

01-Energy Sources

ECEGR 4530
Renewable Energy Systems



Overview

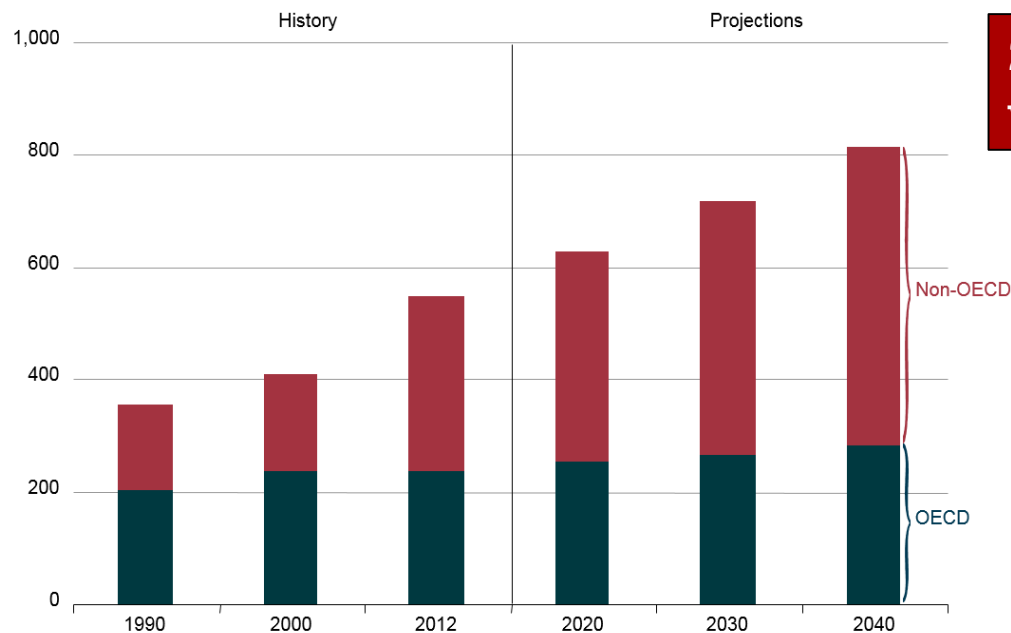
- Global Consumption
- Energy Flows
- Renewable Energy



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)

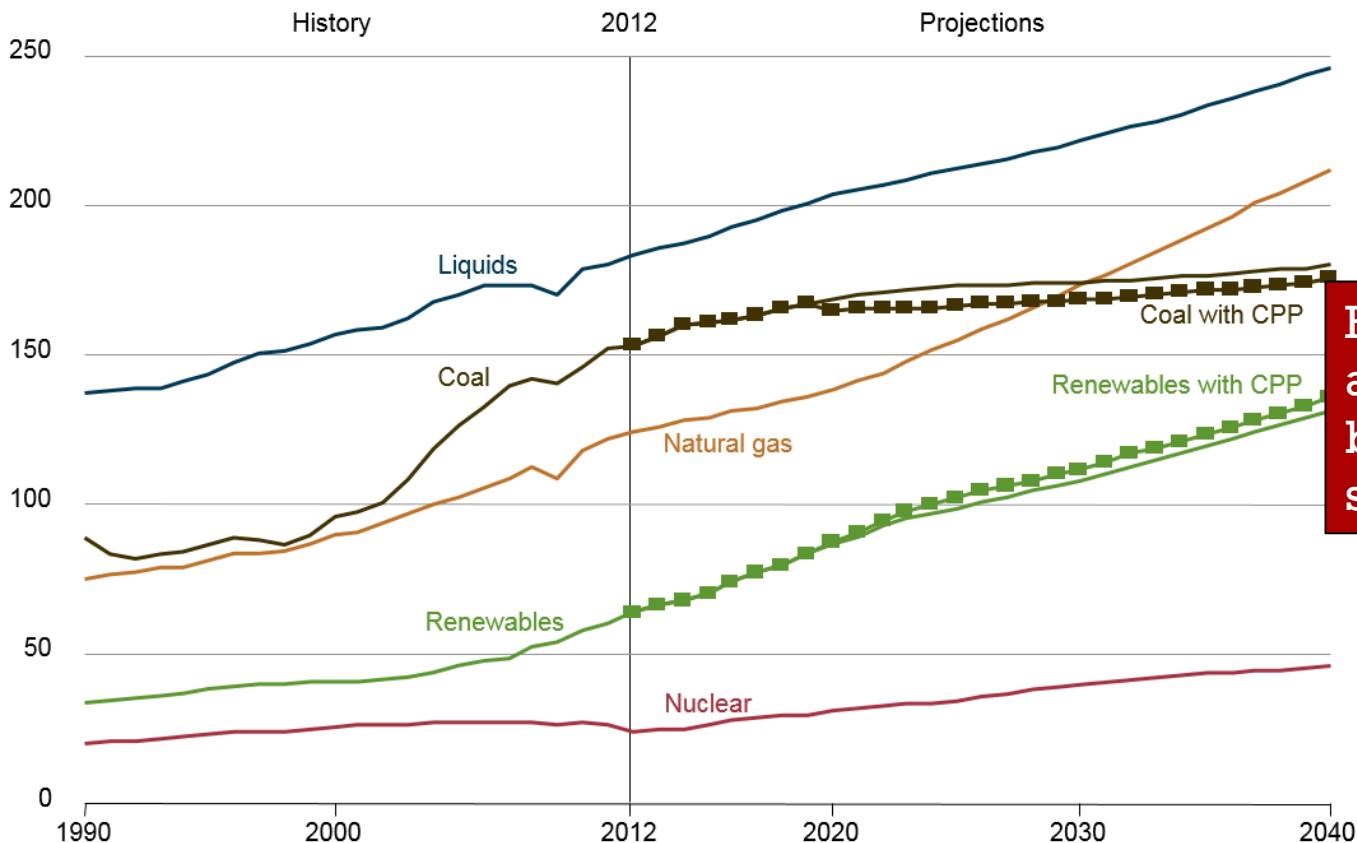
Global per capita consumption is 78 GJ/year—redistribution of energy might be enough for all to have high HDI





Figure 1-5. World energy consumption by energy source, 1990-2040

quadrillion Btu



Fossil fuels account for nearly 80% of our energy use

Renewable energy accounts for just 12%, but is the fastest-growing source



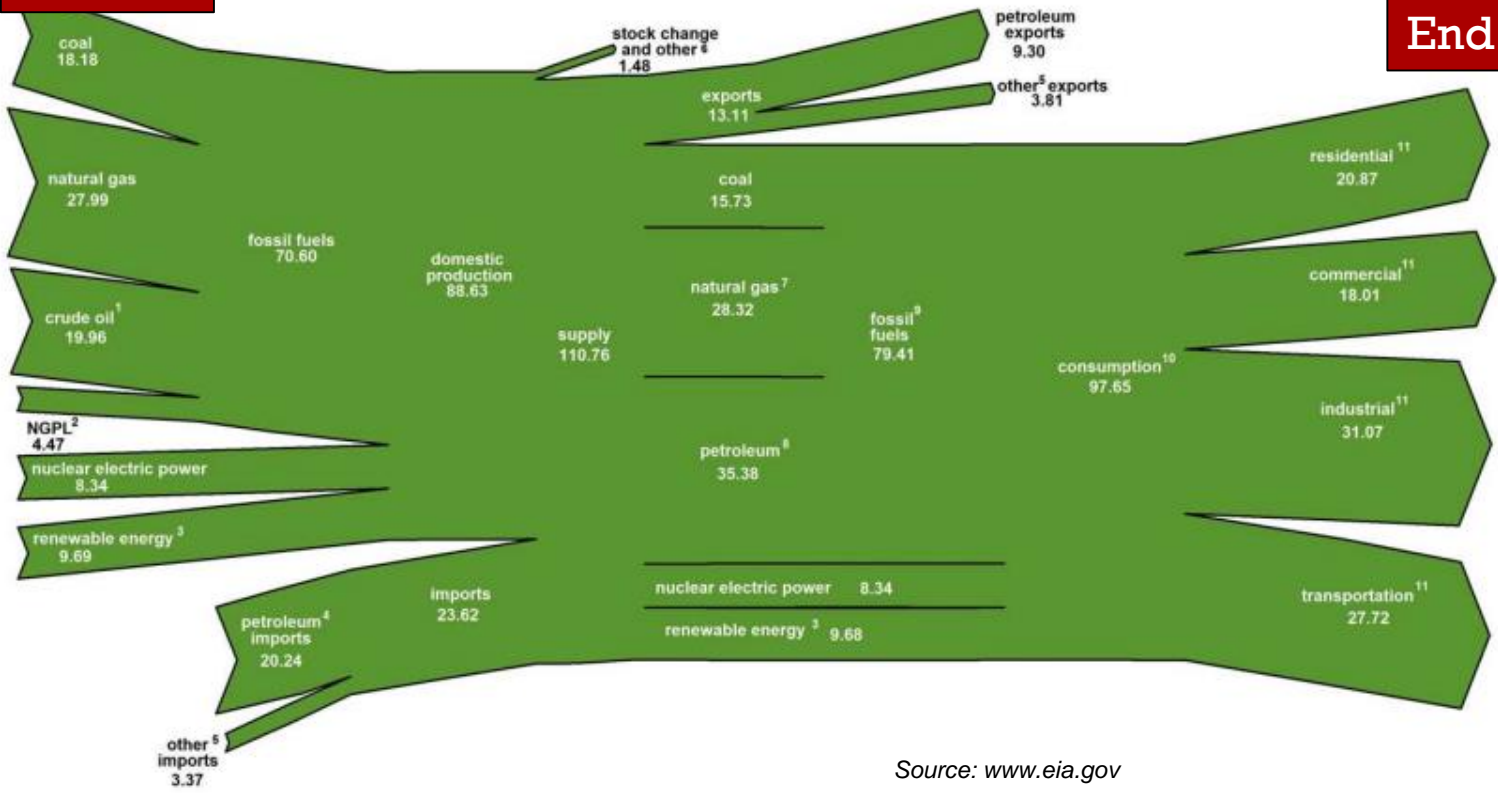


U.S. Energy Flow, 2015

quadrillion Btu

Sources

End Uses



Source: www.eia.gov

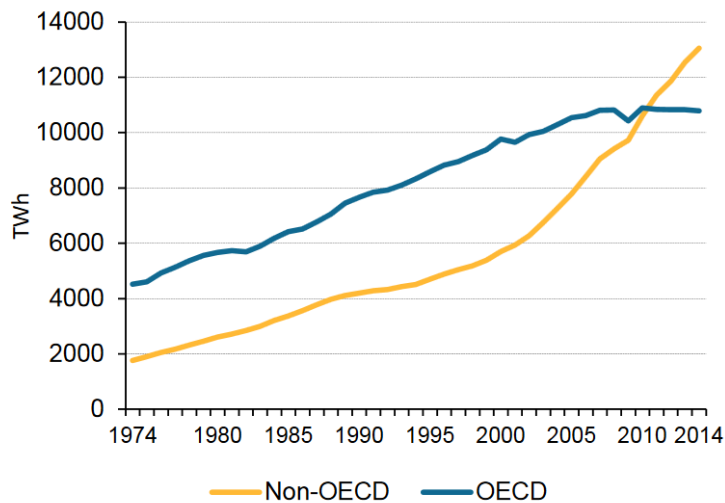


World Electricity Production

Worldwide gross electricity production is 23,815 TWh.

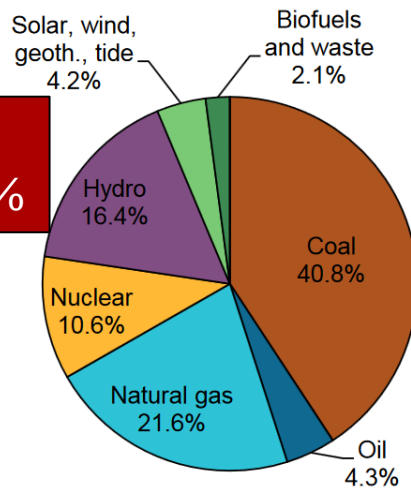
Growth rate of 1.9%, primarily in non OECD countries

Figure 1: Total gross electricity production



Renewable energy <25%

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

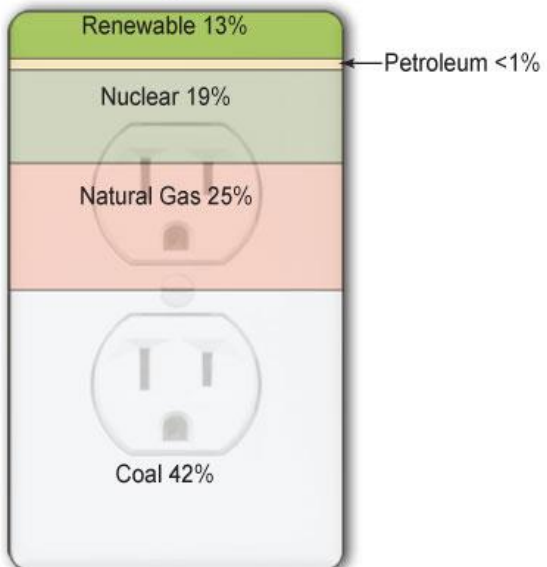


Fossil fuels supply >60% of electricity

Source: www.iea.org

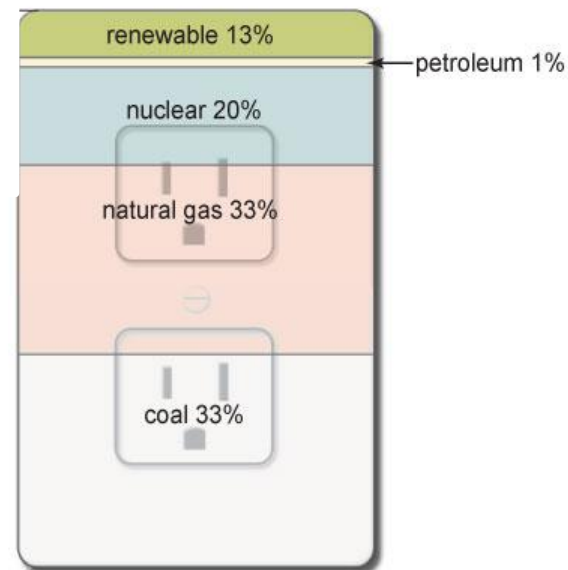


Sources of U.S. Electricity Generation, 2011



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, 2015



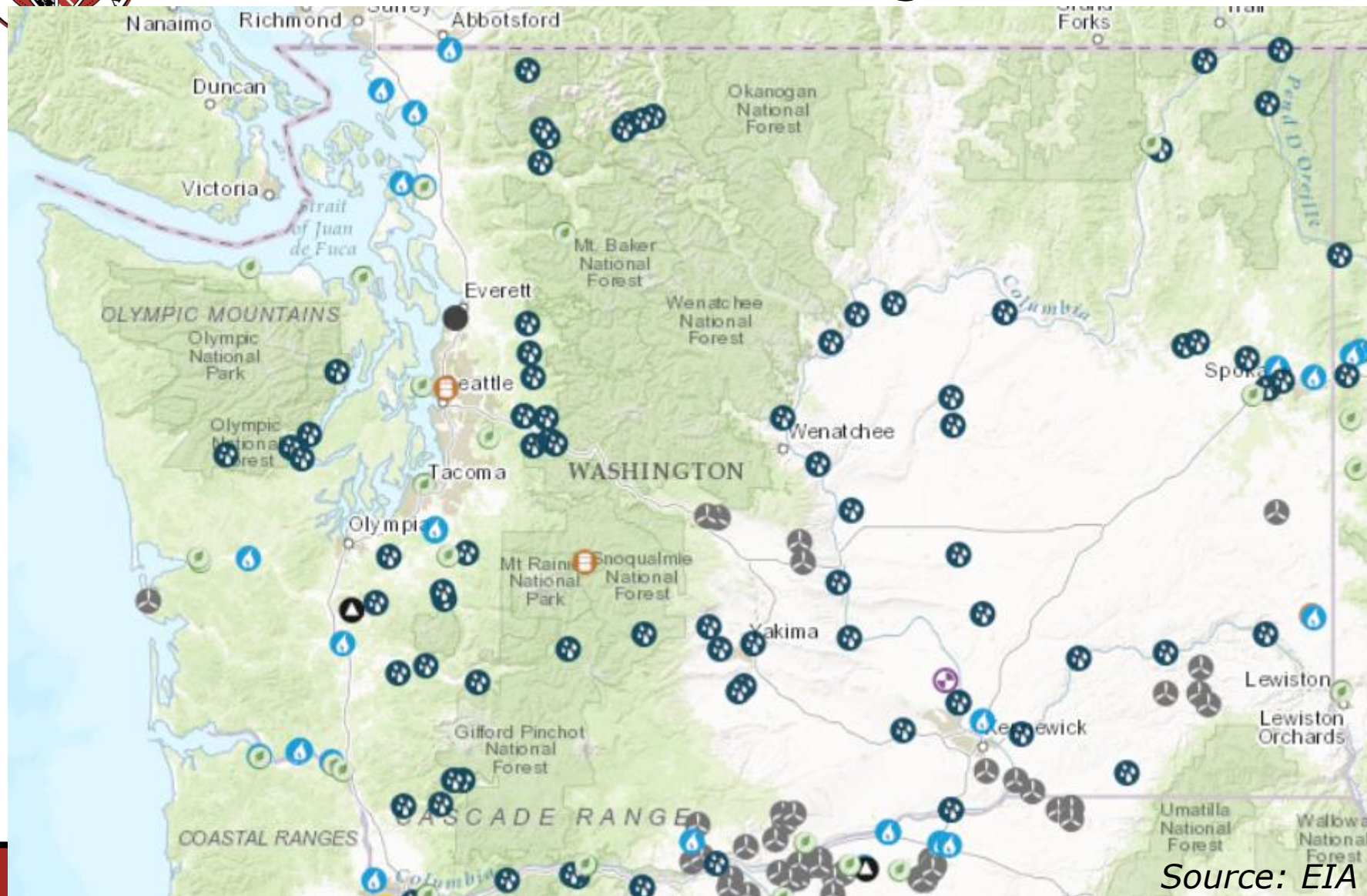
Source: U.S. Energy Information Administration, *Electric Power Monthly* (February 2016). Preliminary data for 2015

Note: Sum of components may not equal 100% due to independent rounding.





Power Plants in Washington State



Source: EIA



Renewable Energy

- 13% of U.S. electricity is from renewable sources
- Which of these sources of energy would you consider to be renewable?

Wind

Tidal

Biomass

Solar

Wave

Hydrogen

Coal

Geothermal

Oil

Natural Gas

Hydro



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



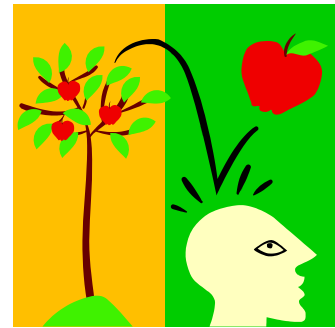
Renewable Energy

- 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)



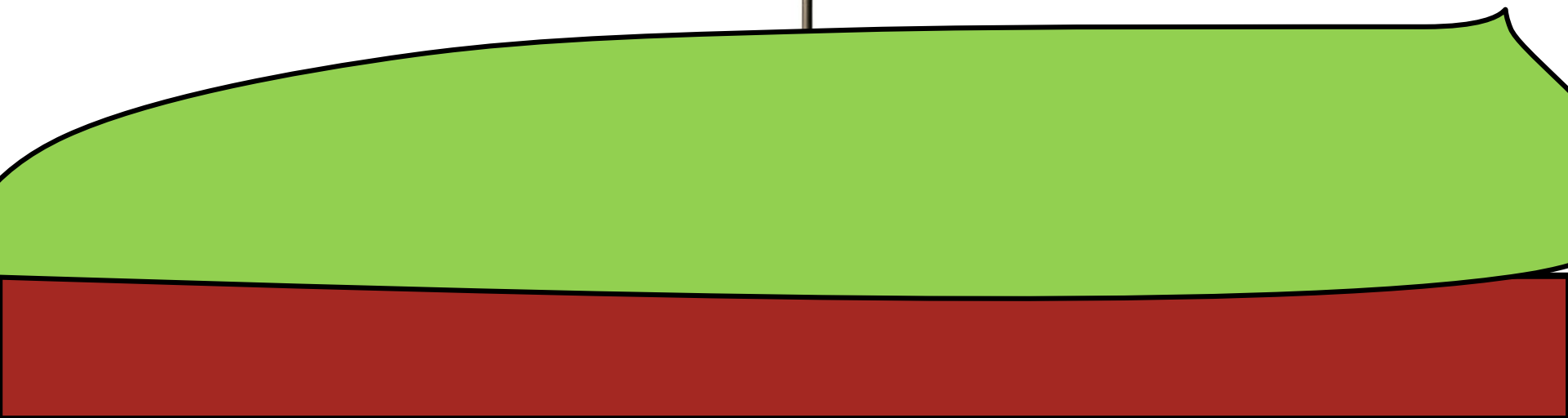
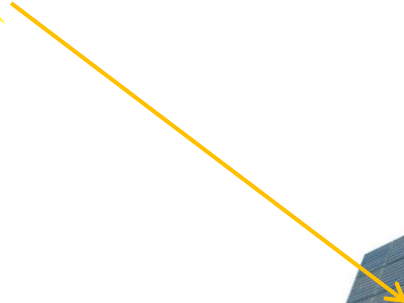


Solar Radiation

- 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

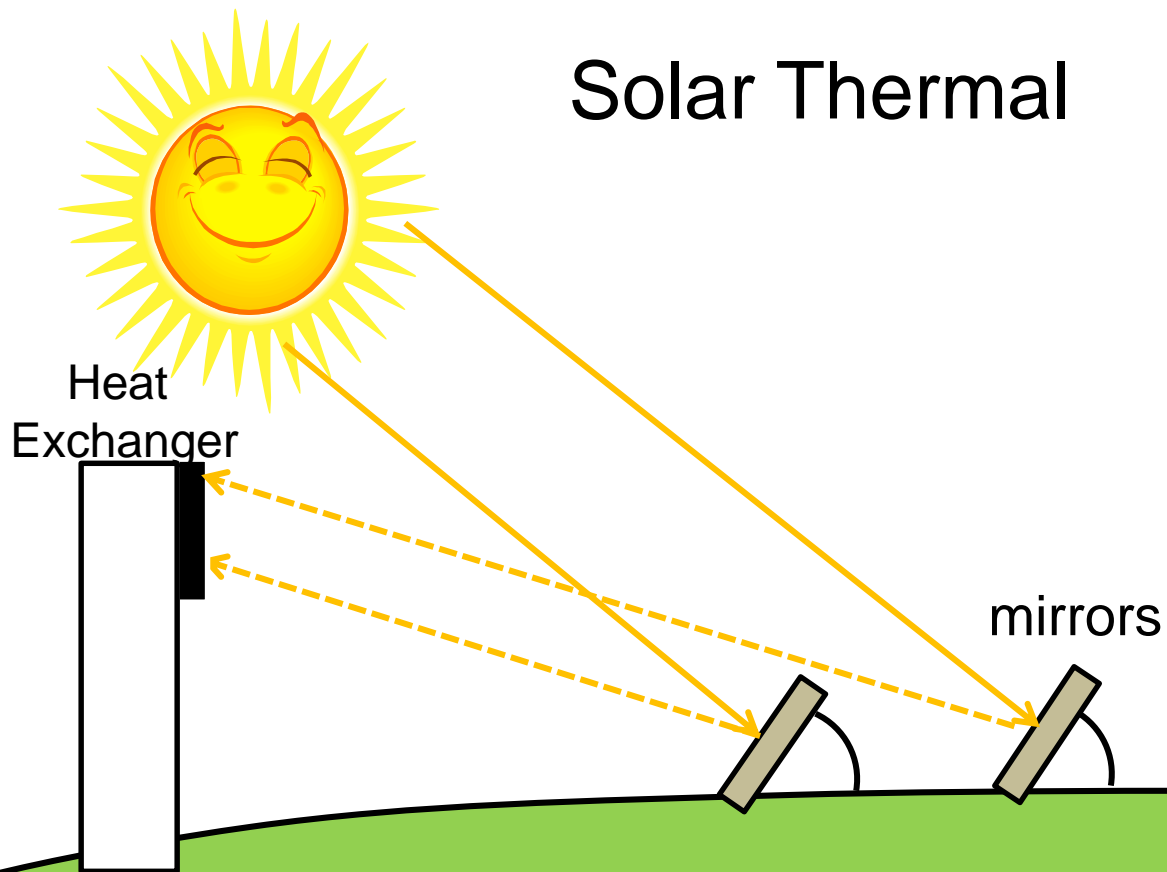


Solar Photovoltaic (PV)





Solar Thermal





Solar Radiation

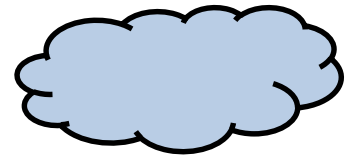
- Solar radiation also drives wind, waves and photosynthesis
 - Wind and waves: 11.17 ZJ/yr (zetta joule: 1×10^{21} J)
 - Photosynthesis: 1.26 ZJ/yr



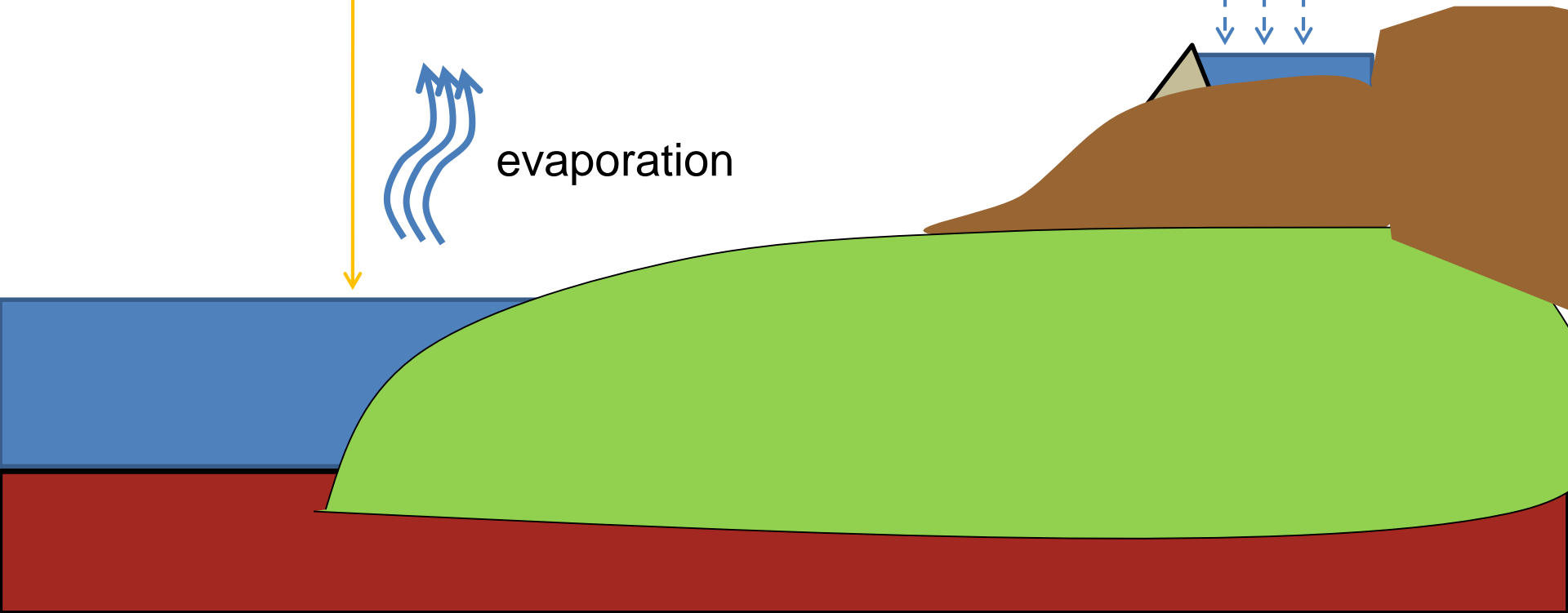
Hydro



evaporation

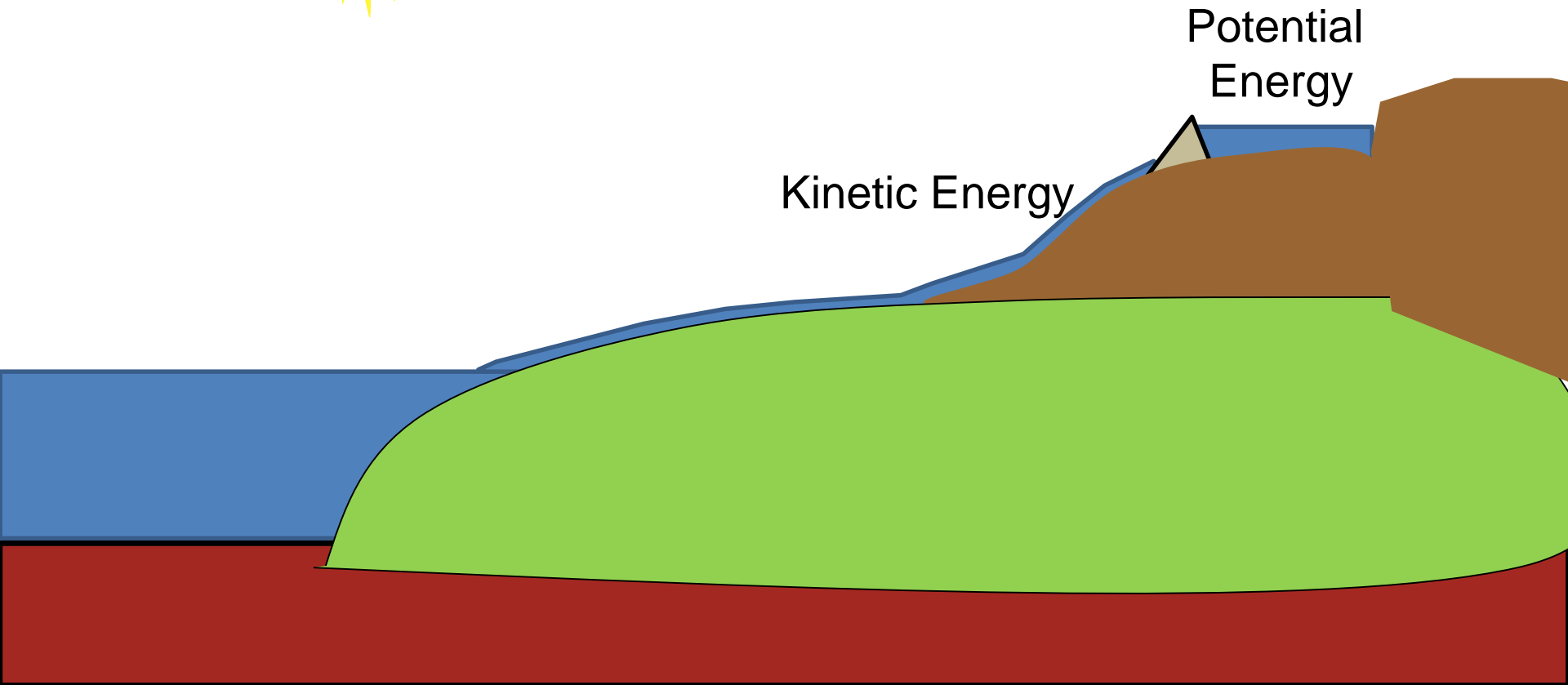


rain





Hydro

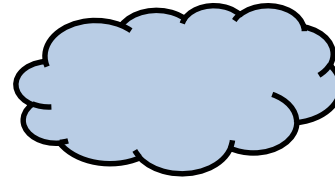
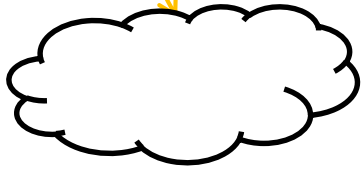


Kinetic Energy

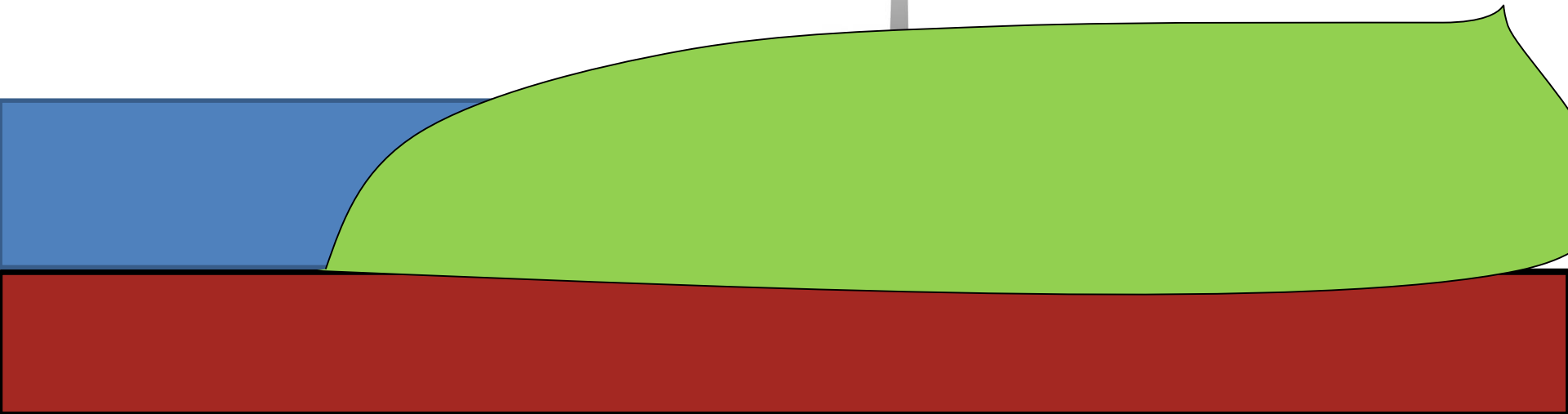
Potential Energy



Wind

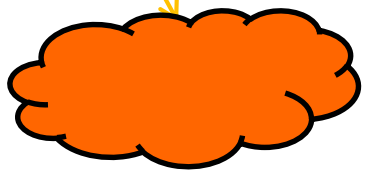


cool air

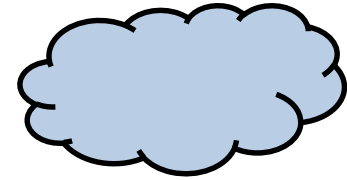




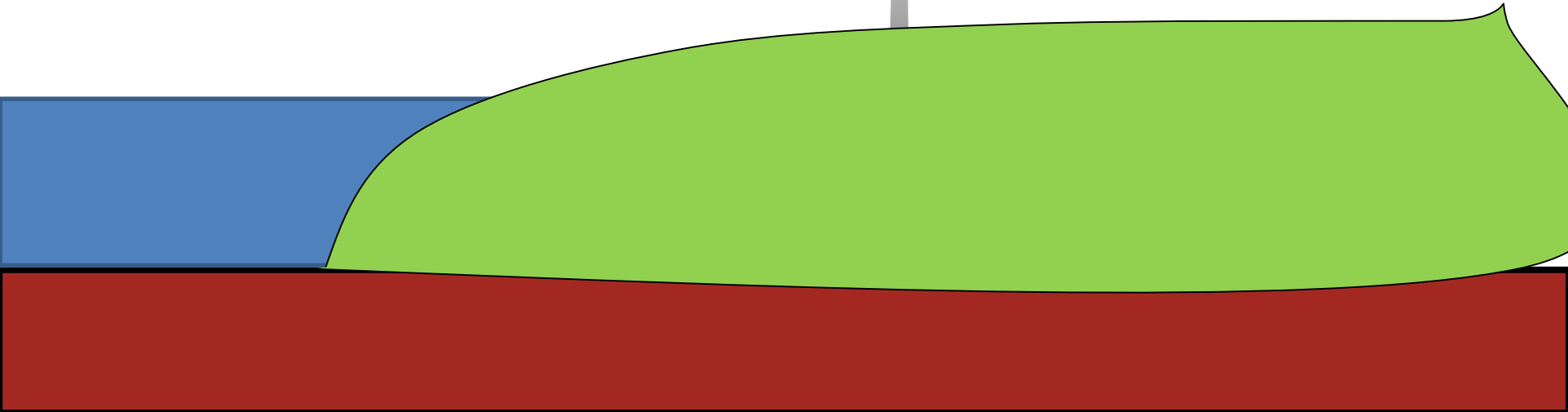
Wind



warm air

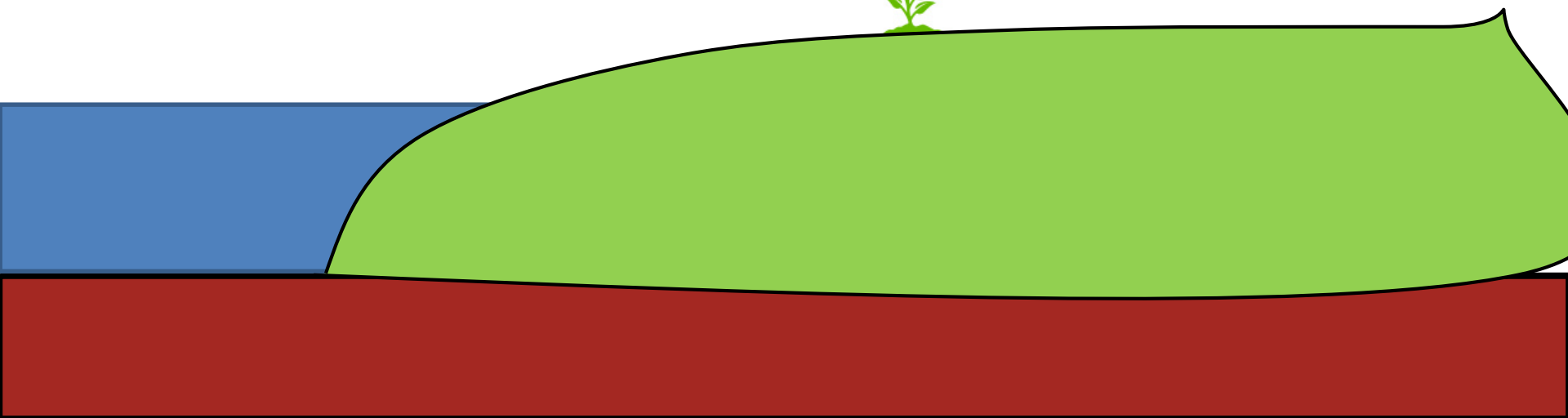
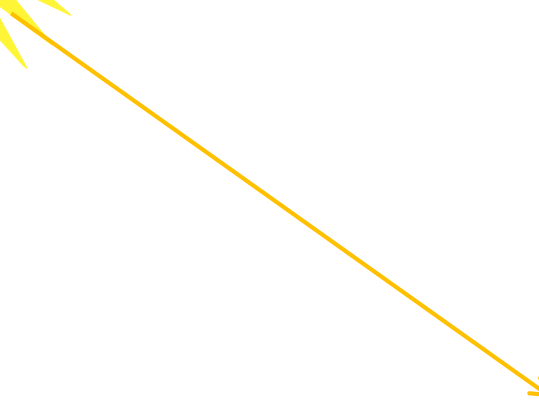


cool air





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

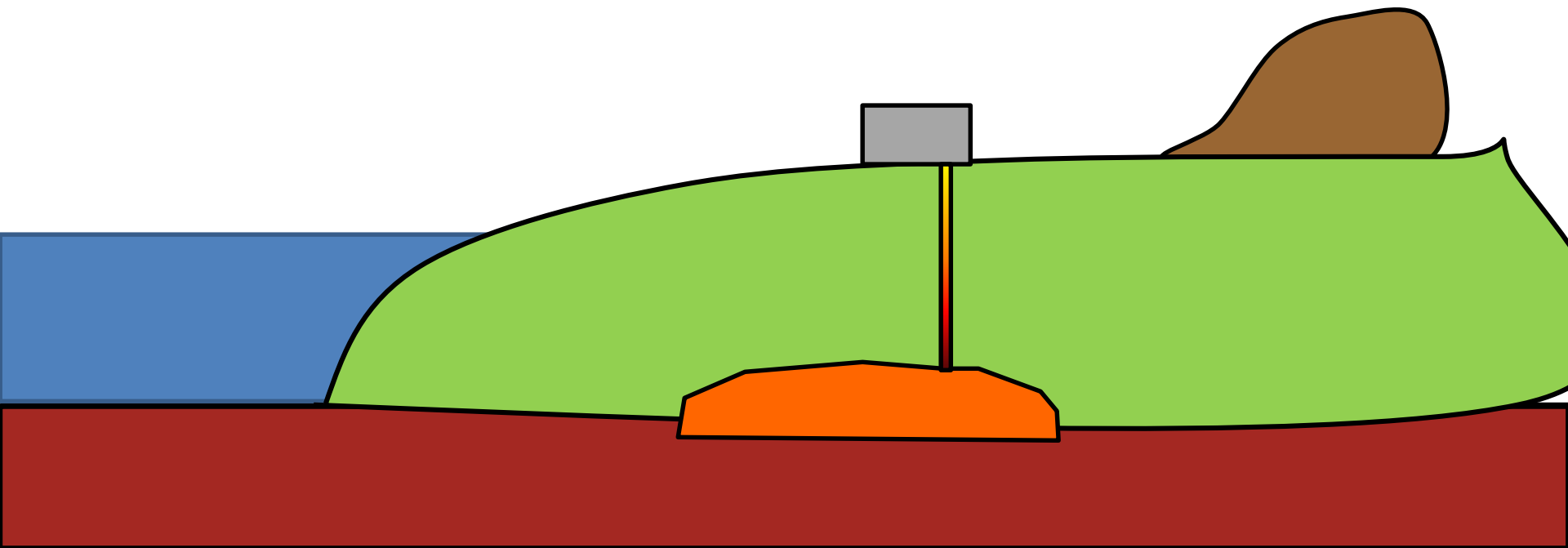


Heat from the Earth

- 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



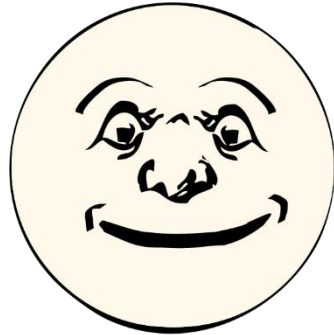


Gravity

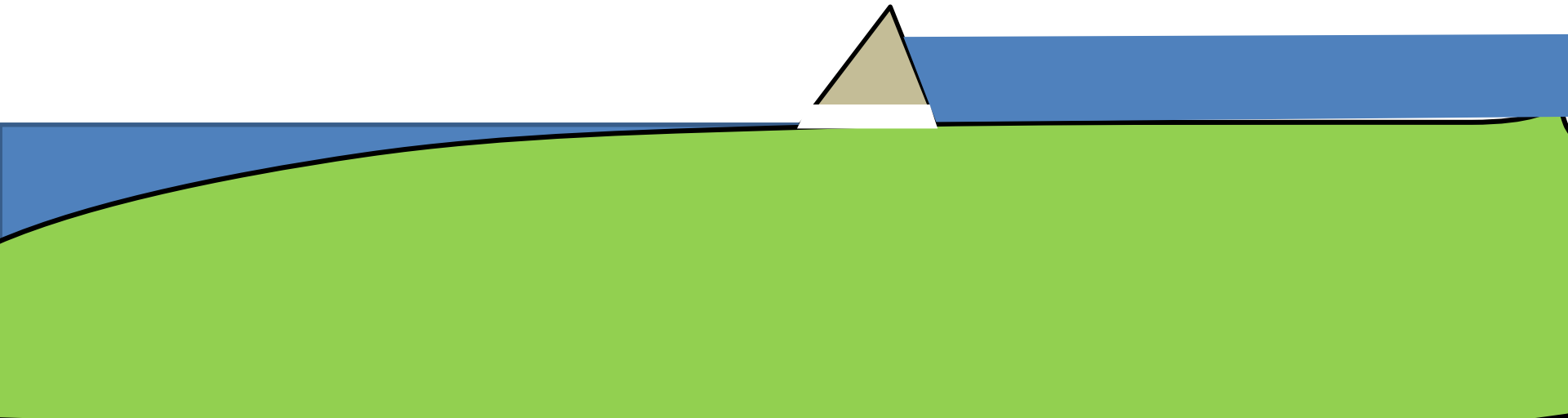
- Potential energy
- Gravity from the moon and Sun cause tides (mostly the moon)
- Approx. 93.6 EJ/yr (exajoule: 1×10^{18} J)
- Gradual slowing down of the Earth (not on any appreciable timescale)
- Tidal action can be harnessed by tidal generators



Tidal

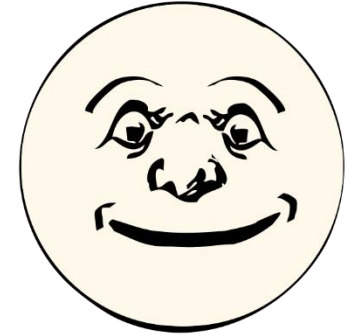


Gravity pulls the water
behind the dam

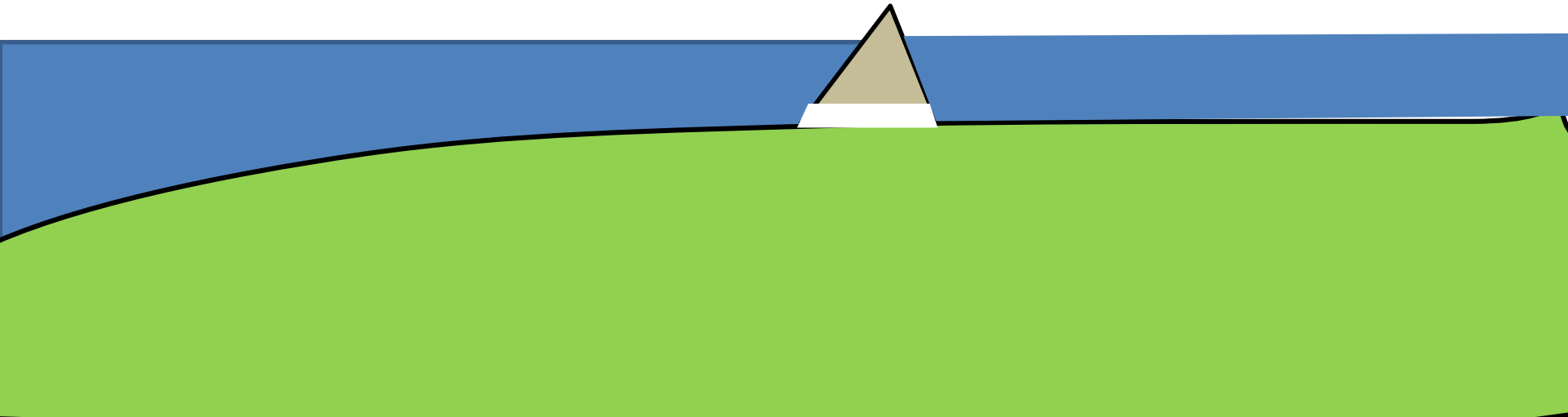




Tidal



Water is released to generate electricity





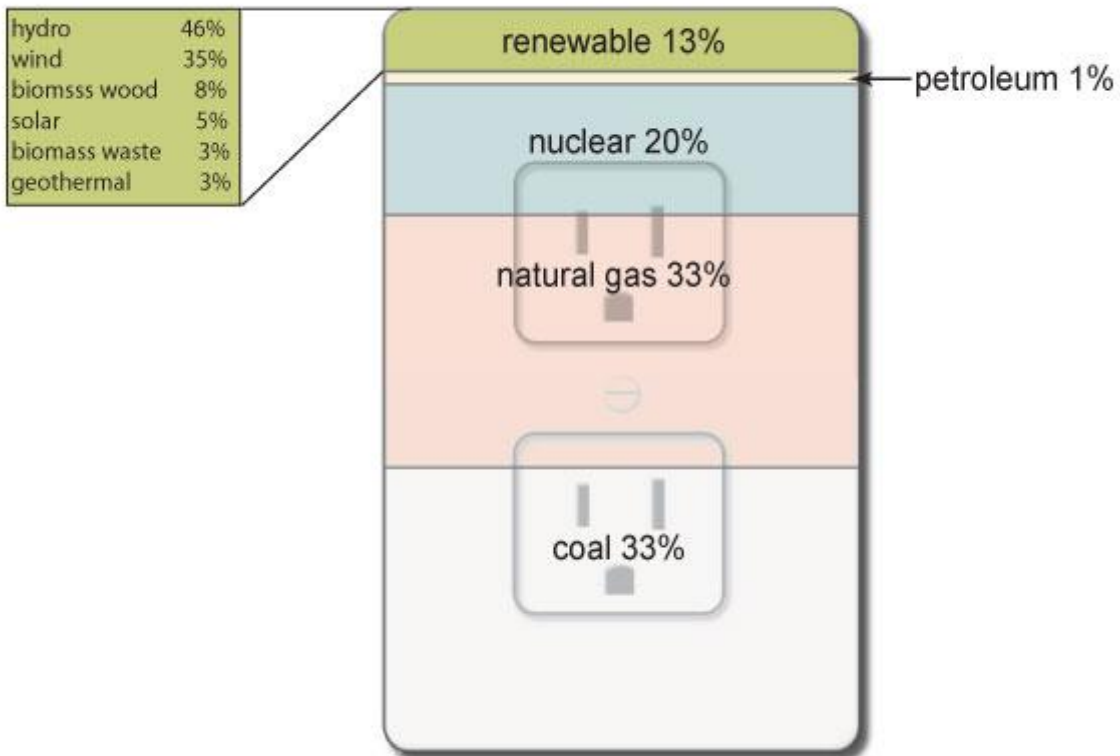
Harnessing Renewable Energy

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



Harnessing Renewable Energy (U.S.)

Sources of U.S. electricity generation, 2015



Source: U.S. Energy Information Administration, *Electric Power Monthly* (February 2016). Preliminary data for 2015

Note: Sum of components may not equal 100% due to independent rounding.

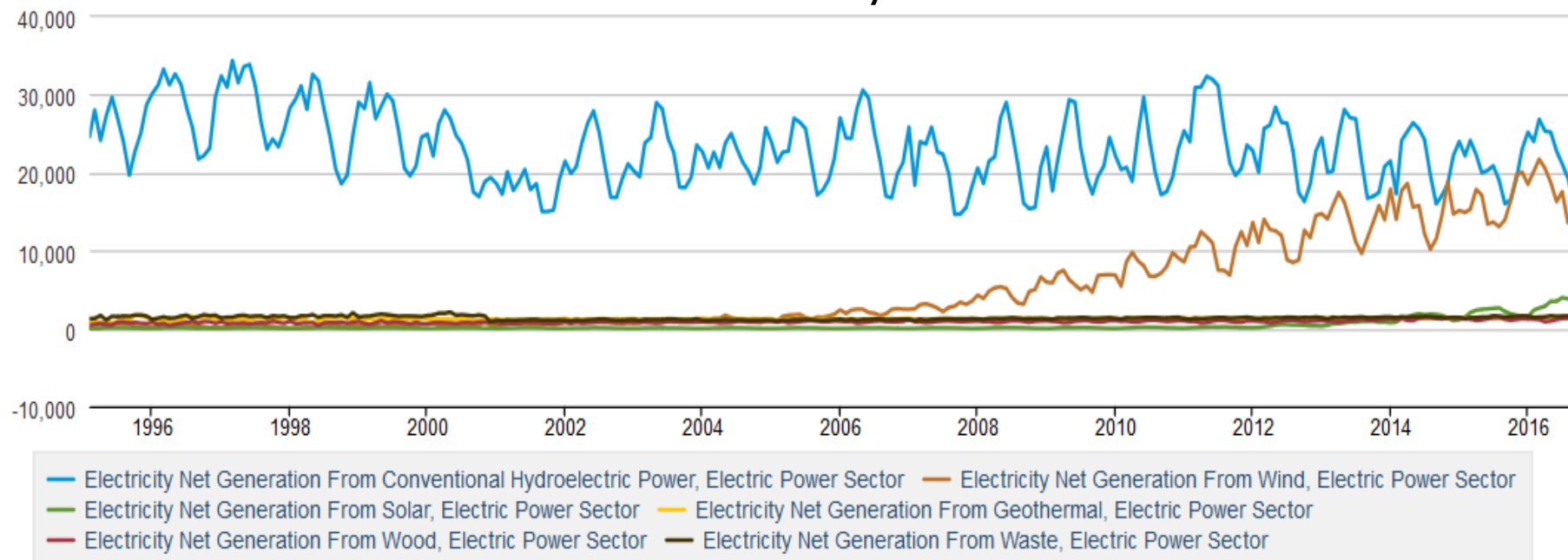




Harnessing Renewable Energy

Note seasonal dependence for hydro and wind

Million Kilowatthours



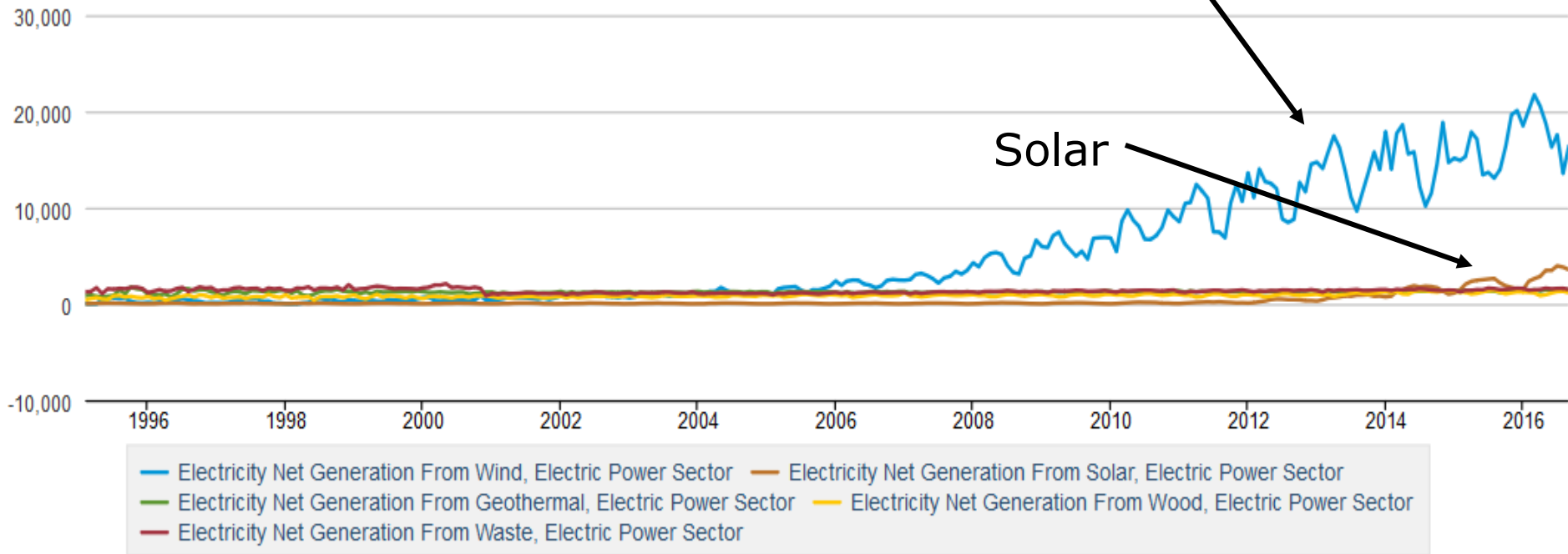
Data source: U.S. Energy Information Administration

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



Non-Hydro Generation

Million Kilowatthours



Data source: U.S. Energy Information Administration



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”?
- What do you think of recent plans to build new nuclear power plants in the U.S.?