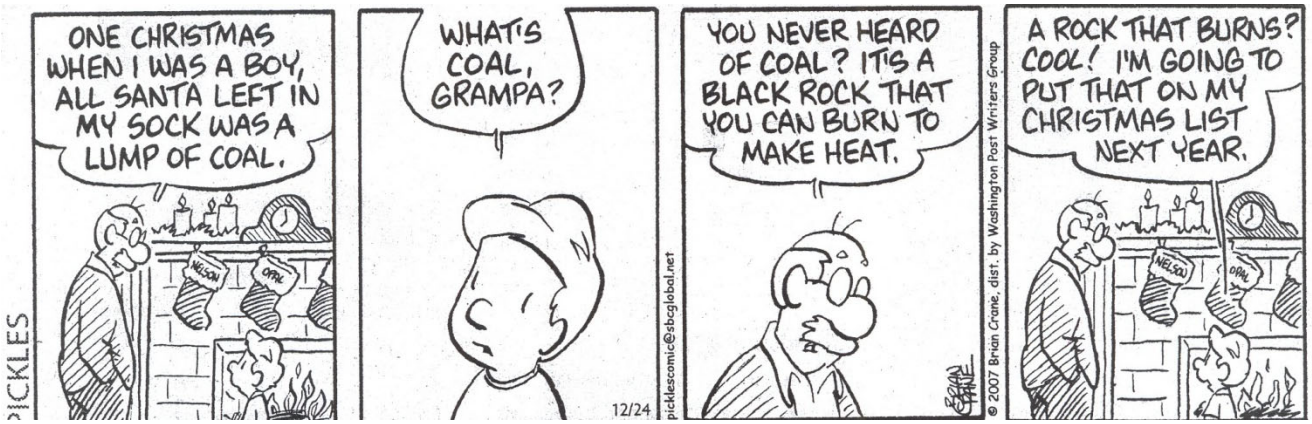
Coal Use

ChEn 733

Coal Combustion



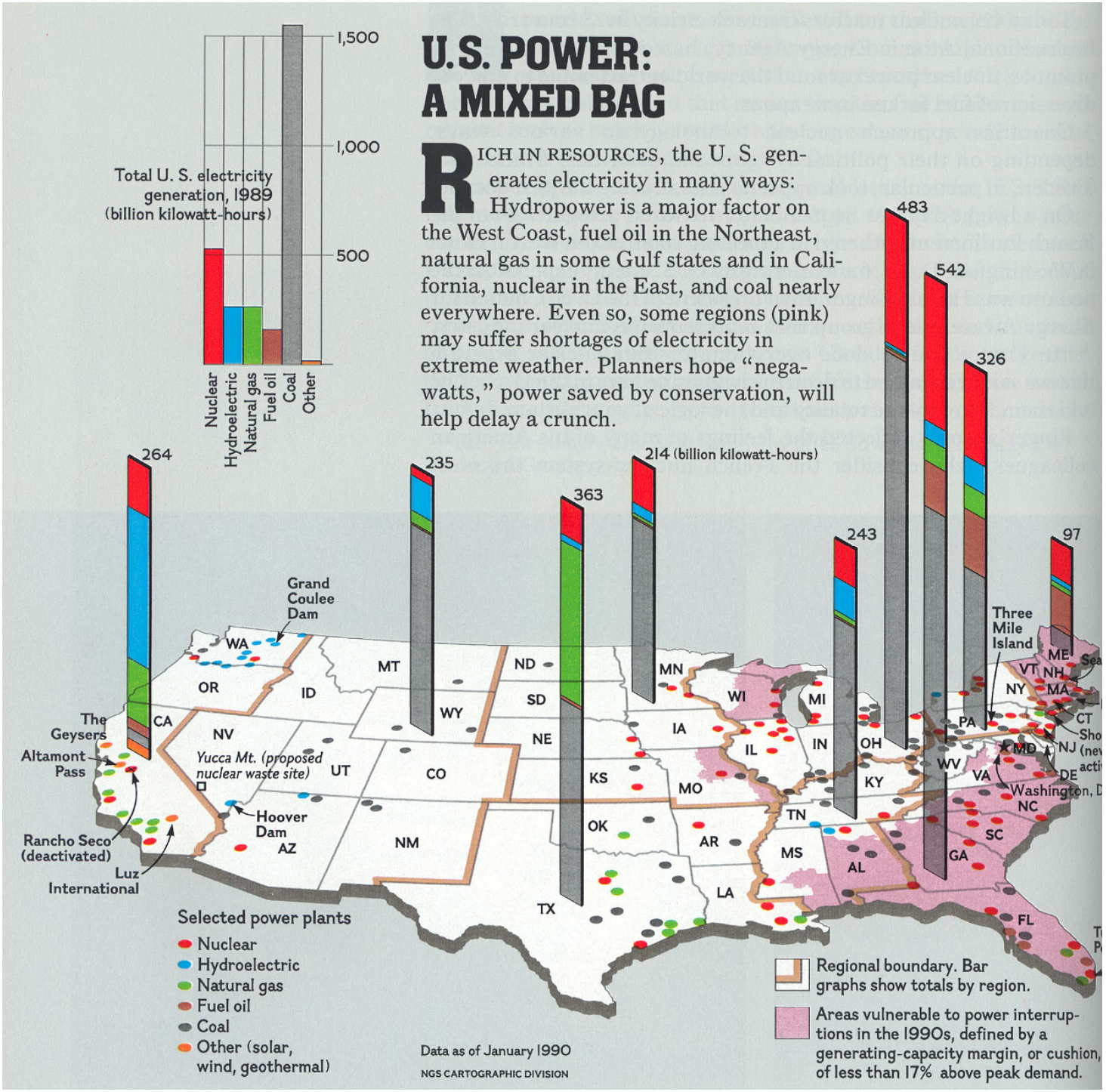
Questions for Class 1

1. Compare the types of electric power generation in the United States by region versus the population (i.e., demand).
2. What is the trend in coal consumption since 1990 in the world and in the United States, China, Germany, England, and South Korea? Look at the following website.
3. What is the current percentage of electric power generation in the United States from coal, natural gas, oil, nuclear, hydroelectric, biomass, solar, wind, and geothermal sources?
4. How does the electric power generation vary between the countries with the top 20 electric power use? Discuss the differences.
5. Describe the main features of a pulverized coal-fired utility, including the cycle used for power generation. Why don't utilities use more advanced cycles or combined cycles?
6. Describe how coal is classified according to rank in the United States, including how the appropriate ASTM analyses are performed. What are the pluses and minuses of this system?
7. Where are the main coal fields in the United States located? Where in the United States is the highest potential for biomass use for electric power generation?
8. Describe what the Argonne Premium Coal Samples are, how they are used, and what other coal sample banks are available. Why are these coal banks valuable?

Question 1

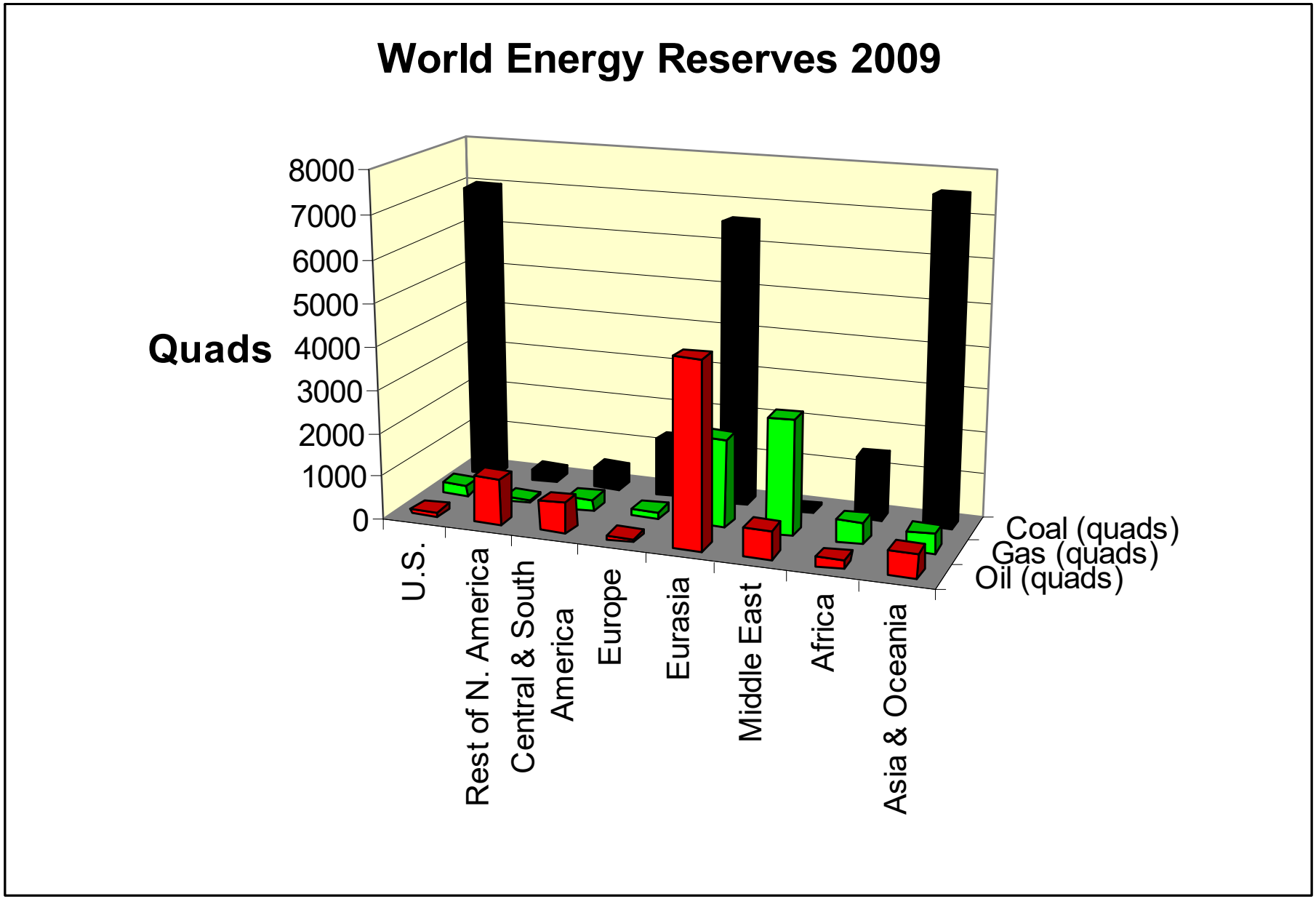
Compare the types of electric power generation in the United States by region versus the population (i.e., demand).

National Geographic (Aug., 1991)



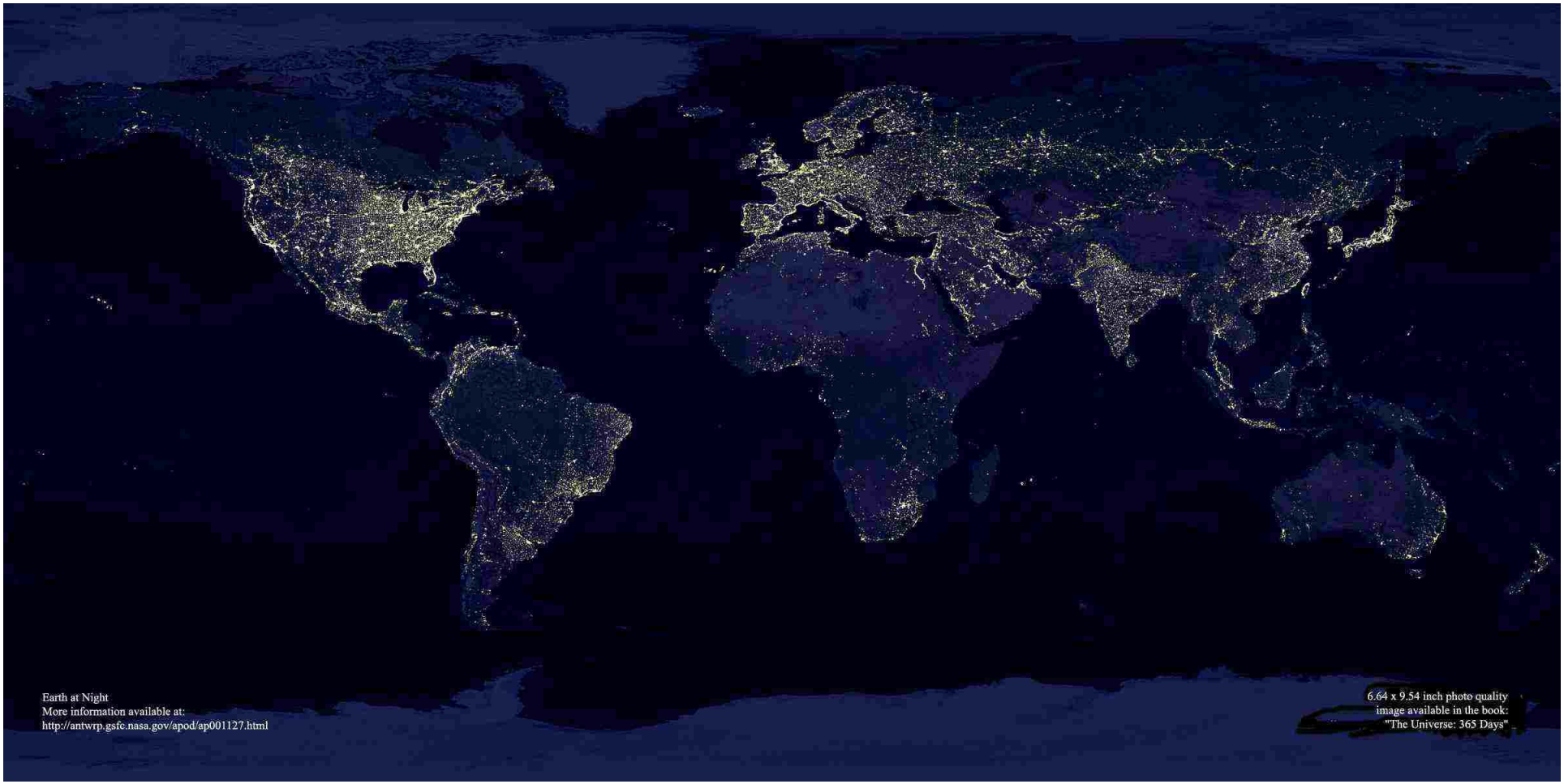
U.S. Satellite Image at Night

From http://antwrp.gsfc.nasa.gov/apod/image/0011/earthlights_dmsp_big.jpg

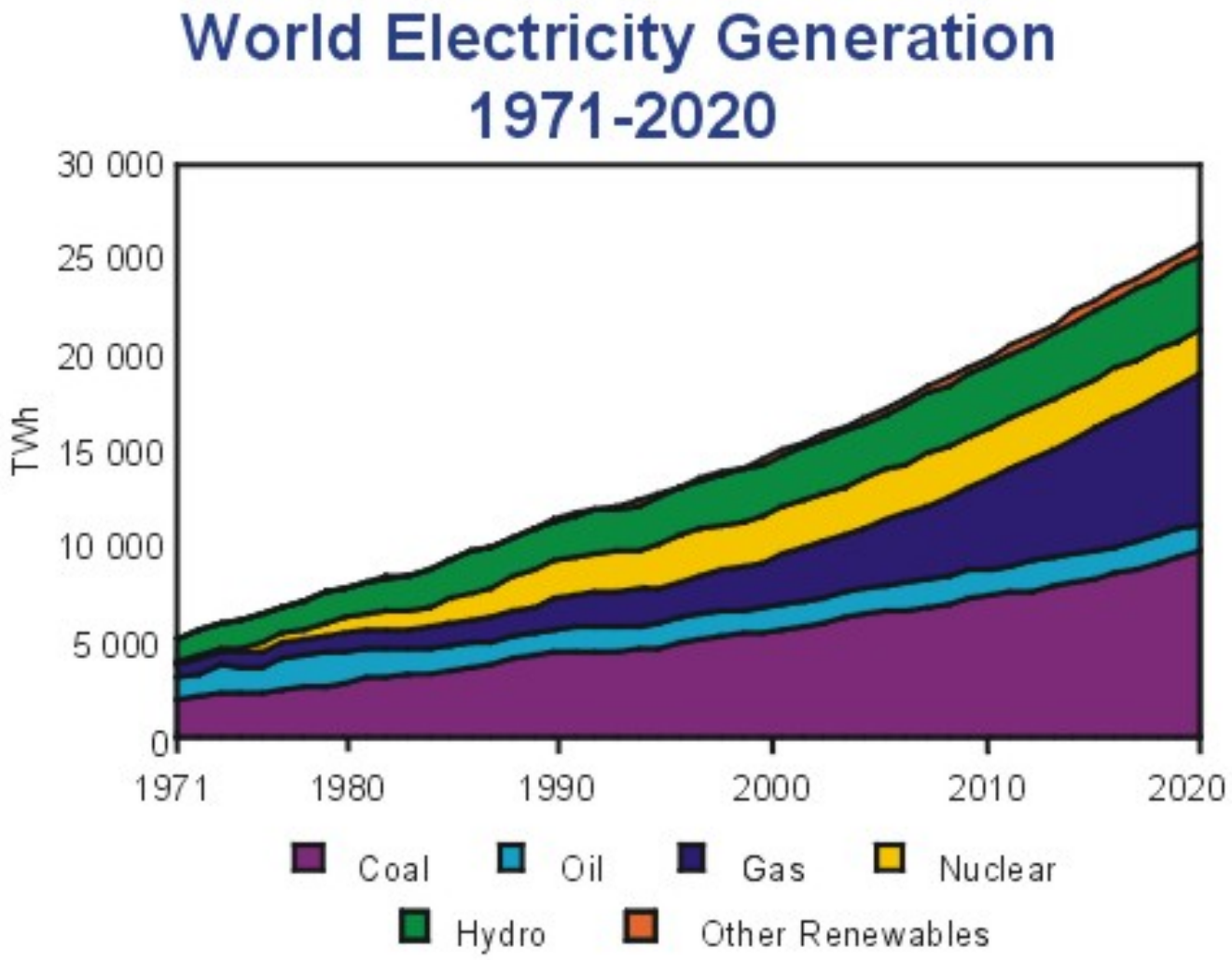


Source: DOE EIA Pages, *http://tonto.eia.doe.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=57&aid=6*

World Satellite Image at Night



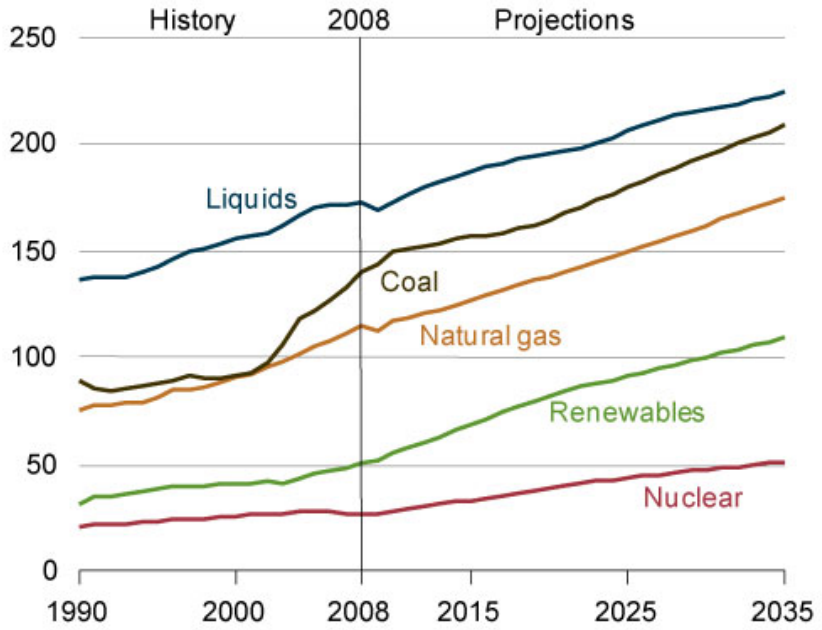
From http://antwrp.gsfc.nasa.gov/apod/image/0011/earthlights_dmsp_big.jpg



from IEA web pages

Projected Energy Use

Figure 15. World energy consumption by fuel, 1990-2035
(quadrillion Btu)



from IEA web pages

Figure 65. World coal consumption by region, 1980-2035
(quadrillion Btu)

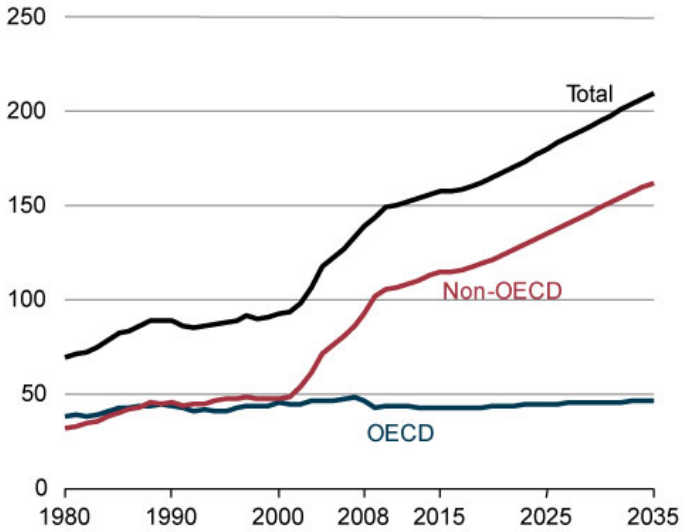
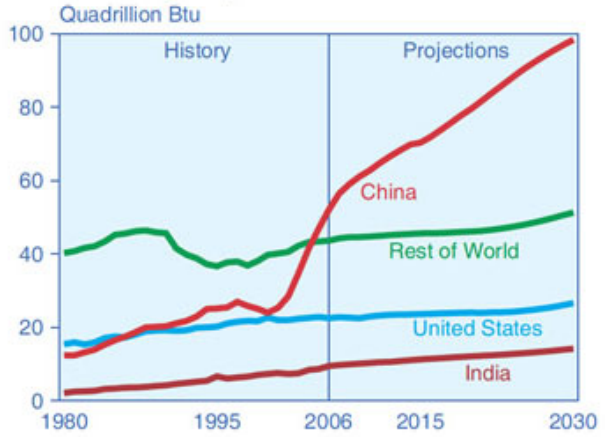


Figure 15. Coal Consumption in Selected World Regions, 1980-2030



Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

Question 2

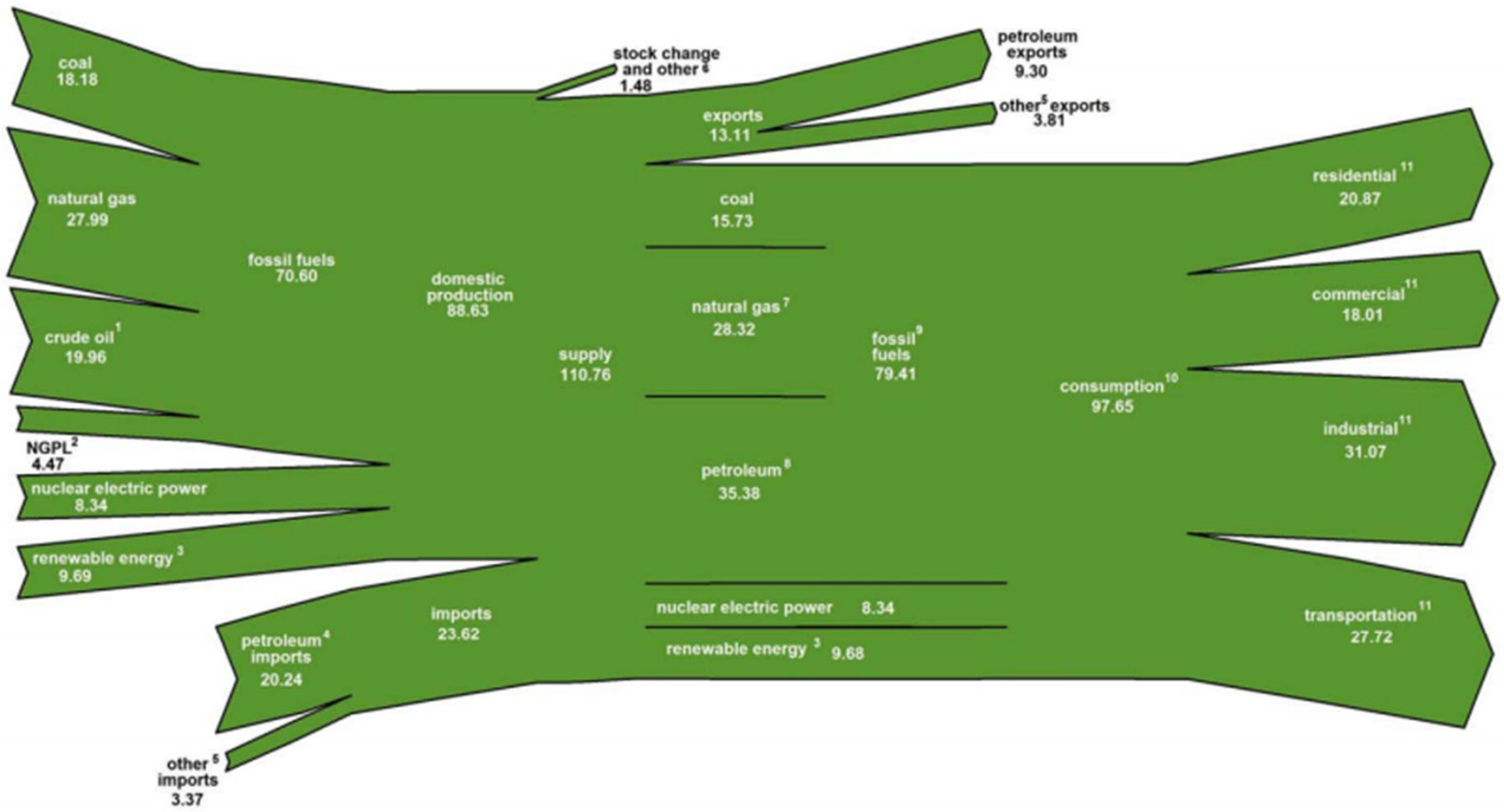
2. What is the trend in coal consumption since 1990 in the world and in the United States, China, Germany, England, and South Korea? Look at the following website.

3. What is the current percentage of electric power generation in the United States from coal, natural gas, oil, nuclear, hydroelectric, biomass, solar, wind, and geothermal sources?

U.S. Total Energy Production & Consumption

U.S. Energy Flow, 2015

quadrillion Btu

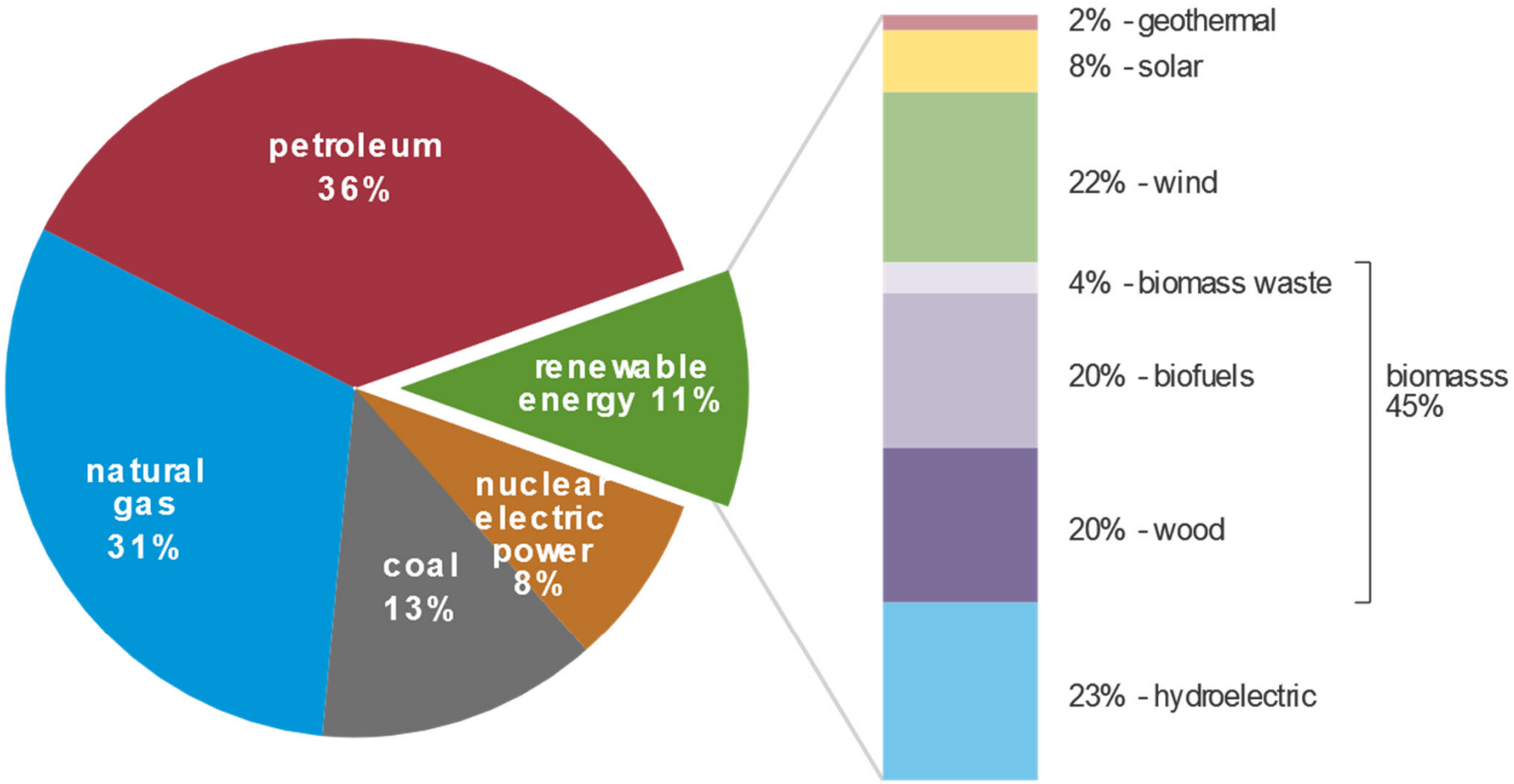


[1] Includes lease condensate.
[2] Natural gas plant liquids.
[3] Conventional hydroelectric power, biomass, geothermal, solar, and wind.
[4] Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve.
[5] Natural gas, coal, coal coke, biofuels, and electricity.
[6] Adjustments, losses, and unaccounted for.
[7] Natural gas only; excludes supplemental gaseous fuels.
[8] Petroleum products, including natural gas plant liquids, and crude oil burned as fuel.
[10] Includes 0.23 quadrillion Btu of electricity net imports.
[11] Total energy consumption, which is the sum of primary energy consumption, electricity retail sales, and electrical system energy losses. Losses are allocated to the end-use sectors in proportion to each sector's share of total electricity retail sales. See Note 1, "Electrical System Energy Losses," at the end of U.S. Energy Information Administration, *Monthly Energy Review* (April 2016), Section 2.
Notes: • Data are preliminary. • Values are derived from source data prior to rounding for publication. • Totals may not equal sum of components due to independent rounding.

U.S. primary energy consumption by energy source, 2018

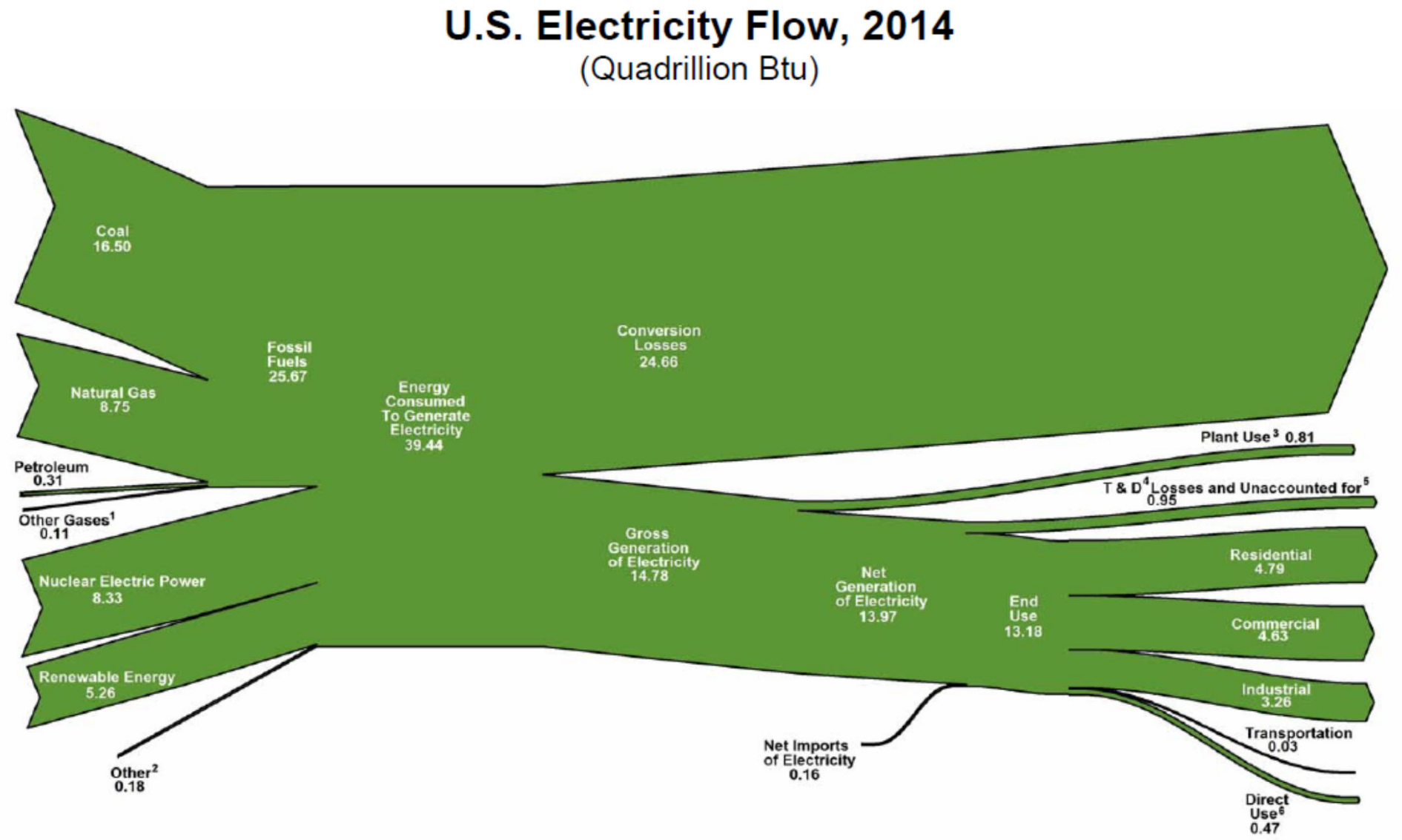
total = 101.3 quadrillion British thermal units (Btu)

total = 11.5 quadrillion Btu



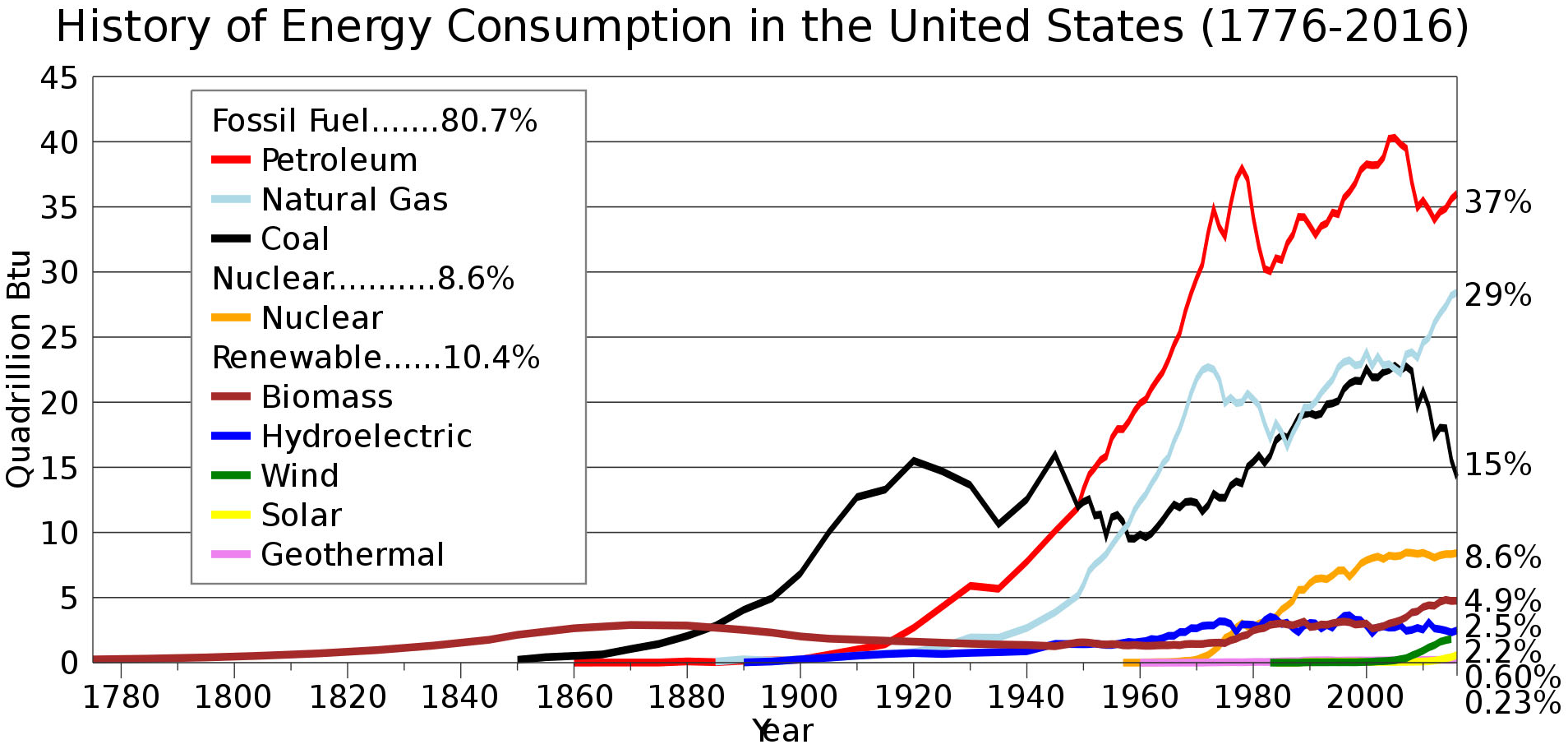
Note: Sum of components may not equal 100% because of independent rounding.
Source: U.S. Energy Information Administration, *Monthly Energy Review*, Table 1.3 and 10.1, April 2019, preliminary data

U.S. Electricity Production & Use

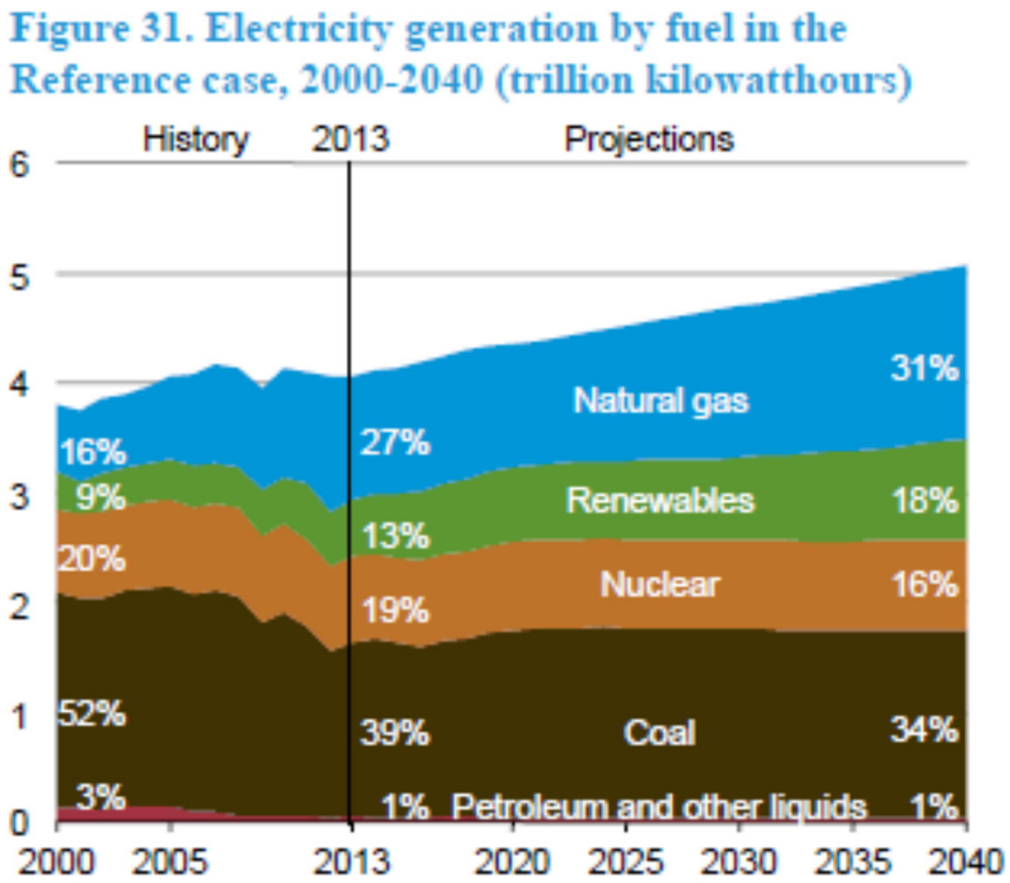


from DOE EIA web pages

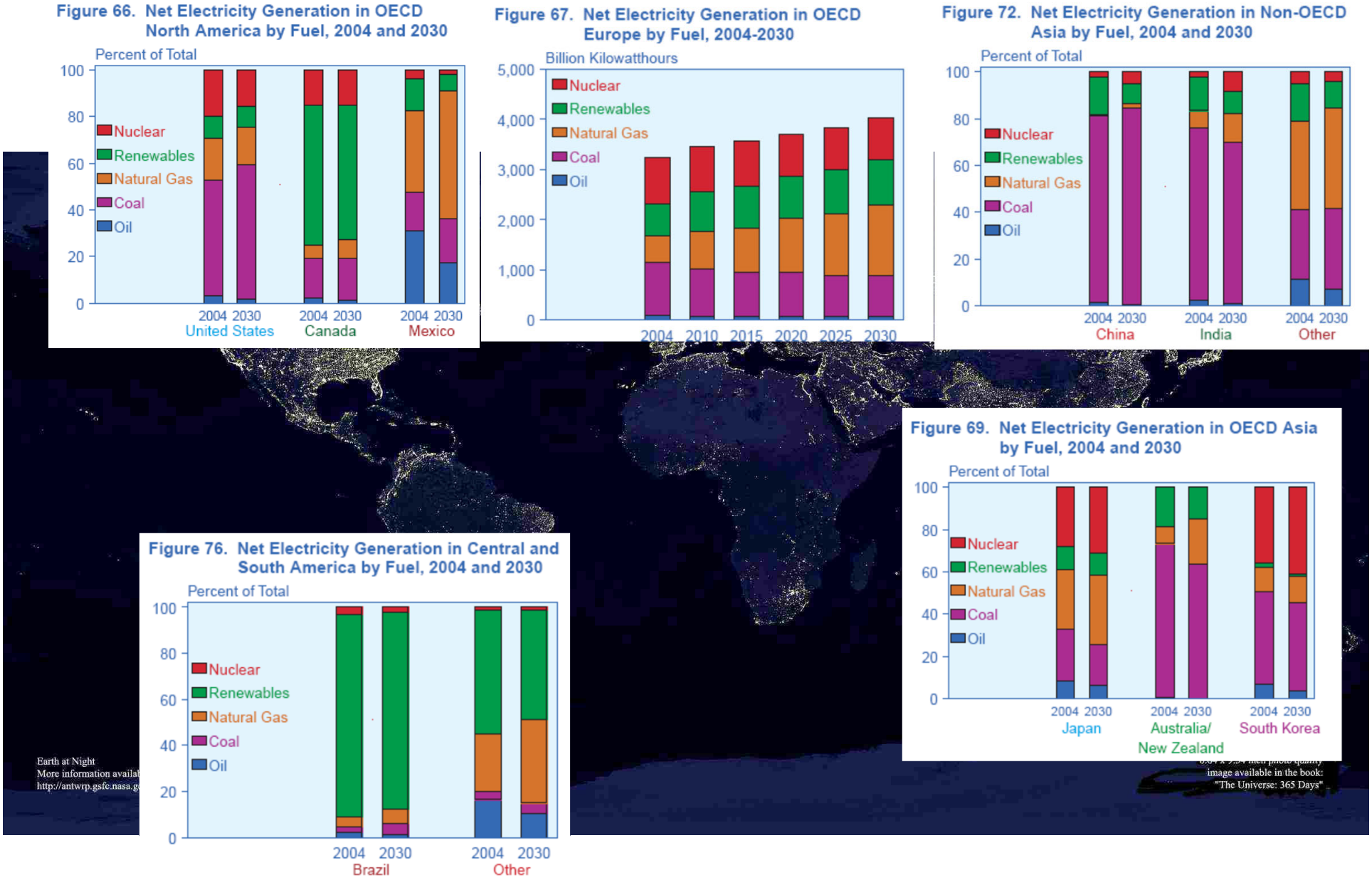
U.S. Total Energy Production



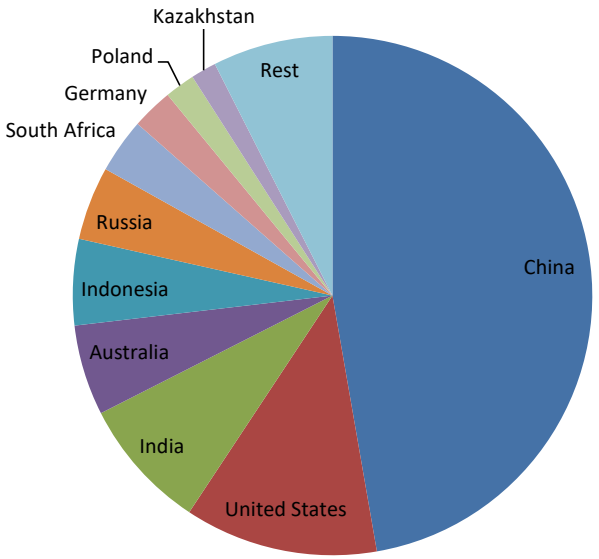
U.S. Electricity Projection

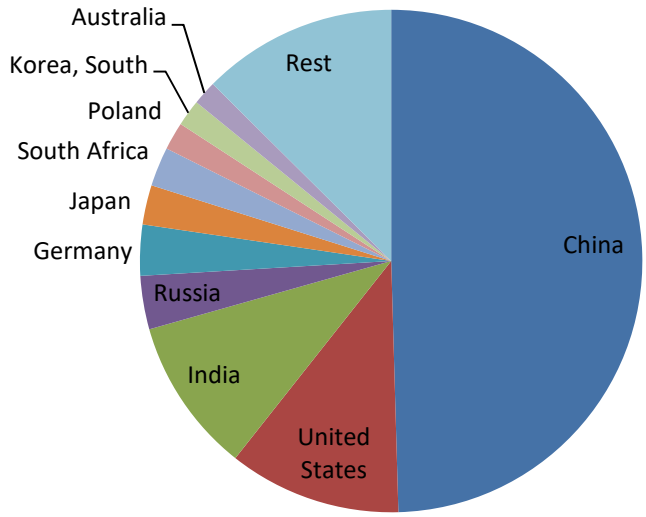


http://www.eia.gov/forecasts/aeo/

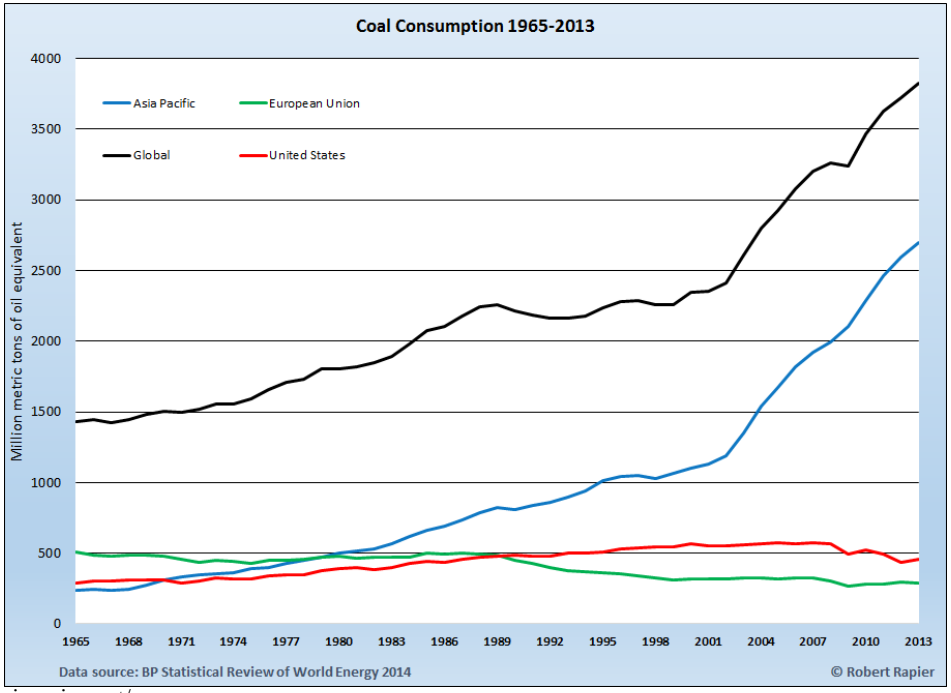


from DOE EIA web pages
http://www.eia.doe.gov/oiaf/ieo/pdf/electricity.pdf

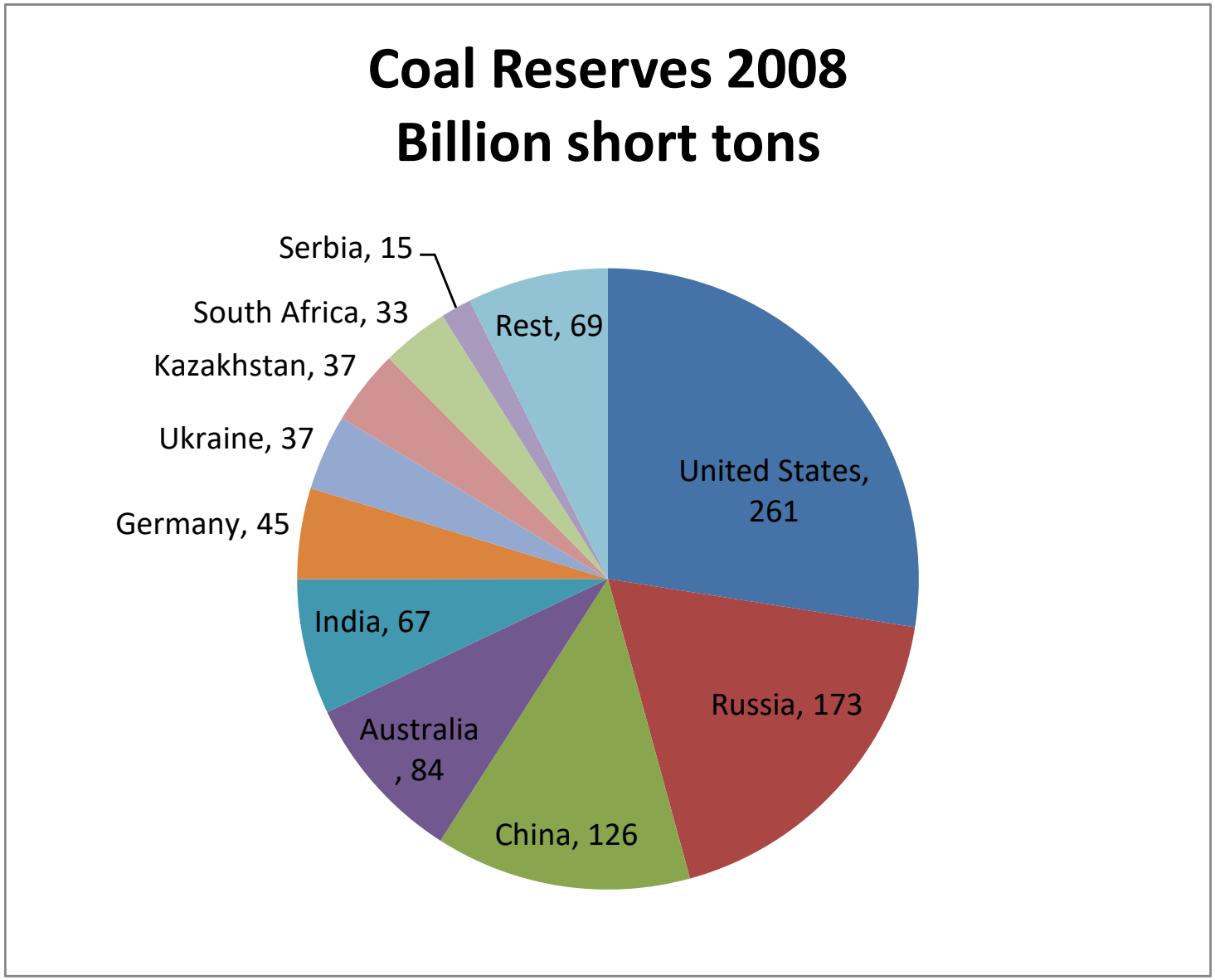




from DOE EIA web pages



http://www.energytrendsinsider.com/2014/07/30/king-coal-deposed-in-west-but-reigns-in-east/

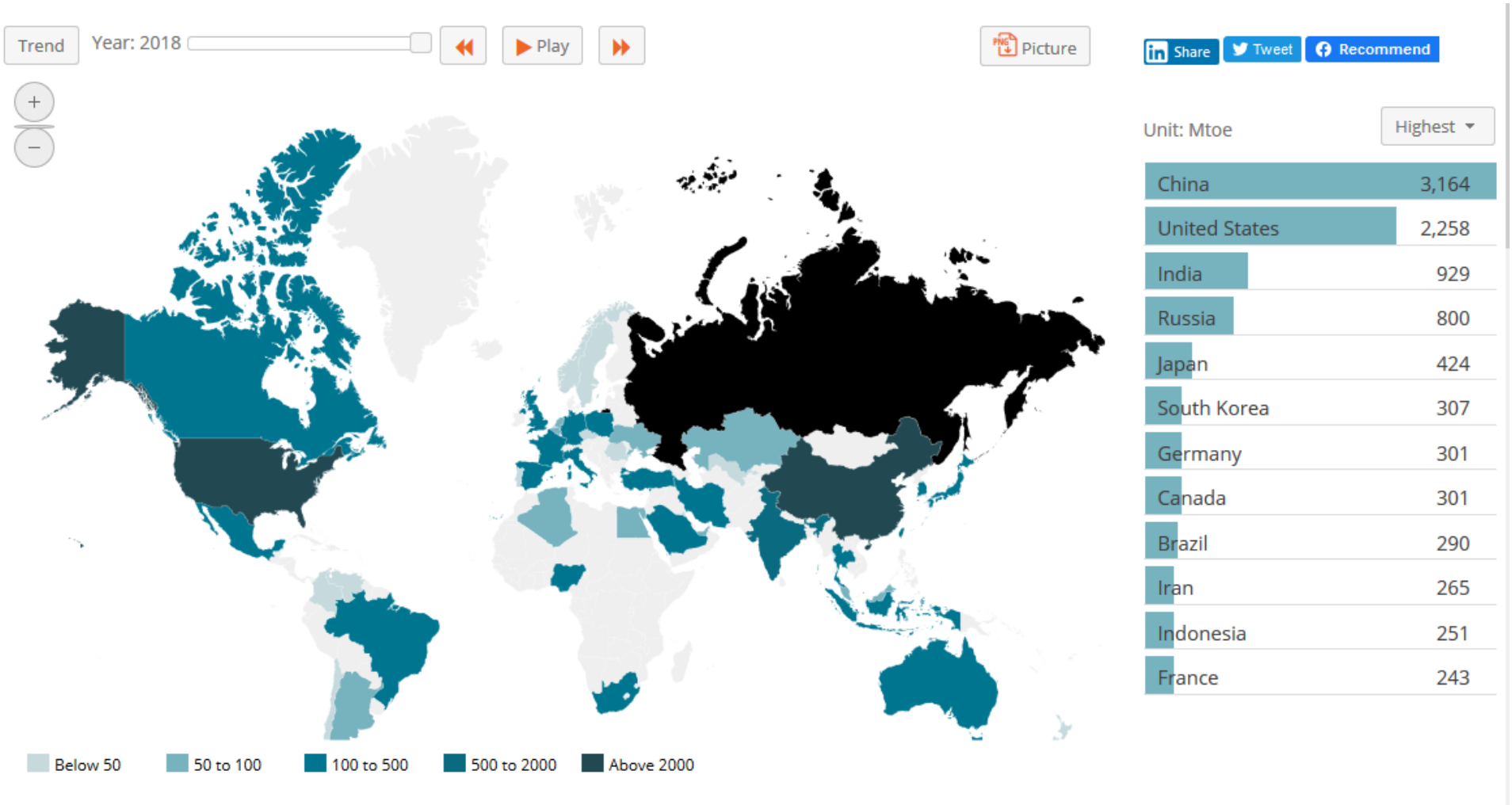


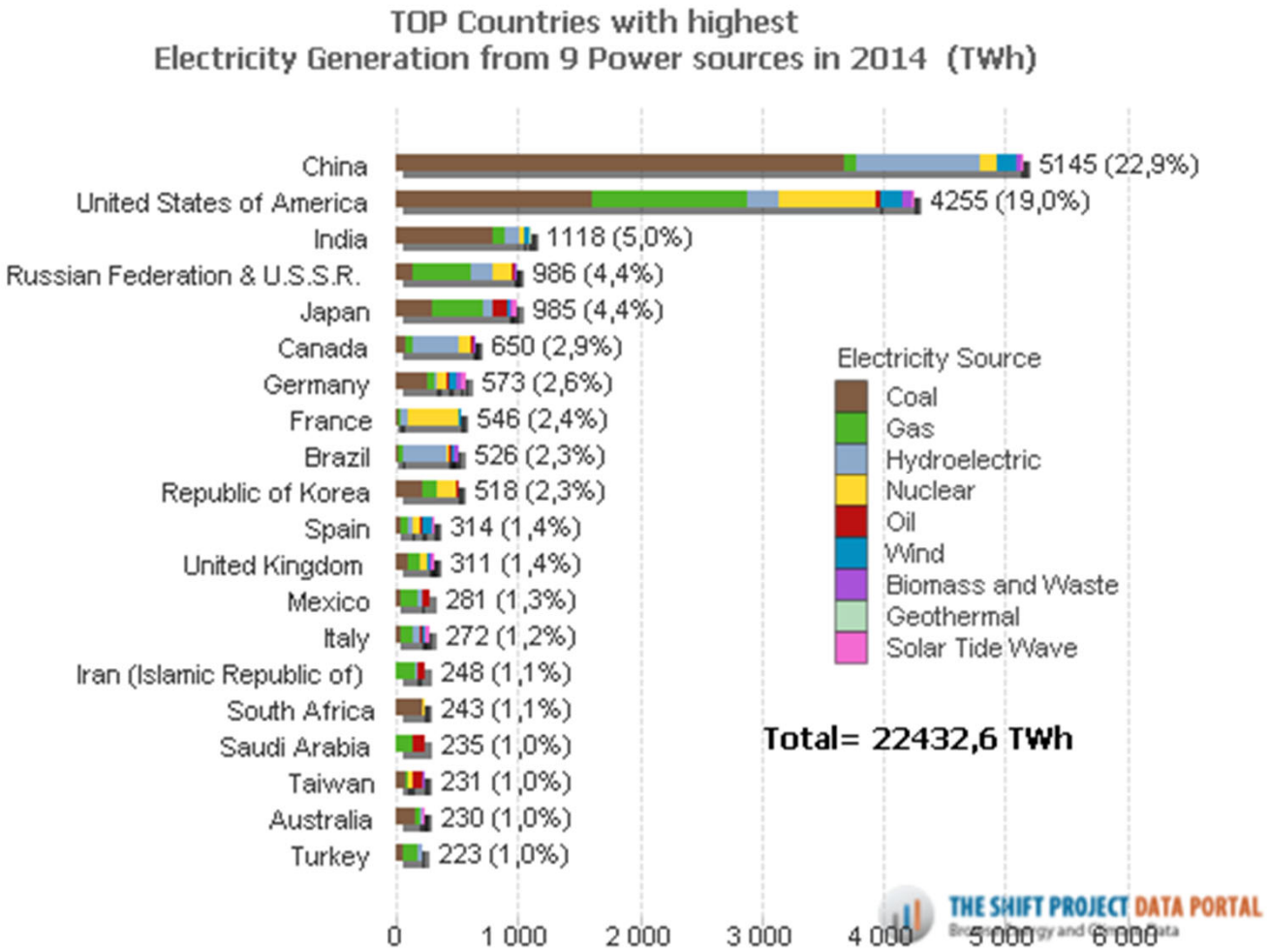
from DOE EIA web pages

Question 4

How does the electric power generation vary between the countries with the top 20 electric power use? Discuss the differences.

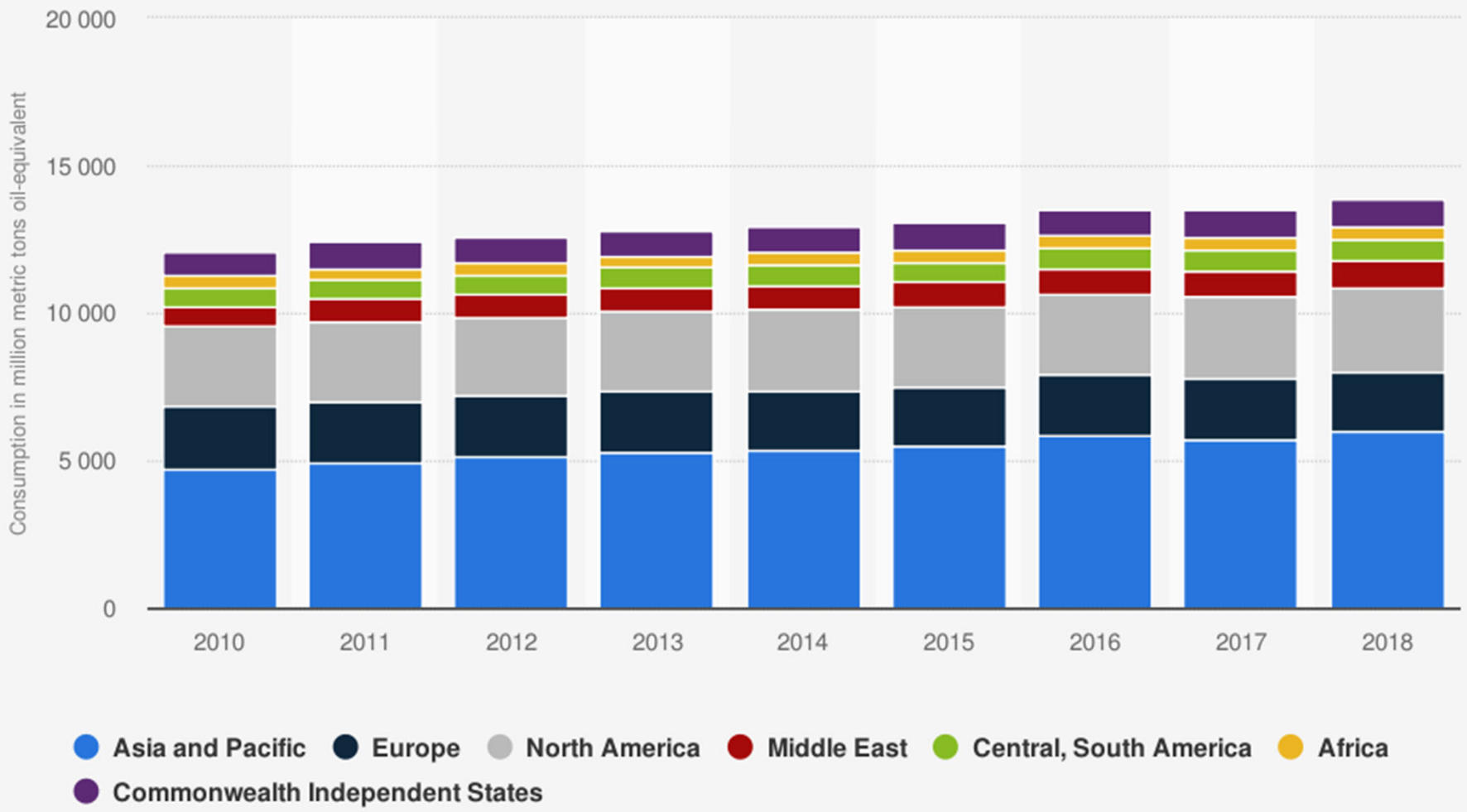
Total Energy Consumption by Country 2018





http://www.tsp-data-portal.org/TOP-20-Generation#tspQvChart

Primary energy consumption worldwide between 2010 and 2018, by region (in million metric tons oil-equivalent)

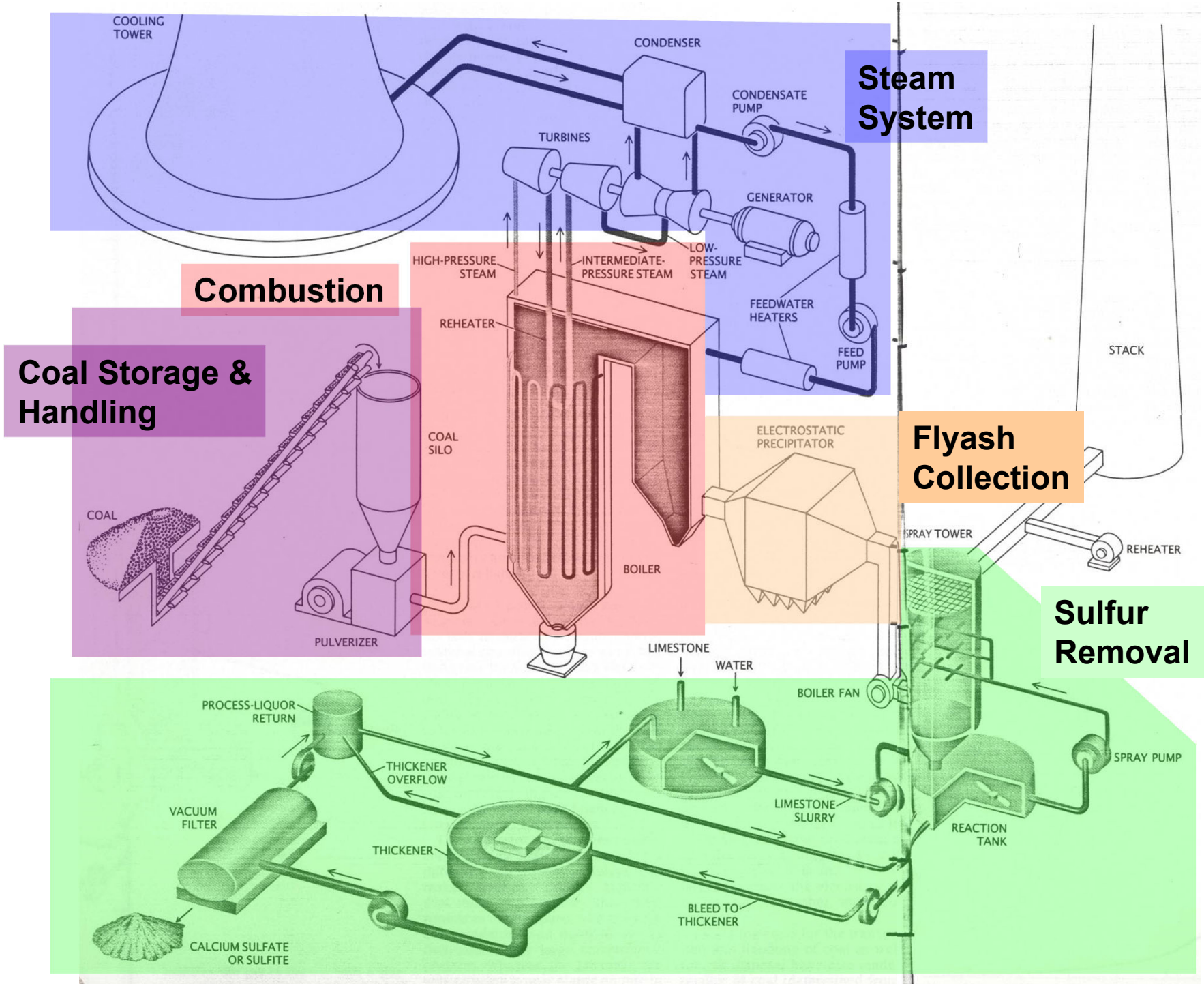


Source
BP

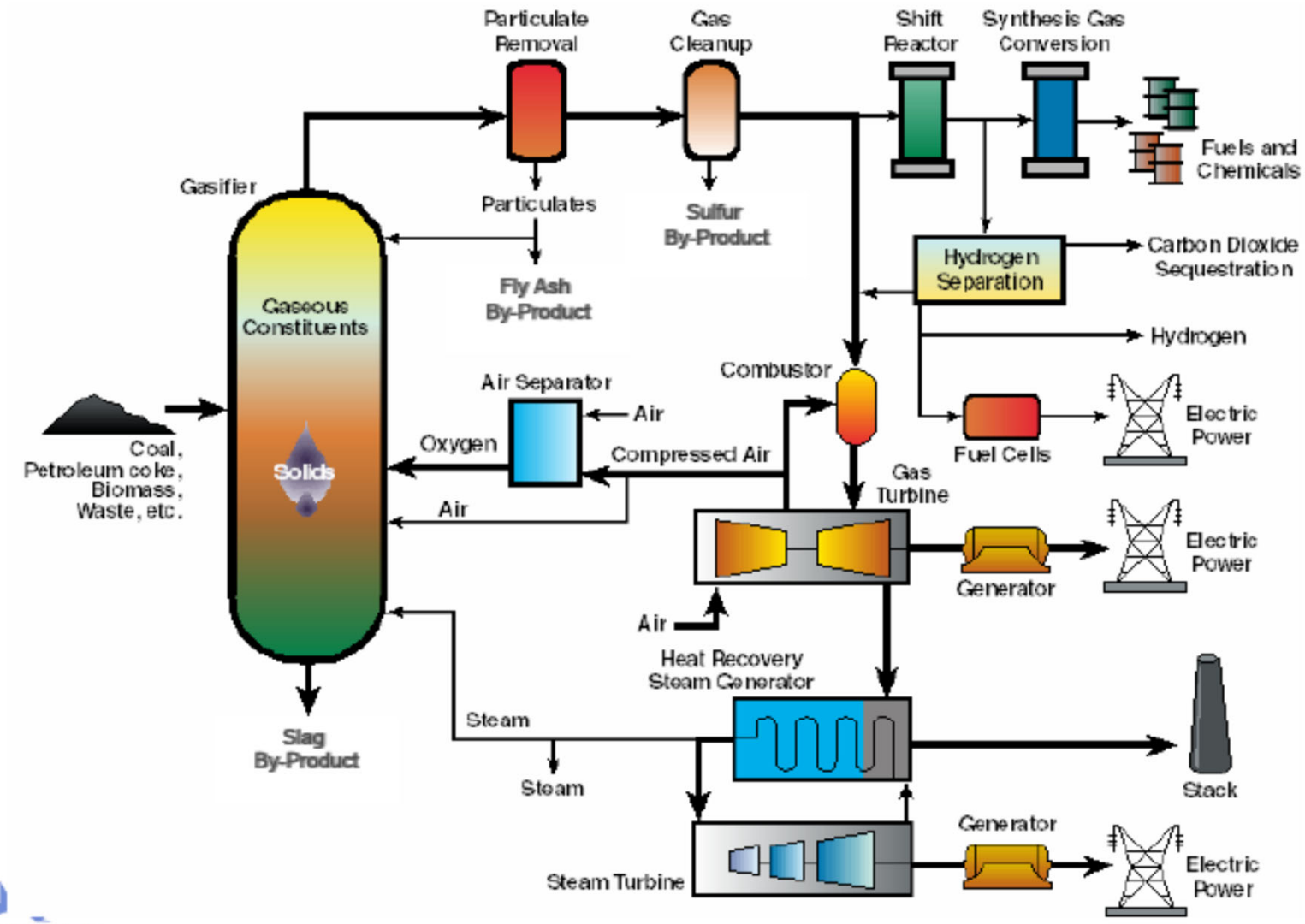
Additional Information:
Worldwide; 2010 to 2018

Question 5

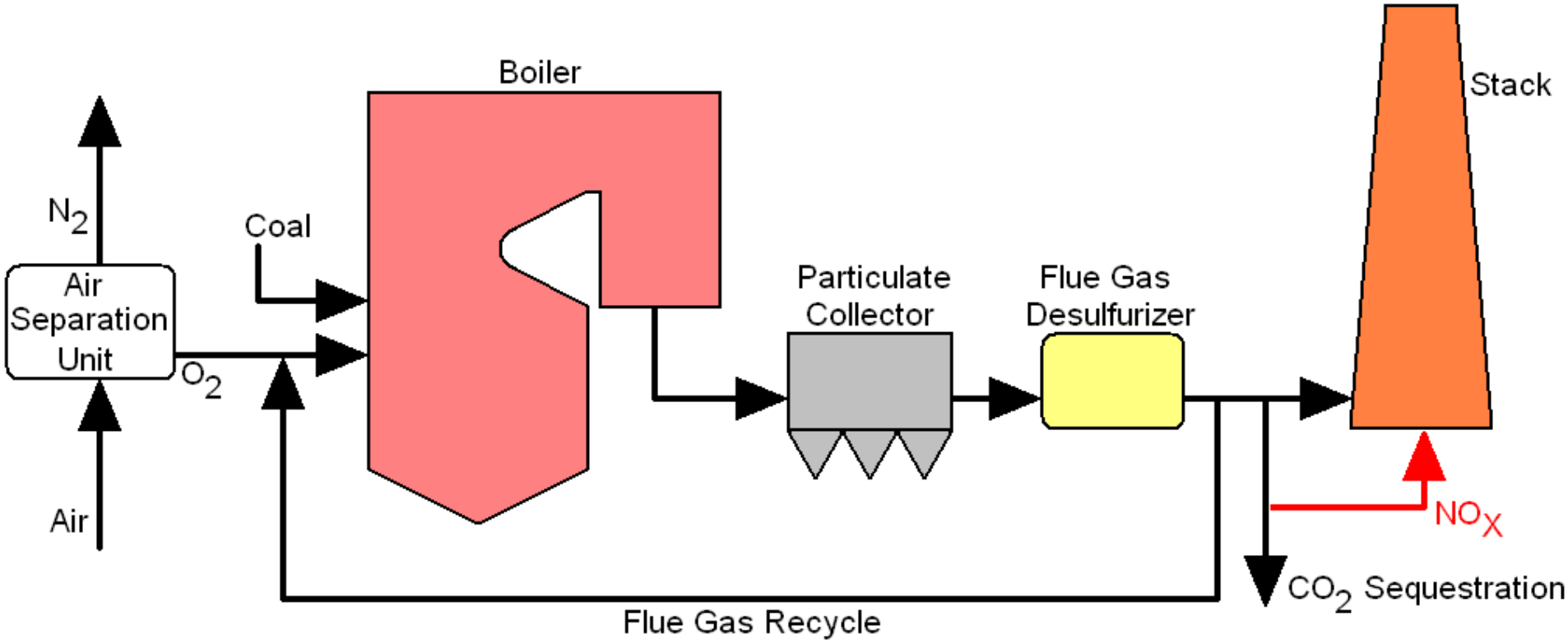
Describe the main features of a pulverized coal-fired utility, including the cycle used for power generation. Why don't utilities use more advanced cycles or combined cycles?


Steam System
COOLING TOWER
CONDENSER
CONDENSATE PUMP
TURBINES
GENERATOR
LOW-PRESSURE STEAM
INTERMEDIATE-PRESSURE STEAM
HIGH-PRESSURE STEAM
FEEDWATER HEATERS
FEED PUMP
Combustion
REHEATER
Coal Storage & Handling
COAL SILO
COAL
PULVERIZER
BOILER
ELECTROSTATIC PRECIPITATOR
Flyash Collection
STACK
SPRAY TOWER
REHEATER
Sulfur Removal
LIMESTONE
WATER
BOILER FAN
PROCESS-LIQUOR RETURN
THICKENER OVERFLOW
VACUUM FILTER
THICKENER
LIMESTONE SLURRY
SPRAY PUMP
REACTION TANK
BLEED TO THICKENER
CALCIUM SULFATE OR SULFITE

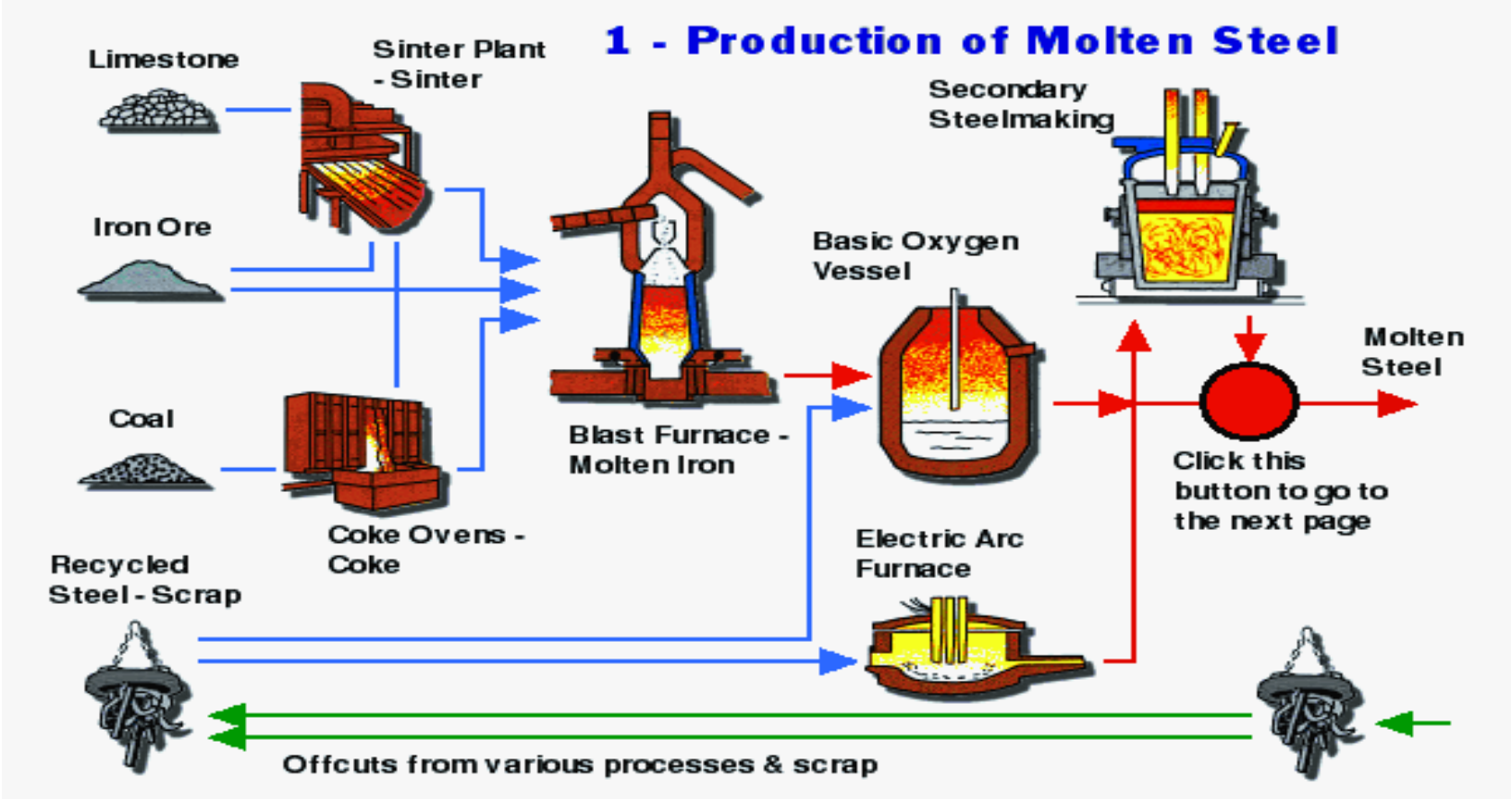
Gasification-Based Energy Production System Concepts



Oxyfuel


Boiler
Stack
N_2
Coal
Air Separation Unit
O_2
Particulate Collector
Flue Gas Desulfurizer
Air
NO_X
CO_2 Sequestration
Flue Gas Recycle

Steelmaking



Question 6

Describe how coal is classified according to rank in the United States, including how the appropriate ASTM analyses are performed.

What are the pluses and minuses of this system?

TABLE I *Classification of Coals by Rank*

Class	Group	Fixed carbon limits (%) (dry, mineral-matter-free basis) ⩾	Fixed carbon limits (%) (dry, mineral-matter-free basis) <	Volatile matter limits (%) (dry, mineral-matter-free basis) >	Volatile matter limits (%) (dry, mineral-matter-free basis) ⩾	Calorific value limits (Btu/lb) (moist mineral-matter-free basis) ⩾	Calorific value limits (Btu/lb) (moist mineral-matter-free basis) <	Agglomerating character
I.	Anthracitic							
	1. Meta-anthracite	98	—	—	2	—	—	nonagglomerating
	2. Anthracite	92	98	2	8	—	—	
	3. Semianthracite	86	92	8	14	—	—	
II.	Bituminous							
	1. Low volatile bituminous coal	78	86	14	22	—	—	commonly agglomerating
	2. Medium volatile bituminous coal	69	78	22	31	—	—	
	3. High volatile A bituminous coal	—	69	31	—	14,000	—	
	4. High volatile B bituminous coal	—	—	—	—	13,000	14,000	
	5. High volatile C bituminous coal	—	—	—	—	11,500	13,000	
						10,500	11,500	agglomerating
III.	Subbituminous							
	1. Subbituminous A coal	—	—	—	—	10,500	11,500	nonagglomerating
	2. Subbituminous B coal	—	—	—	—	9,500	10,500	
	3. Subbituminous C coal	—	—	—	—	8,300	9,500	
IV.	Lignitic							
	1. Lignite A	—	—	—	—	6,300	8,300	
	2. Lignite B	—	—	—	—	—	6,300	

ASTM Standard Tests

Proximate Analysis

Moisture	**104-110°C for exactly 1 hour, swept with dry air**
Volatile Matter	**1g coal in covered crucible, inserted into furnace (in air) at 950 ° C, 7 minutes**
Ash	**From moisture sample, heat to 500 ° C in 1 hour, to 750 ° C in 2 hrs, and remain at 750 ° C until constant weight**
Fixed Carbon	**100-% Volatile matter (on dry, ash-free basis)**

Heating Value

Calorimeter	**moist, mineral-matter free basis**

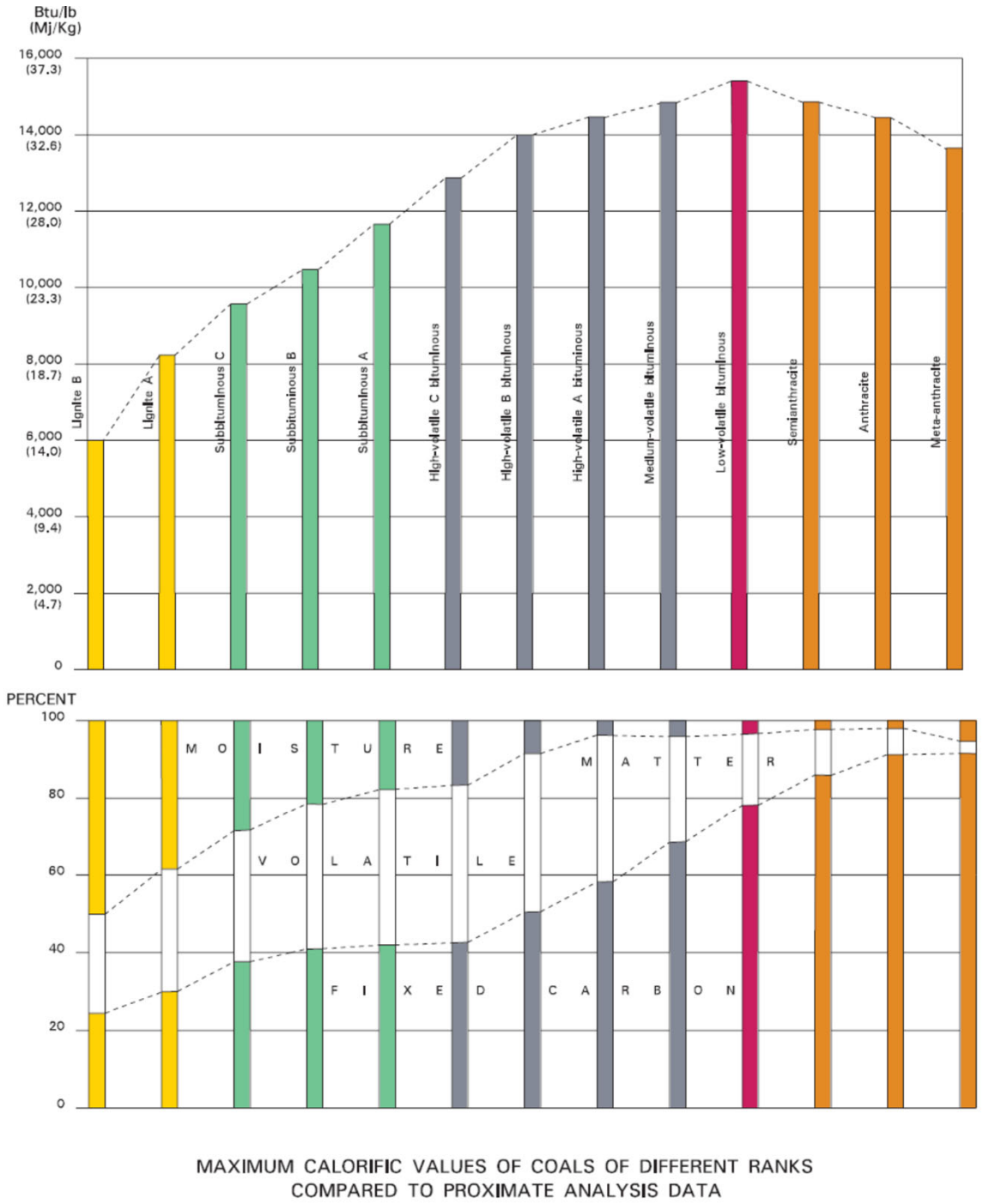
ASTM Standard Tests (cont.)

Ultimate Analysis

- **Carbon**
- **Hydrogen**
- **Nitrogen**
- **Sulfur**
- **Oxygen (Usually by difference)**

There are several instruments available for ultimate analysis, but usually C, H, and N are determined on one machine and total S is determined on a separate machine.

Note that the ultimate analysis does not distinguish between organic sulfur (bound up in the aromatic ring structure) and pyritic sulfur (iron pyrite, FeS2).



MAXIMUM CALORIFIC VALUES OF COALS OF DIFFERENT RANKS
COMPARED TO PROXIMATE ANALYSIS DATA

Proximate Analyses

What are the main points?

(in Smoot & Smith, 1985)

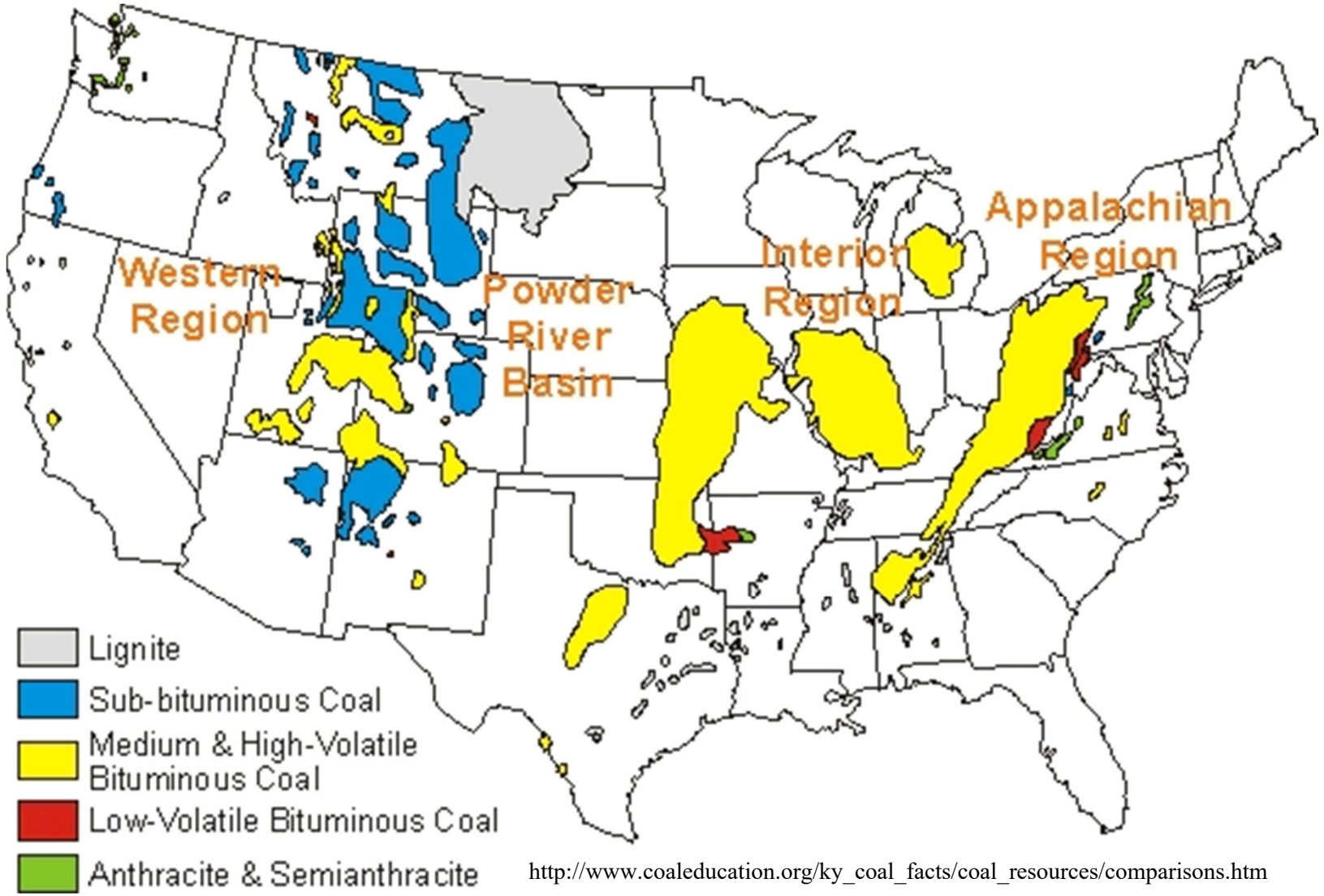
http://pubs.usgs.gov/of/1996/of96-092/other_files/us_coal.pdf

Question 7

Where are the main coal fields in the United States located?

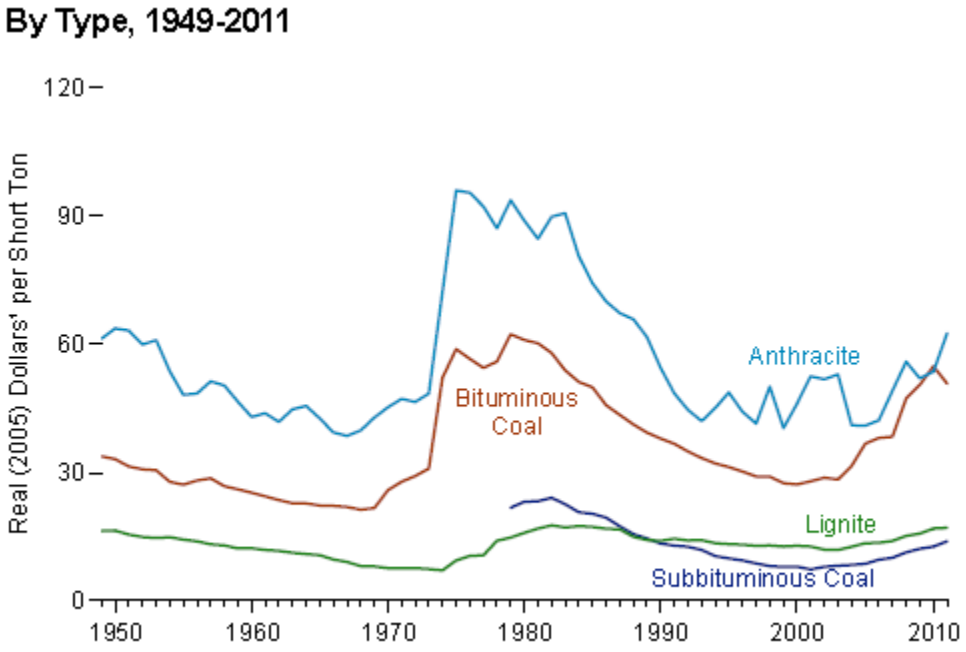
Where in the United States is the highest potential for biomass use for electric power generation?

U.S. Coal Fields

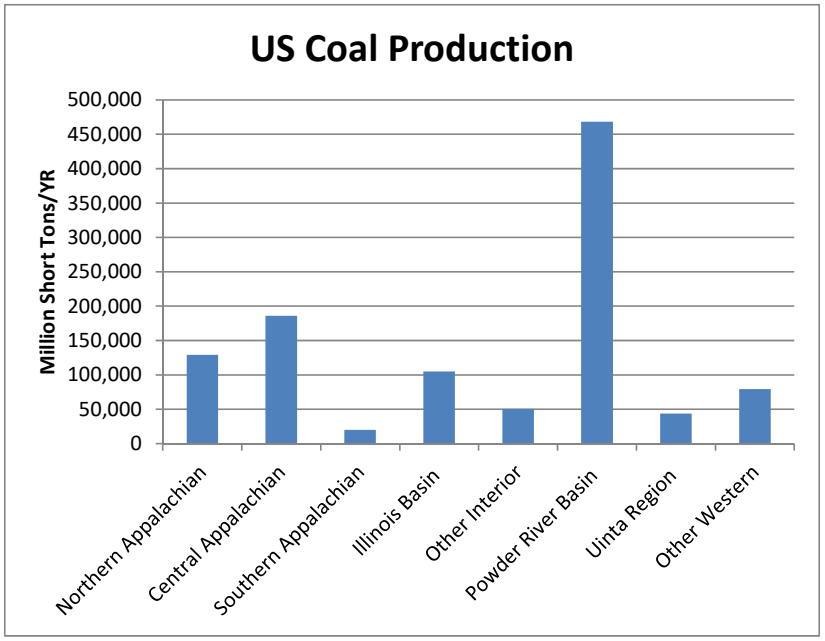


http://www.coaleducation.org/ky_coal_facts/coal_resources/comparisons.htm

Source: Developed from the U.S. Geological Survey

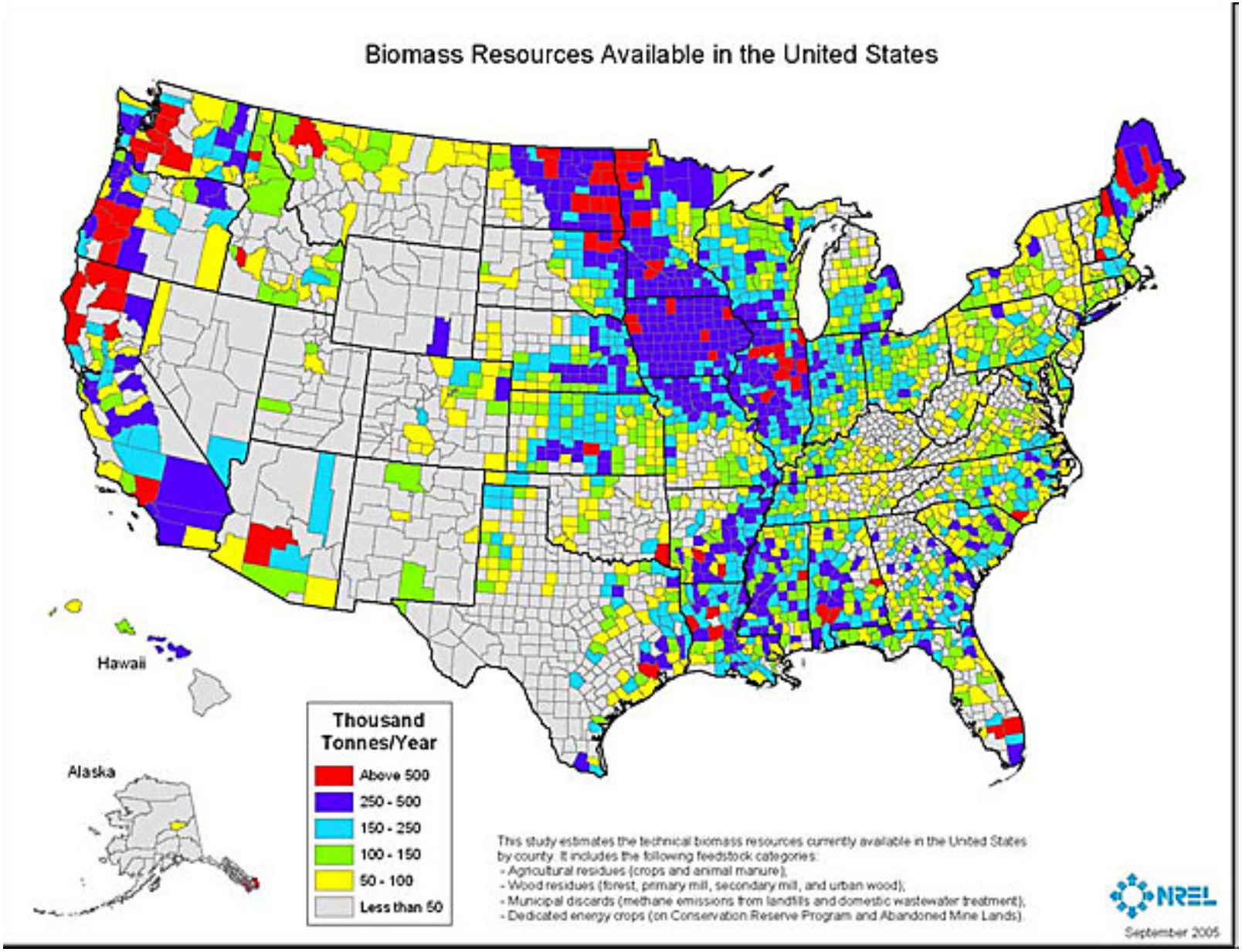


http://www.eia.gov/totalenergy/data/annual/index.cfm#coal



http://www.eia.gov/coal/data.cfm#production

Biomass Potential



http://www.lowcarboneconomy.com/Resources/UserImages/biomassOriginal.jpg

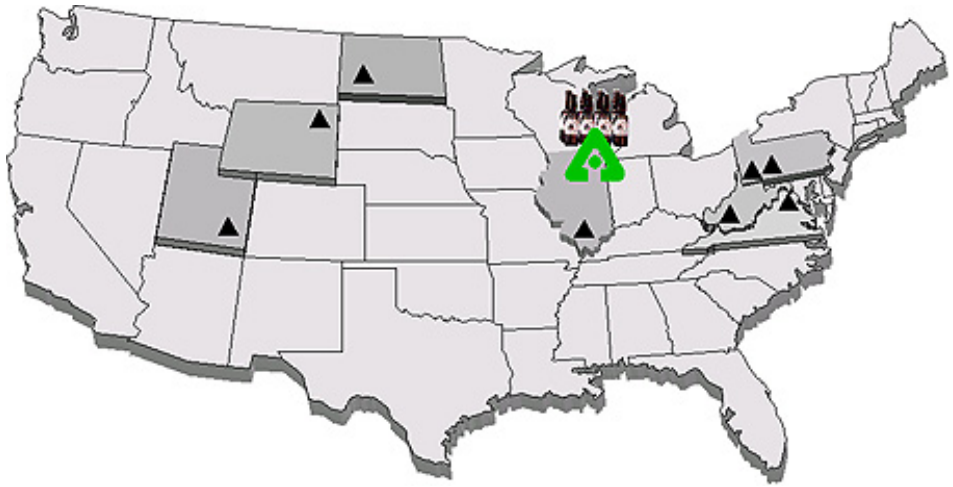
Question 8

Describe what the Argonne Premium Coal Samples are, how they are used, and what other coal sample banks are available. Why are these coal banks valuable?

Argonne Premium Coals

- Pocahontas #3 (VA) Low Vol. Bit.
- Upper Freeport (PA) Med. Vol. Bit.
- Lewiston-St. (WV) High Vol. Bit.
- Pittsburgh #8 (PA) High Vol. Bit.
- Illinois #6 (IL) High Vol. Bit.
- Beulah-Zap (ND) Lignite
- Wyodak-And. (WY) Subbituminous
- Blind Canyon (UT) High Vol. Bit.

Argonne Premium Coals



Pocahontas #3 (VA) Low Vol. Bit.
Upper Freeport (PA) Med. Vol. Bit.
Lewiston-St. (WV) High Vol. Bit.
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Illinois #6 (IL) High Vol. Bit.
Beulah-Zap (ND) Lignite
Wyodak-And. (WY) Subbituminous
Blind Canyon (UT) High Vol. Bit.

Bottom Line

Coal will be used for a long time!