

01-Energy Sources

ECEGR 4530

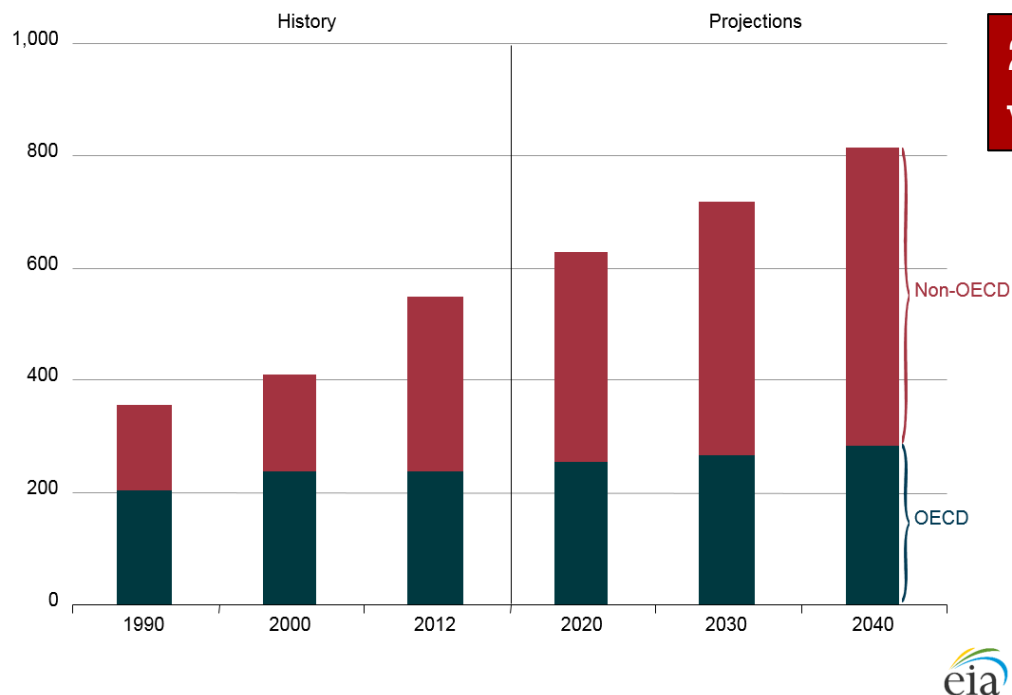
Renewable Energy Systems

➤ Overview

- Global Consumption
- Energy Flows
- Renewable Energy

How much energy is consumed by the world?

Figure 1-1. World energy consumption, 1990-2040
quadrillion Btu

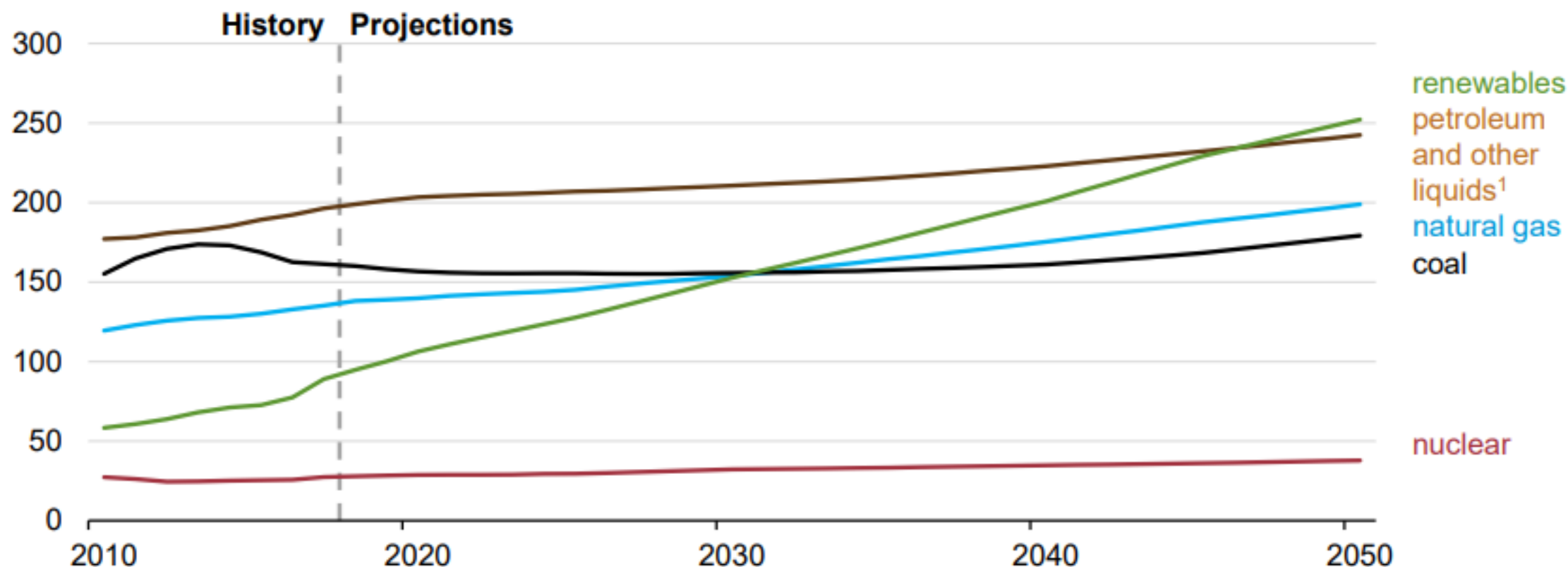


2012 worldwide energy consumption was 549 Quad (549 EJ)

Global per capita consumption is 78 GJ/year—redistribution of energy might be enough for all to have high HDI

IEO2019 projects renewables the most used energy source by 2050

Primary energy consumption by fuel, world
quadrillion British thermal units



Note: 1 = Includes biofuels

Source: U.S. Energy Information Administration, International Energy Outlook 2019

United States milestones in meeting global energy consumption

2011

Becomes petroleum products net exporter

2017

Becomes natural gas net exporter

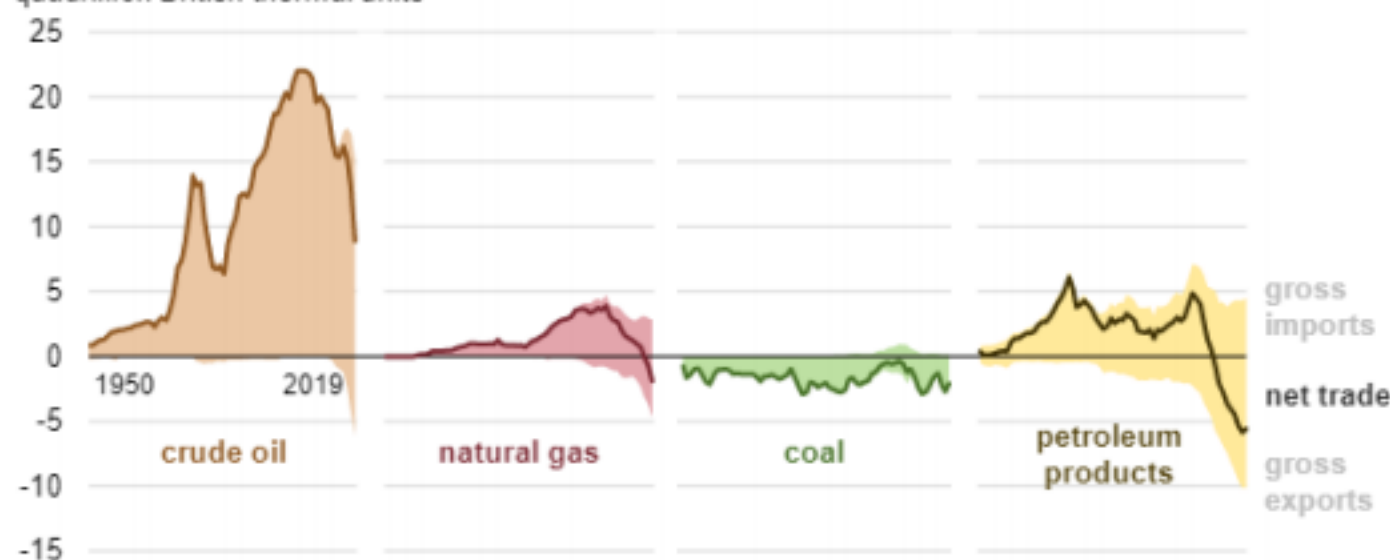
2019

Becomes total energy exporter - total annual energy exports exceed imports

2020

Pandemic leads to market transitions

U.S. energy trade for selected fuel sources (1950-2019)
quadrillion British thermal units

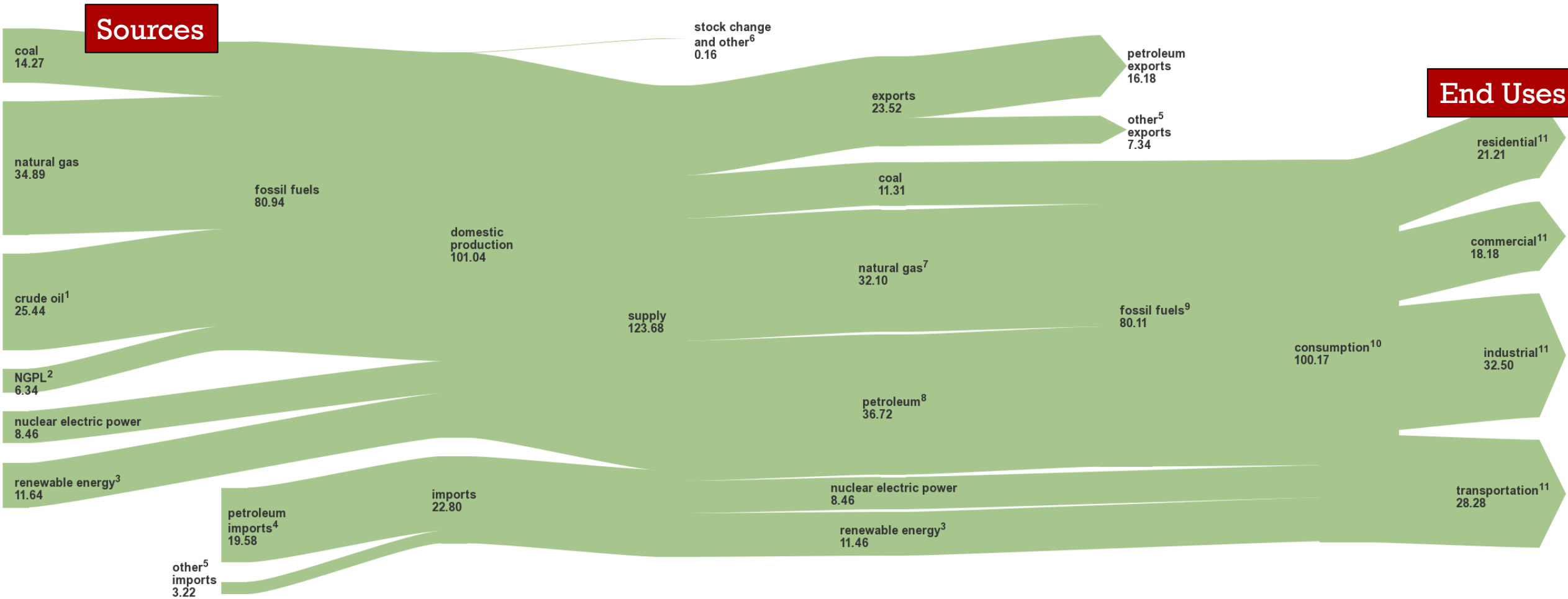


Source: EIA, *Today in Energy*, April 20, 2020 (<https://www.eia.gov/todayinenergy/detail.php?id=43395>)

1 kWh = 3412 BTU

U.S. energy flow, 2019

quadrillion Btu



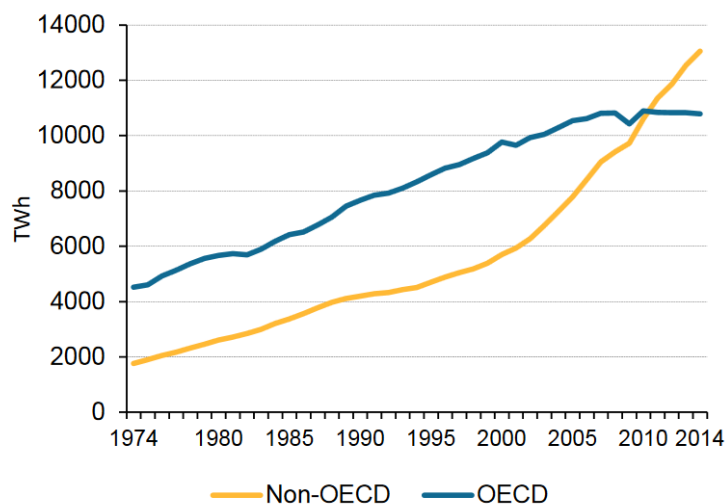
¹ Includes lease condensate. | ² Natural gas plant liquids. | ³ Conventional hydroelectric power, biomass, geothermal, solar, and wind. | ⁴ Crude oil and petroleum products. Includes imports into the Strategic Petroleum Reserve. | ⁵ Natural gas, coal, coal coke, biomass, and electricity. | ⁶ Adjustments, losses, and unaccounted for. | ⁷ Natural gas only; excludes supplemental gaseous fuels. | ⁸ Petroleum products supplied. | ⁹ Includes -0.02 quadrillion Btu of coal coke net imports. | ¹⁰ Includes 0.13 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 (EIA), *Monthly Energy Review* (April 2020), Section 2. See Note 2, "Other Energy Losses," at the end of U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2020), 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.

World Electricity Production

Worldwide gross electricity production is 23,815 TWh.

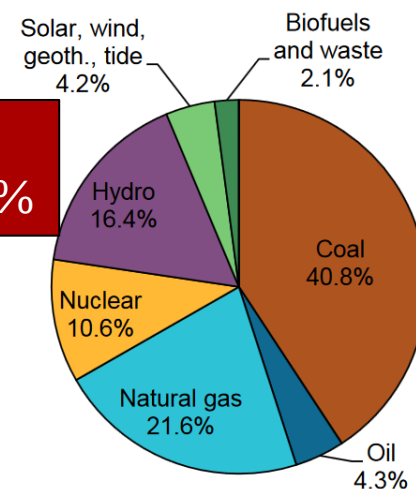
Growth rate of 1.9%, primarily in non OECD countries

Figure 1: Total gross electricity production



Renewable energy <25%

Figure 2: World gross electricity production, by source, 2014

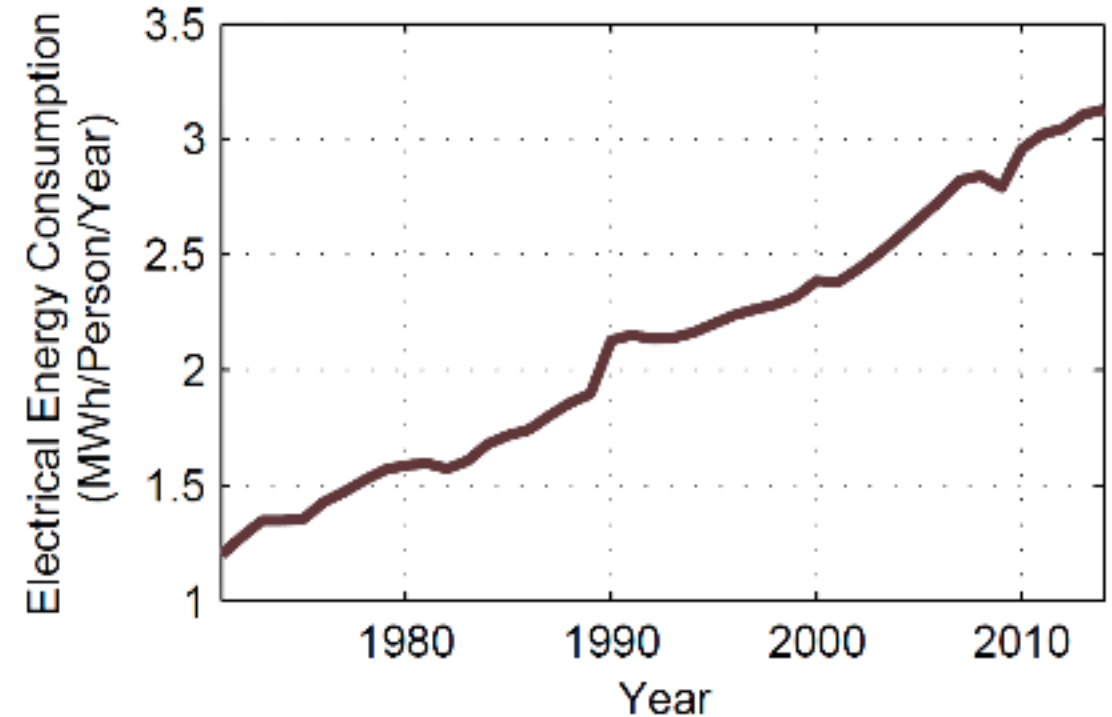


Fossil fuels supply >60% of electricity

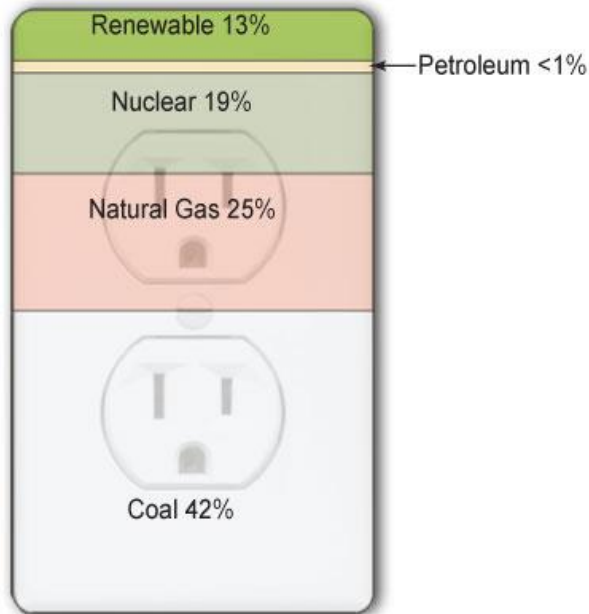
Source: www.iea.org

» Global Electricity Consumption

- Global per person electricity consumption has steadily increased 260% from 1972 to 2015 (2.3% per year)
- Total electricity consumption increased by 505%



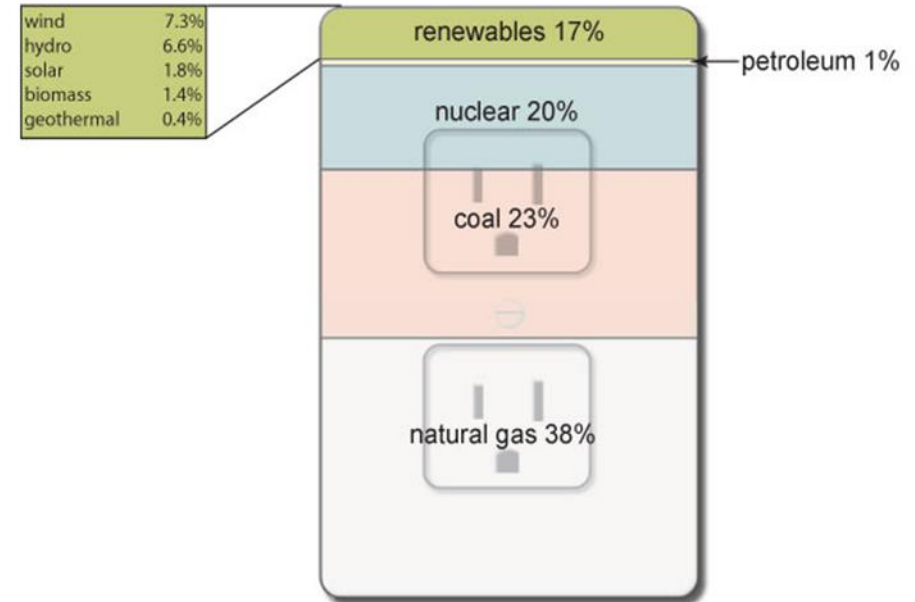
Sources of U.S. Electricity Generation, 2011



Source: U.S. Energy Information Administration, *Electric Power Monthly* (February 2012). Percentages based on Table 1.1, preliminary 2011 data.

Sources of U.S. electricity generation, 2019

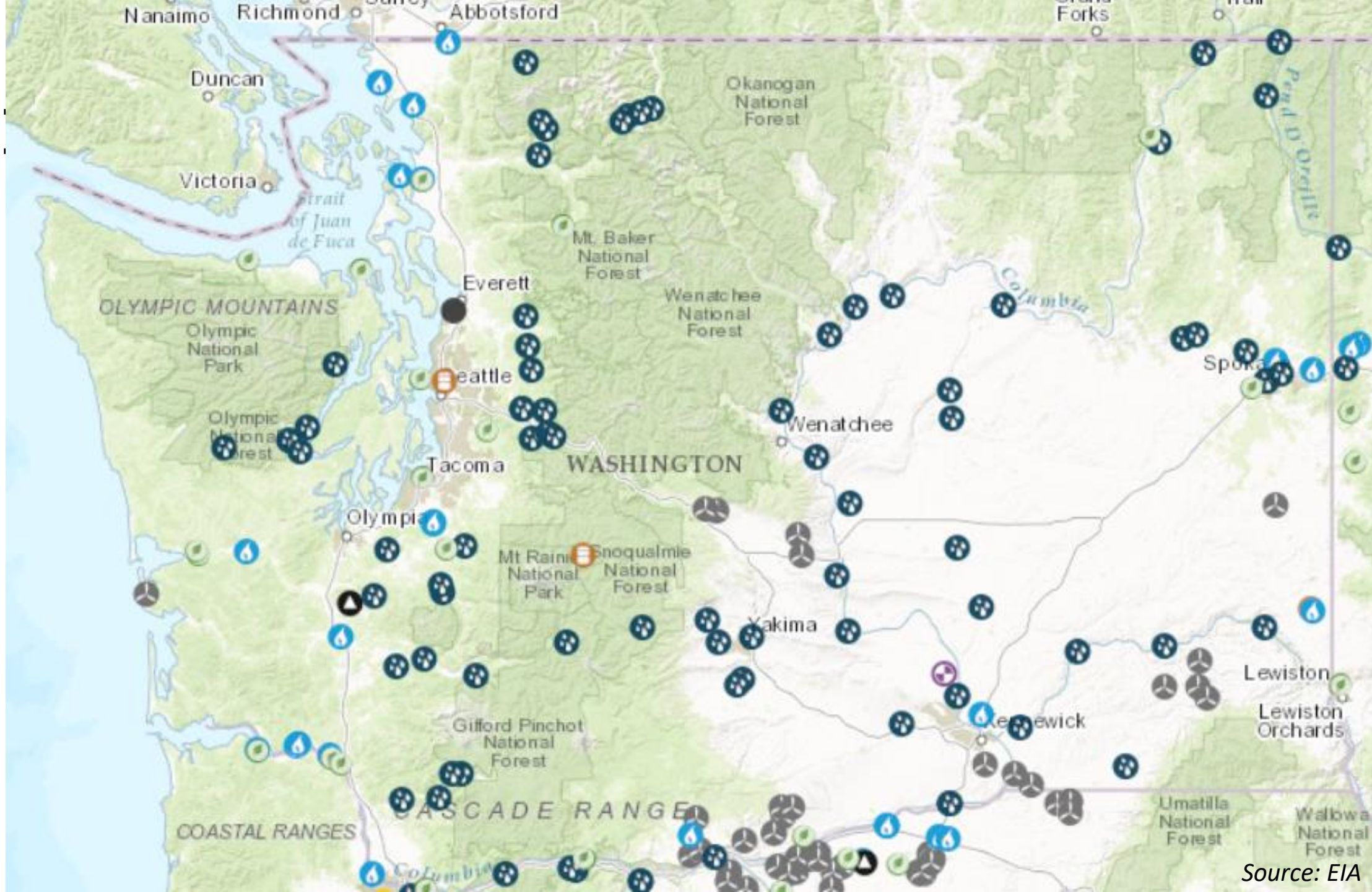
Total = 4.12 trillion kilowatthours



Note: Electricity generation from utility-scale facilities. Sum of percentages may not equal 100% because of independent rounding.

Source: U.S. Energy Information Administration, *Electric Power Monthly*, February 2020, preliminary data





Source: EIA

→ Renewable Energy

- What is your definition of Renewable Energy?
 - Why is solar energy considered renewable but energy derived from burning coal is not?

→ Renewable Energy

- Energy cannot be created or destroyed, only converted from one form to another
- There is no such thing as renewable energy
- “Renewable Energy” is a bit of a misnomer

→ Renewable Energy

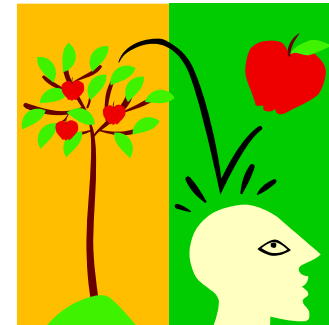
- A better way of defining renewable energy is with respect to the timescale considered (e.g. 1000 years or 1,000,000 years)
- Renewable energy are energy flows which are replenished at the same (or greater) rate than they are used over the timescale considered

→ Renewable Energy

- Coal could be considered renewable if we used it at the rate at which is formed
- Solar energy is considered renewable because the sun will supply energy throughout the timescale considered

➤ Renewable Energy

- What we commonly consider renewable resources come from only three origins
 - Solar Radiation
 - Heat from the Earth
 - Gravity



» Solar Radiation

- The Sun's solar radiation is responsible for:
 - Solar
 - Biomass (photosynthesis)
 - Hydro (evaporation)
 - Wind (uneven heating of the atmosphere)
 - Wave (a result of wind)

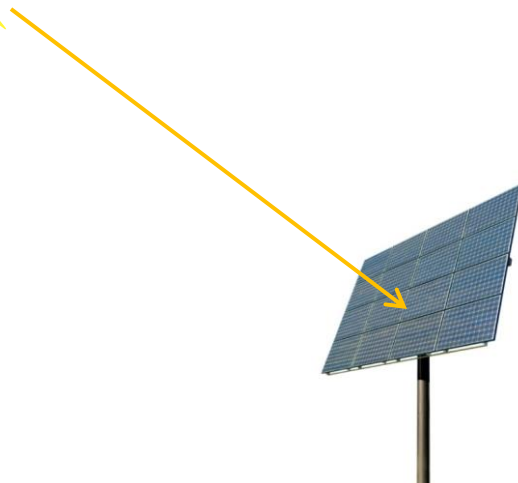


» Solar Radiation

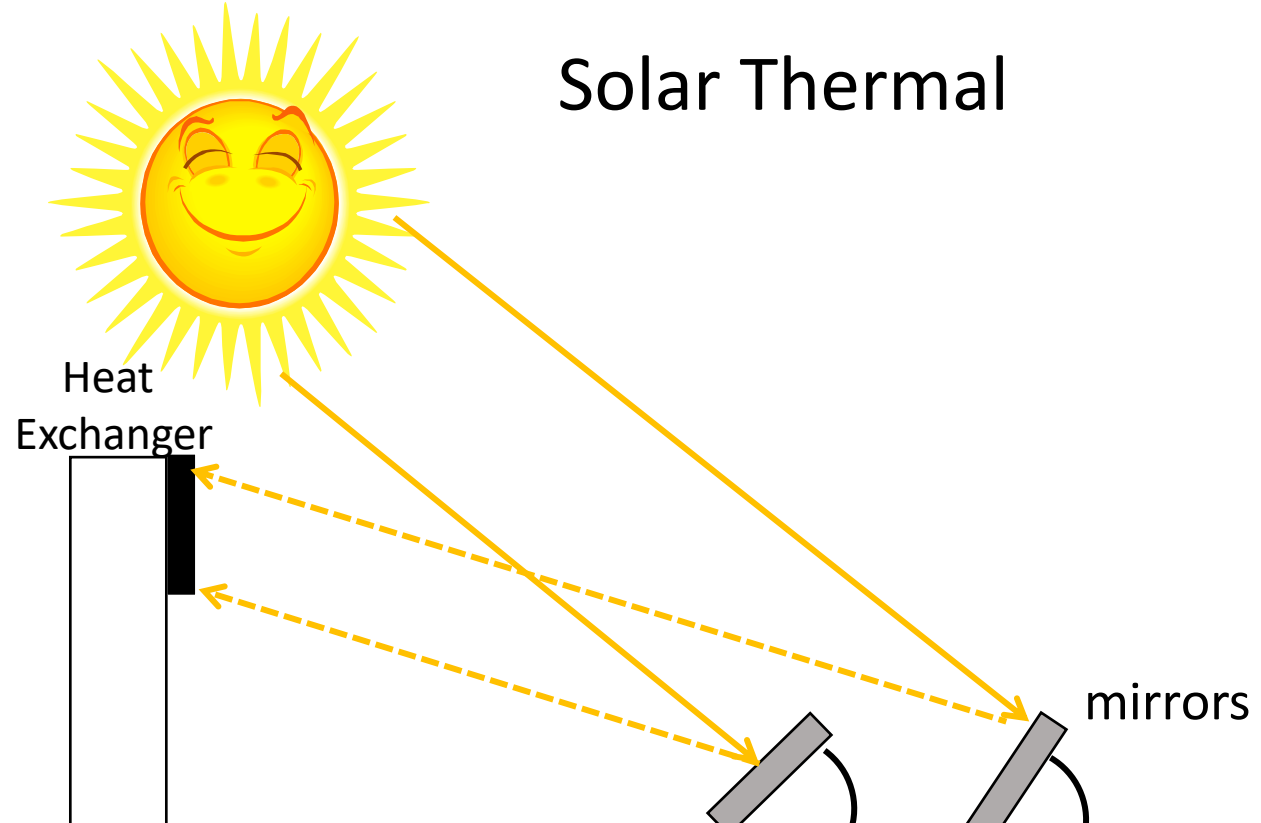
- Sun provides 5.4 YJ/yr (yotta joules: 1×10^{24} J) to Earth's atmosphere
- Approx 30% is deflected back into space
- Remaining 3.8 YJ is approximately 10,000 times the amount of energy used by fossil and nuclear fuels per year



Solar Photovoltaic (PV)



Solar Thermal



» Solar Radiation

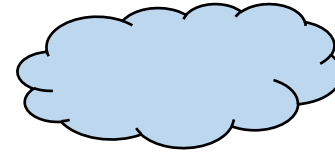
- Solar radiation also drives hydrological cycle, wind, waves and photosynthesis
 - Wind and waves: 11.17 ZJ/yr (zetta joule: 1×10^{21} J)
 - Photosynthesis: 1.26 ZJ/yr



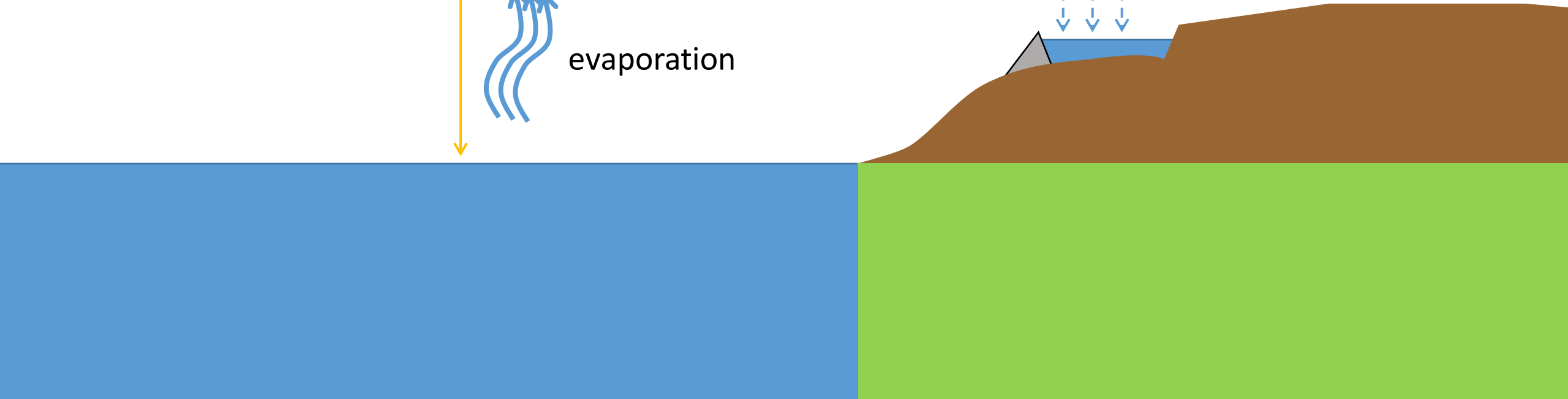
Hydro



evaporation



rain

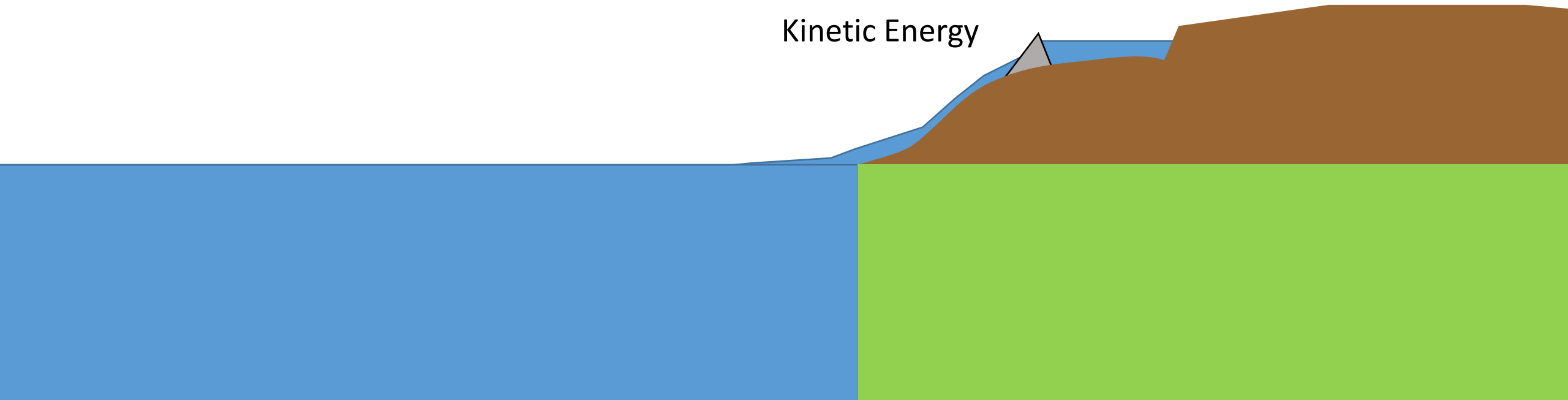


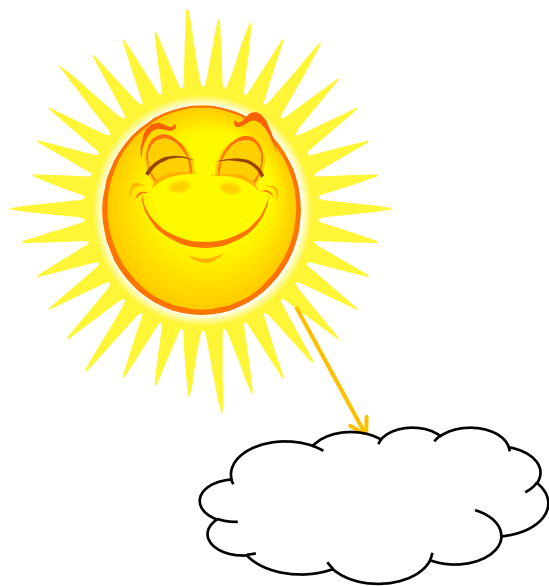


Hydro

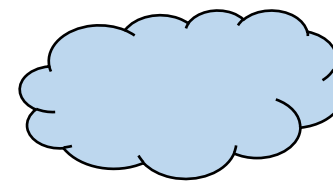
Potential
Energy

Kinetic Energy





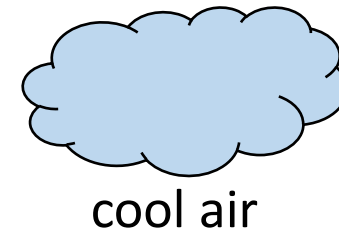
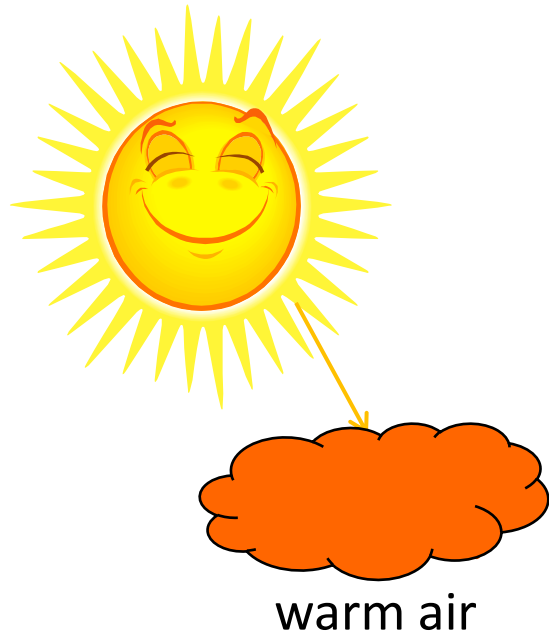
Wind



cool air

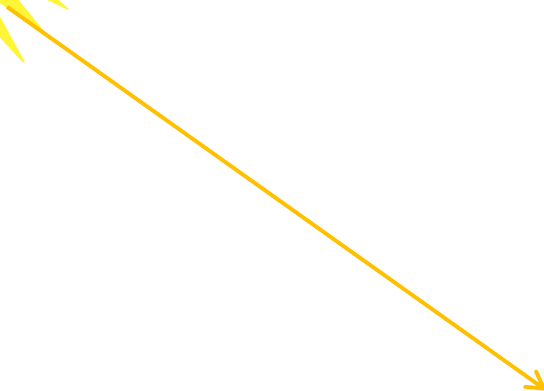


Wind





Biomass



» Heat from the Earth

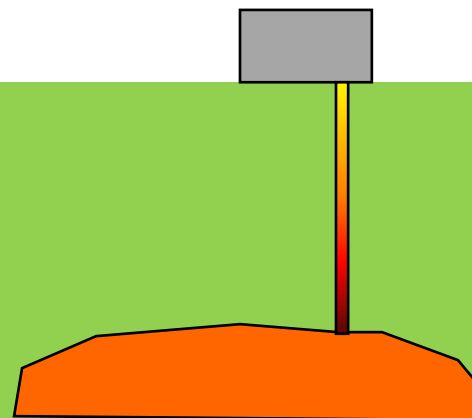
- Interior of the Earth is at a high temperature
- Causes:
 - Decay of radioactive material
 - Residual heat from the formation of the Earth
- Note: scientists' knowledge of the core of the Earth is limited

» Heat from the Earth

- We can only harness the heat that makes it way to the crust (5-50 km depth)
- Approximately 4 ZJ of energy stored as water or steam at depths of 10km
- Pockets of heat can be used to drive steam turbines in geothermal plants



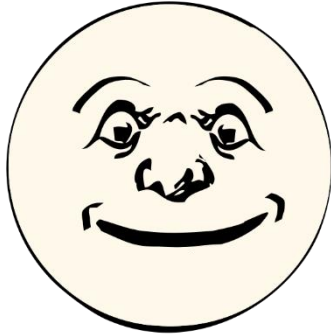
Geothermal



» Gravity

- Potential energy
- Gravity from the moon and Sun cause tides (mostly the moon)
- Approx. 93.6 EJ/yr (exajoule: 1×10^{18} J)
- Gradual slowing down of the Earth (not on any appreciable timescale)
- Tidal action can be harnessed by tidal generators

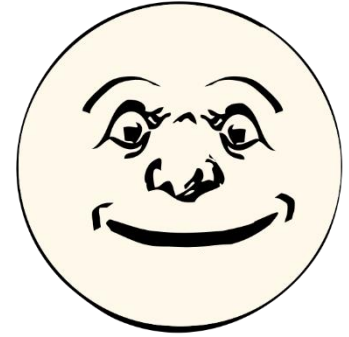
→ Tidal



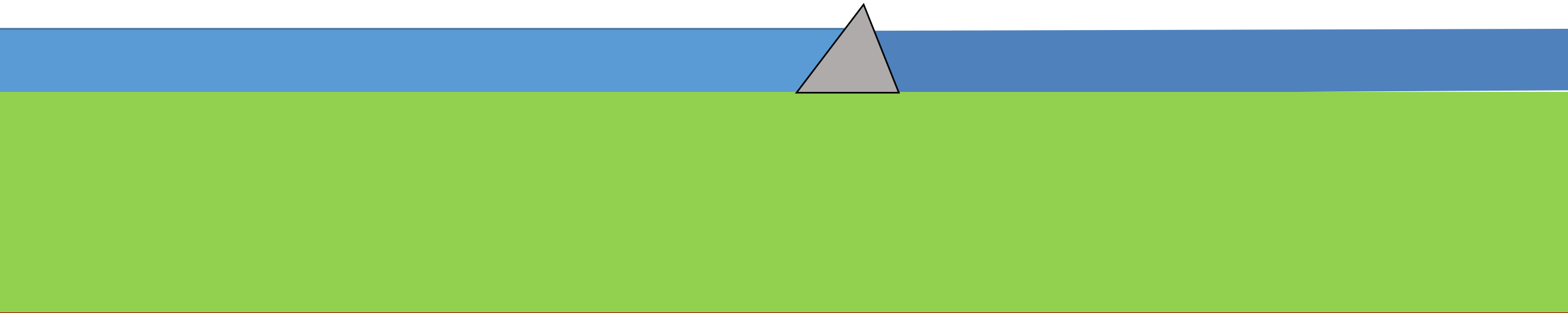
Gravity pulls the water
behind the dam



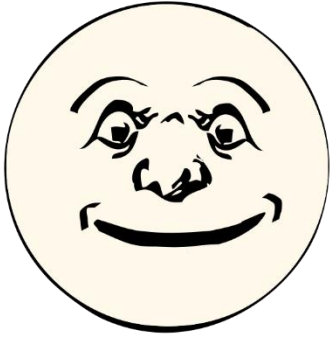
→ Tidal



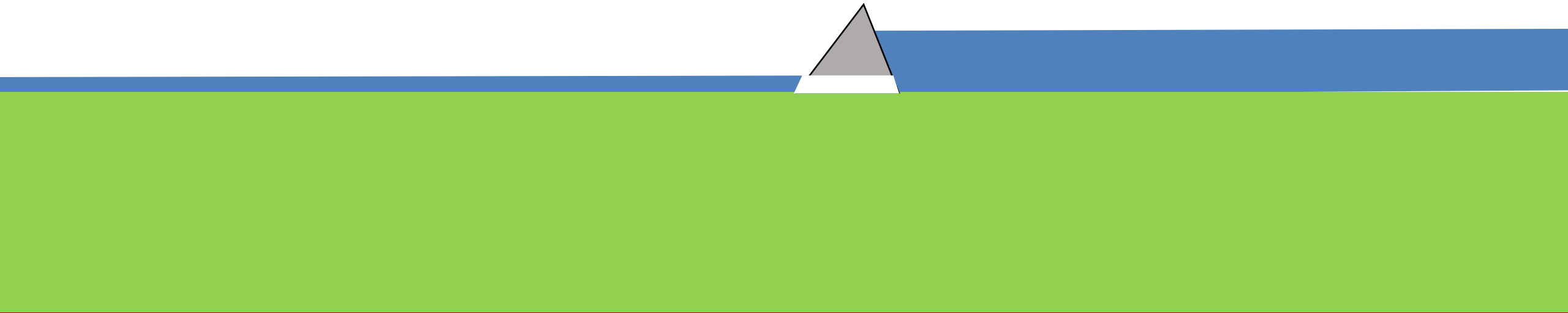
Gravity pulls the water
behind the dam



→ Tidal



Water is released



→ Harnessing Renewable Energy

- Enough renewable energy available to more than fulfill mankind's energy appetite
- How well are we doing at harnessing it?

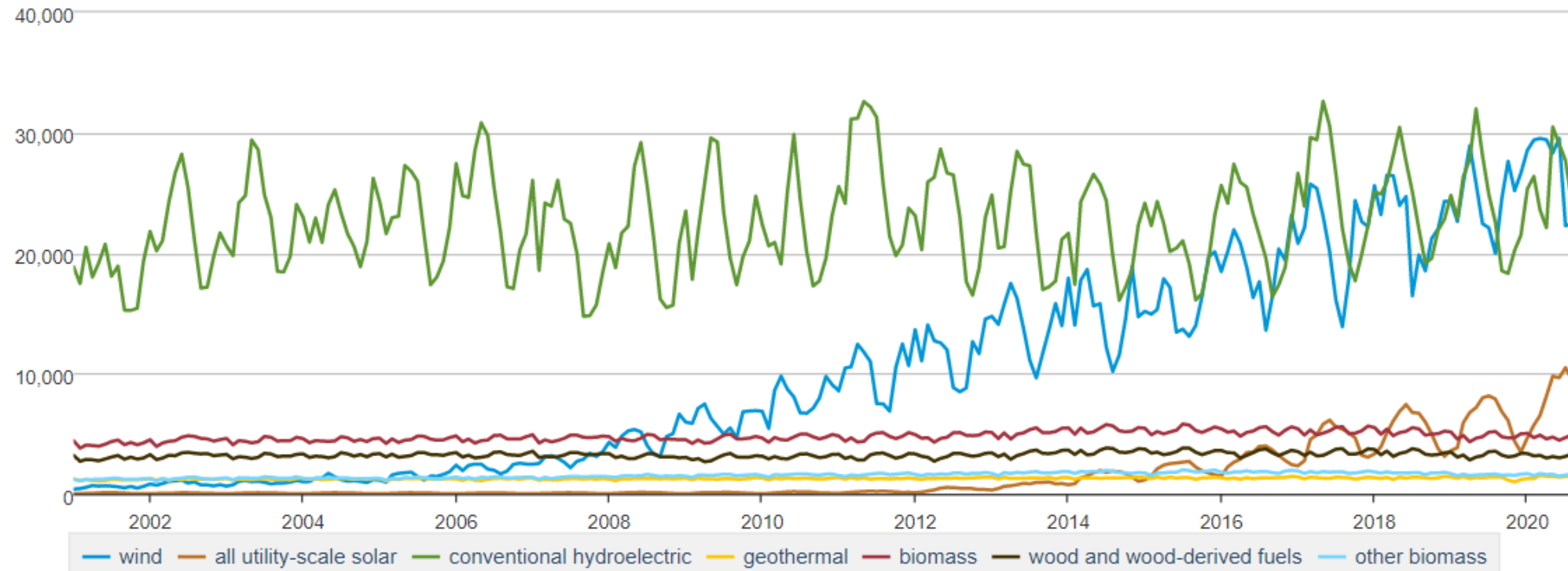
» Harnessing Renewable Energy

Note seasonal dependence for hydro and wind

Net generation, United States, all sectors, monthly

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thousand megawatthours



Data source: U.S. Energy Information Administration

Note: Tidal, wave and others are not utilized on any appreciable scale

» Questions

- What is the relationship between natural gas prices and renewable energy expansion?
- What are the implications if the U.S. stopped using coal “cold turkey”?