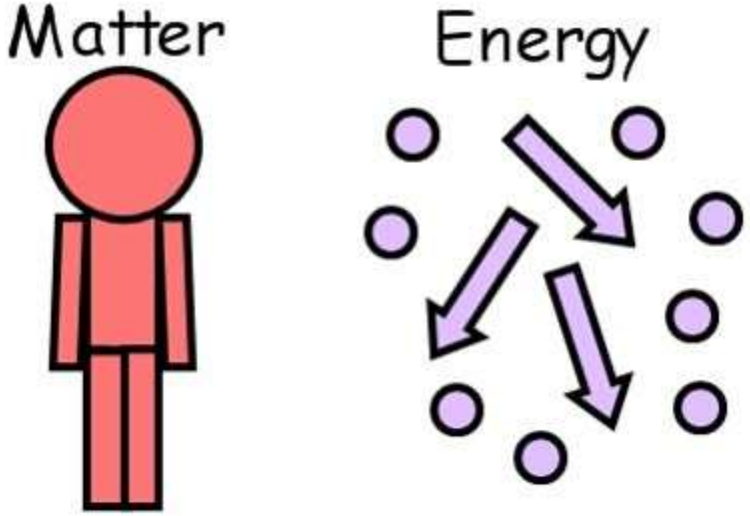
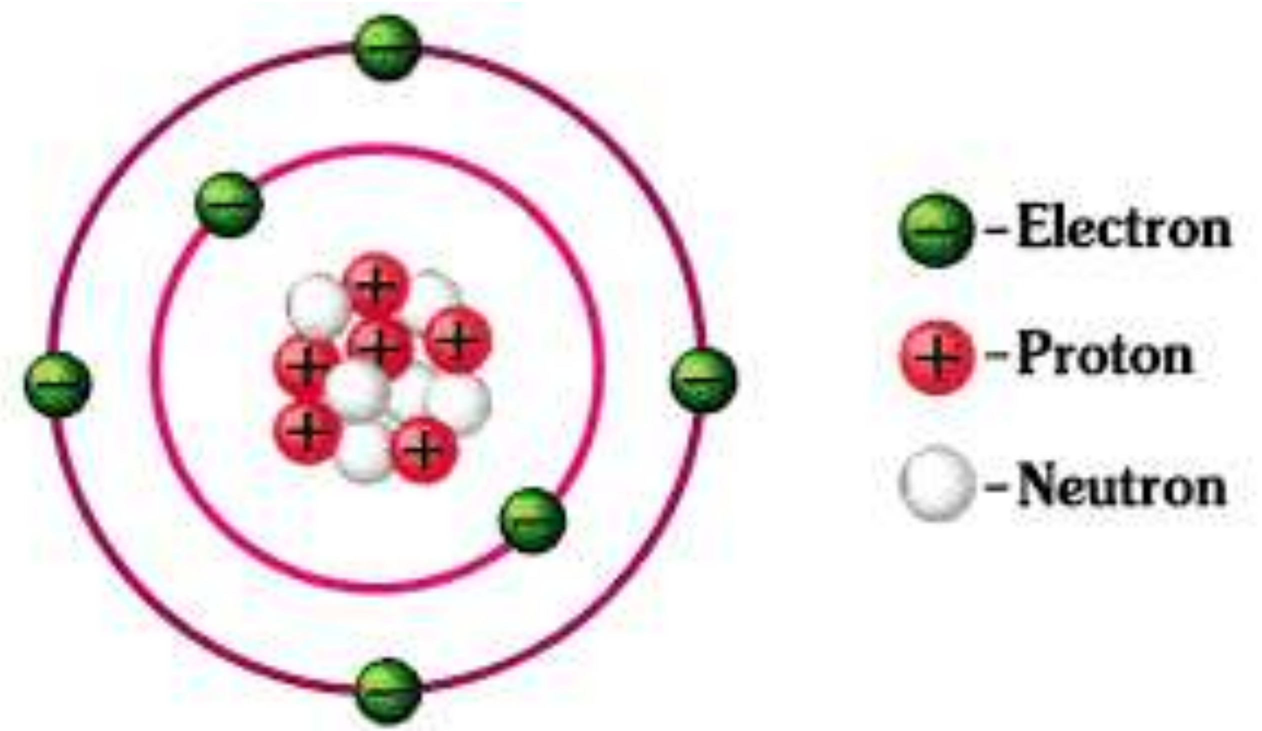
Matter and Energy

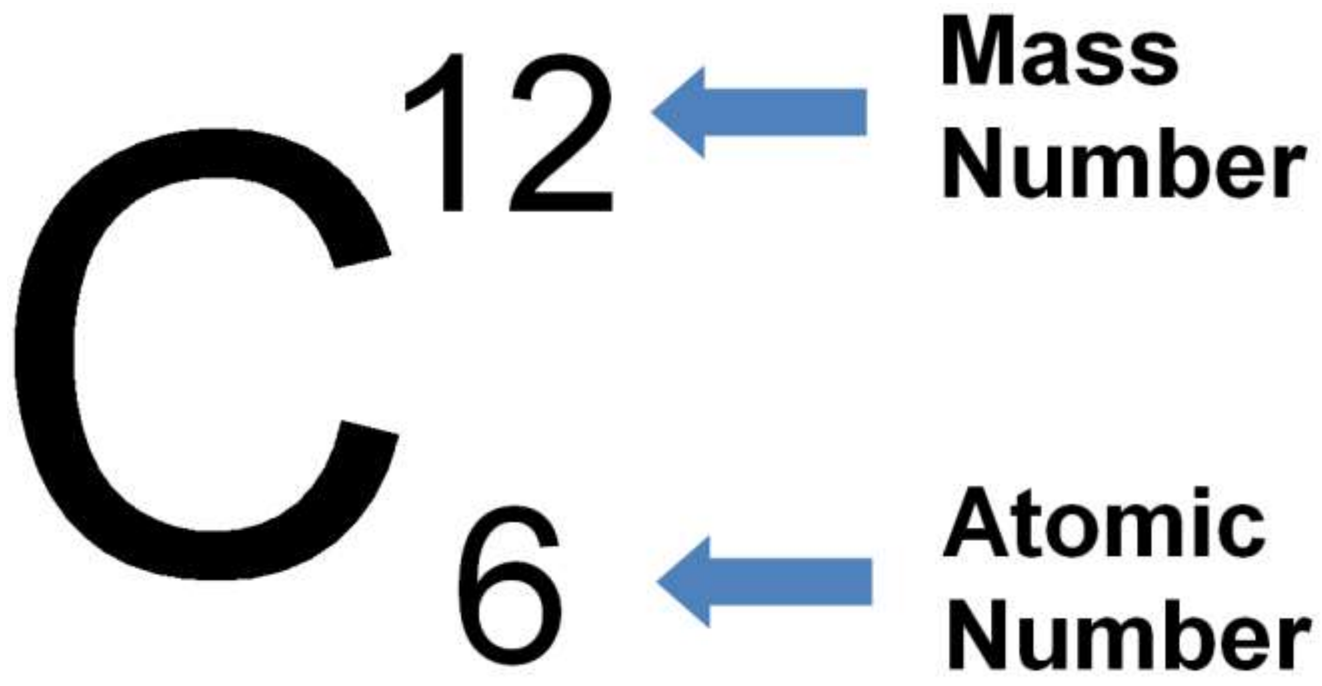


Matter

- Made of atoms



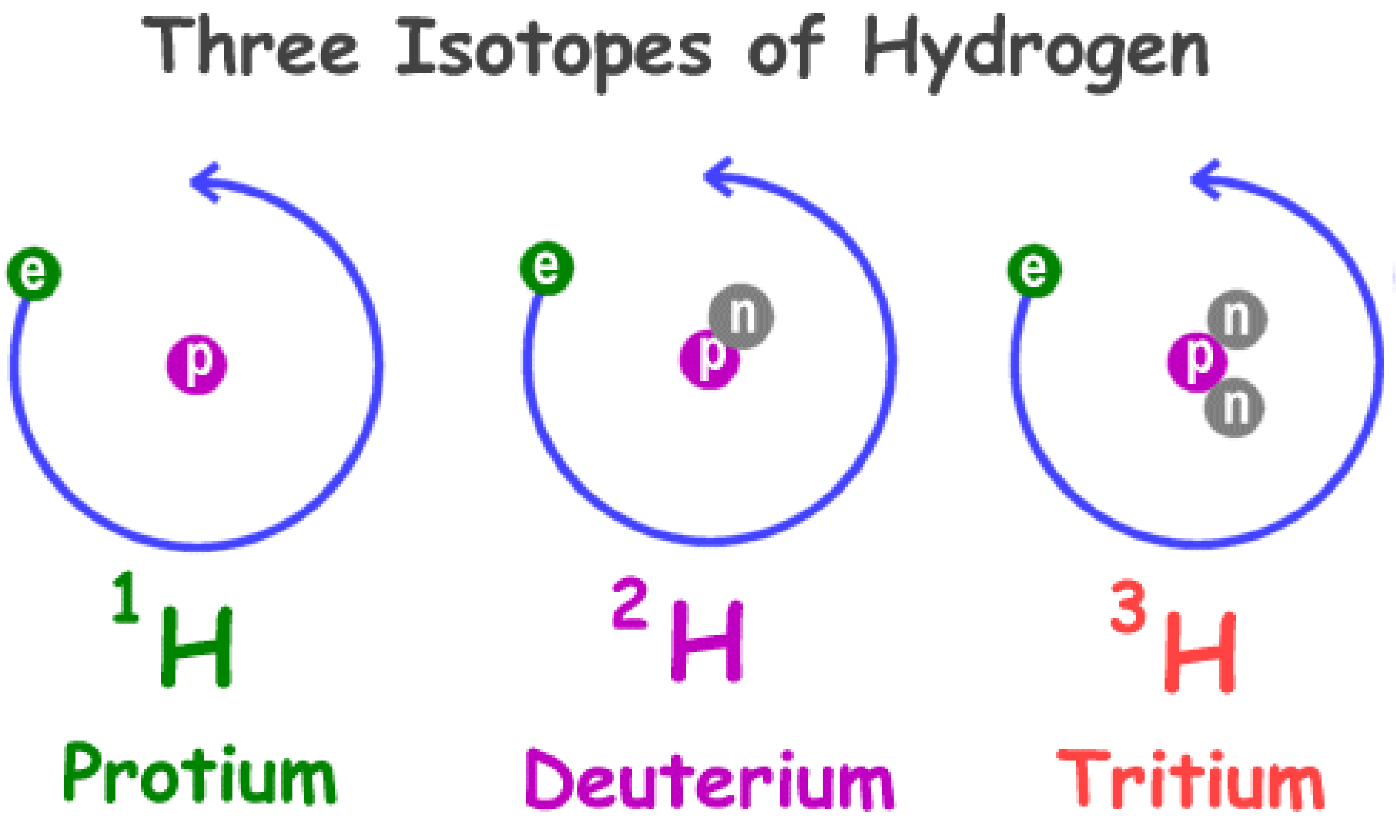
Type of atom determined by # protons = atomic number



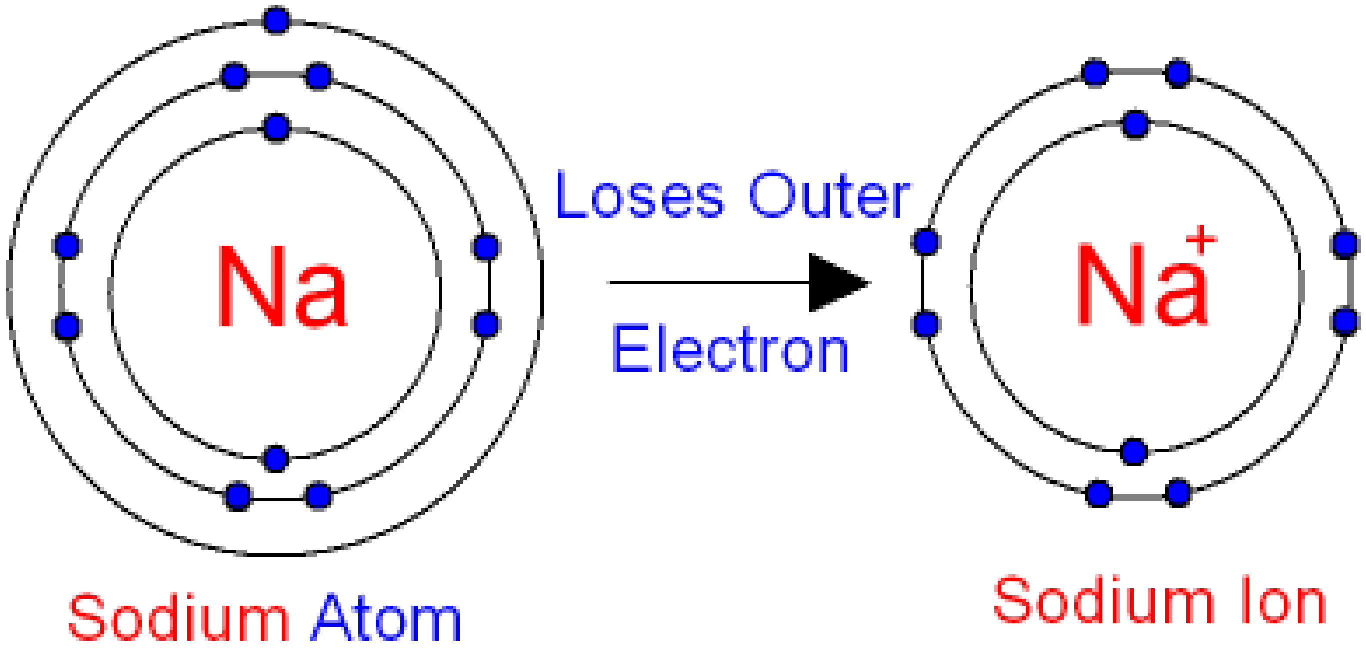
Atomic mass = Neutrons + Protons

- Problem 1 – how many protons in C^{14}
- 6 protons
- How many neutrons
- 14-6 = 8 neutrons
- Problem 2 – how many protons in tritium H^3
- 1 proton
- How many neutrons
- 3-1 = 2 neutrons

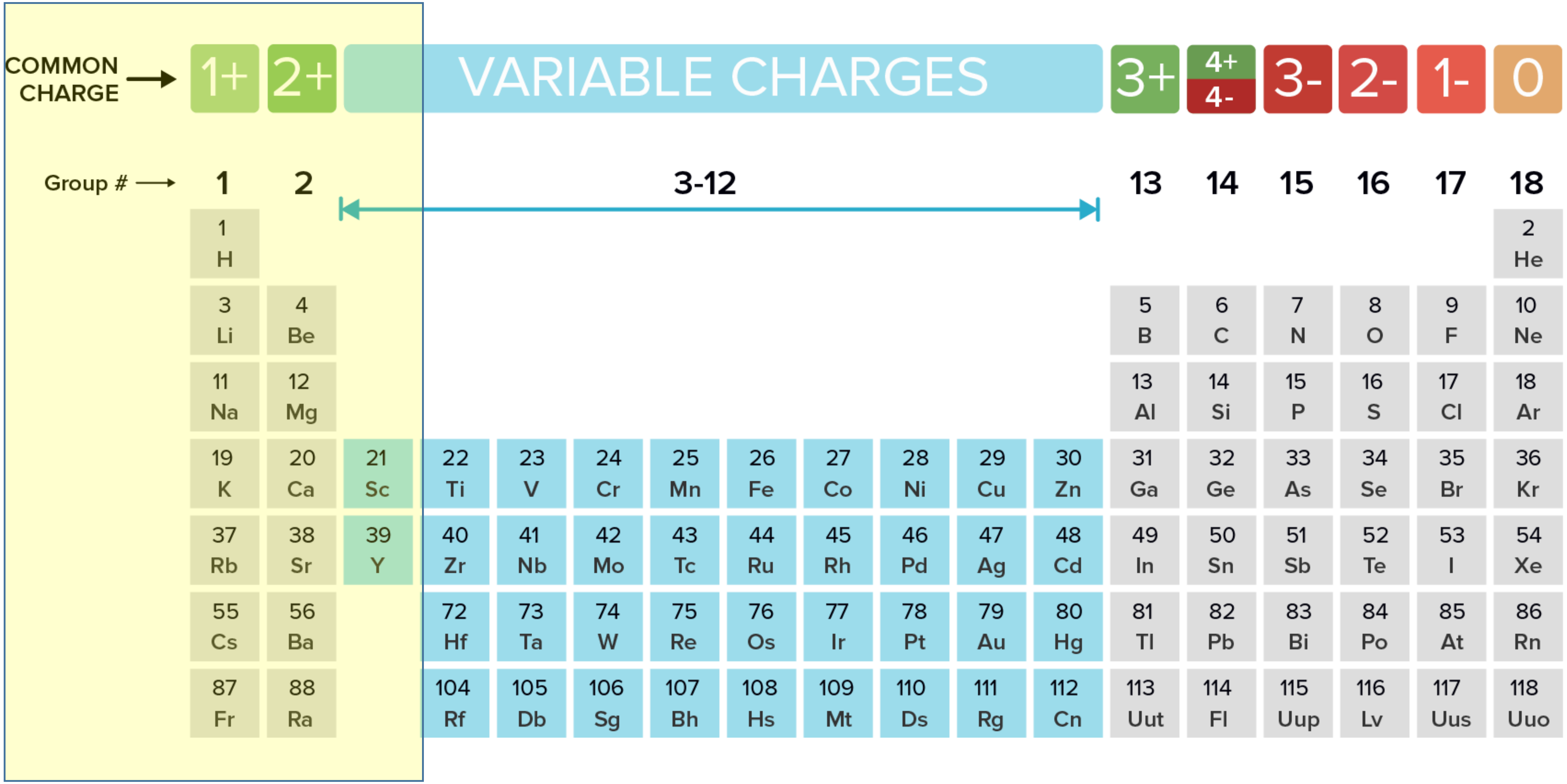
Add or subtract neutrons → <u>isotopes</u>



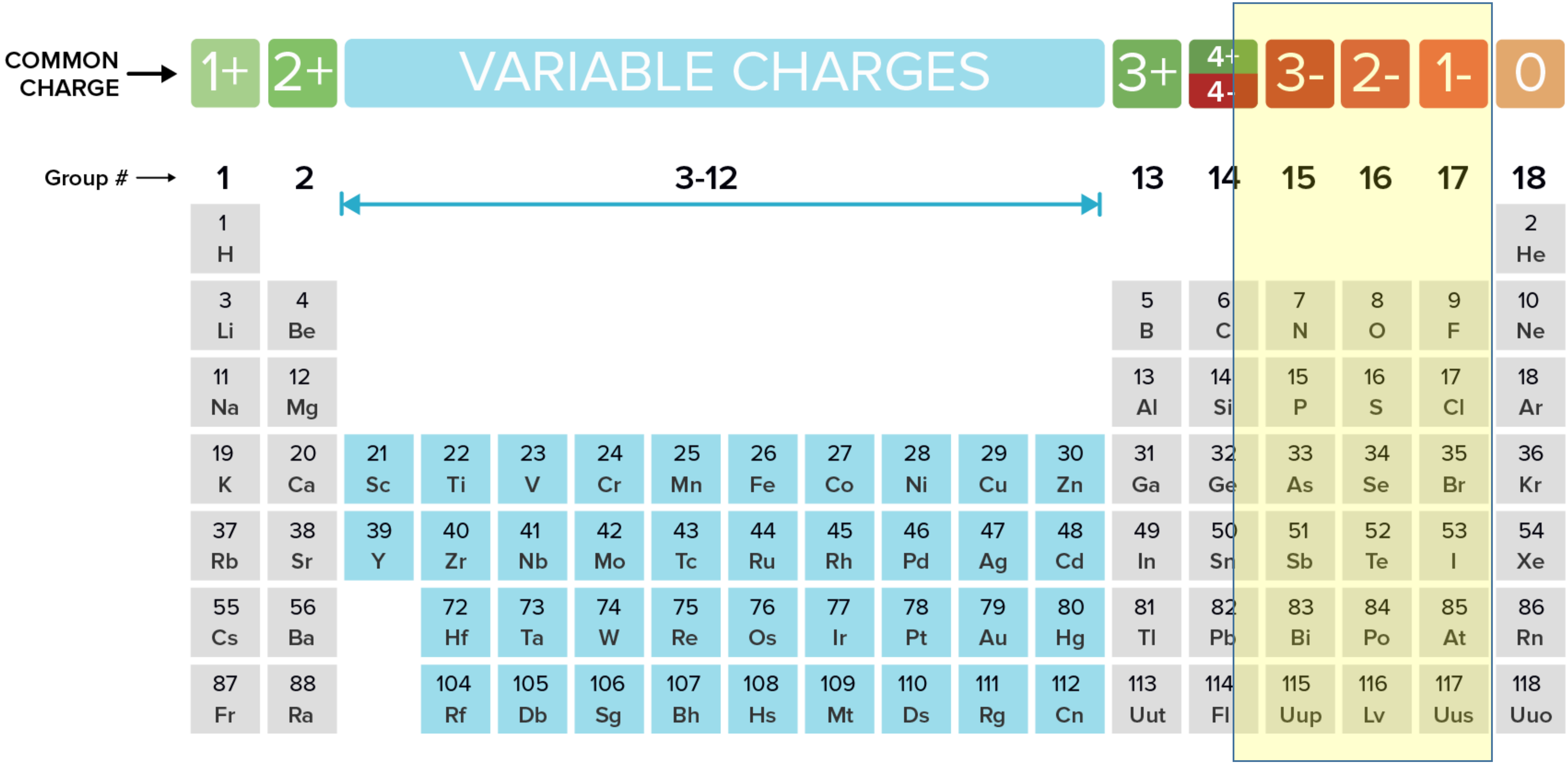
Add or subtract electrons → <u>ions = charged particles</u>



Metals like to lose electrons → + cations



Nonmetals like to gain electrons → - anions



Atoms combine →

- Molecules = two or more atoms bound together (same or different)
  - Ex: O_2 and H_2O

- Compounds = two or more different atoms bound together in a specific proportion
  - ex: H_2O, CO_2

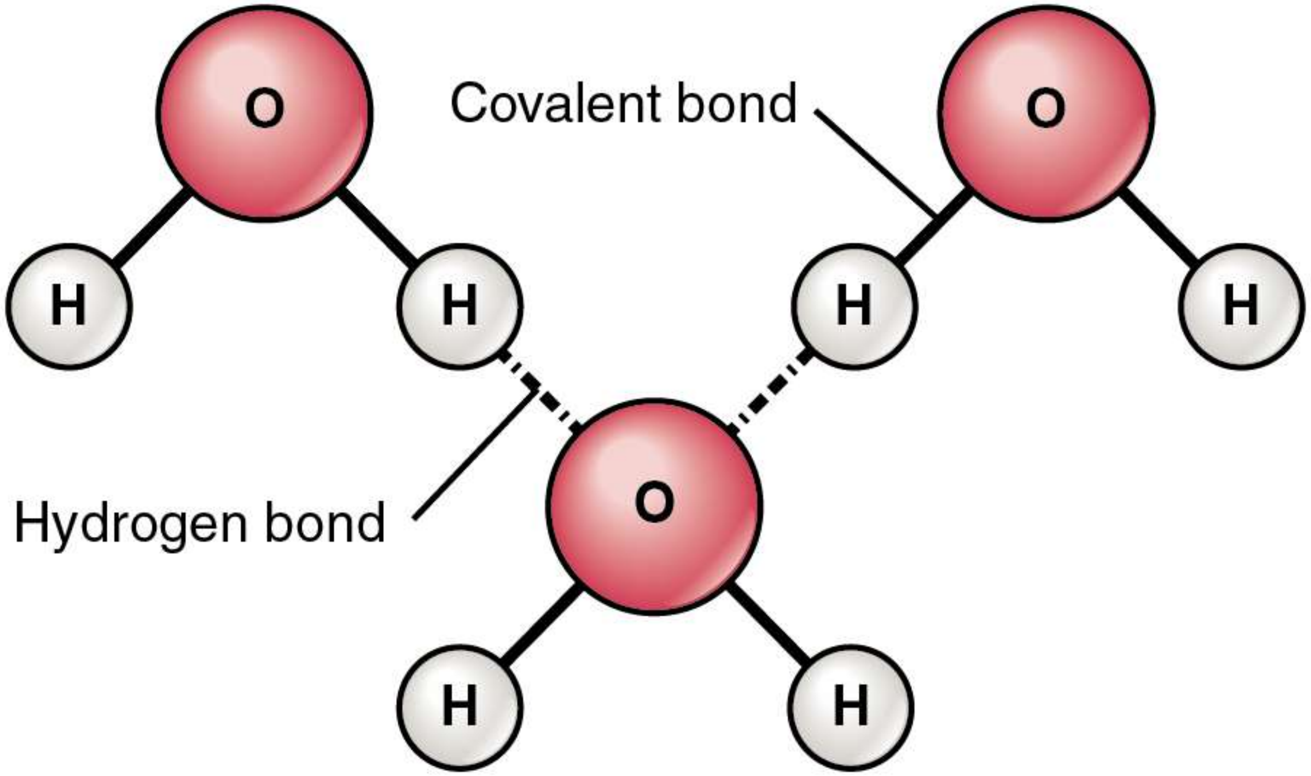
Chemical bonds holds atoms together

1. Ionic = transfer of electrons (metal – nonmetal)
   - Ex: salts (NaCl, $CaSO_4$…)

2. Covalent = sharing electrons (organic molecules)
   - Ex: hydrocarbons (CH_4, benzene…)

Chemical bonds between molecules

- Hydrogen bonds = intermolecular forces → waters unique properties

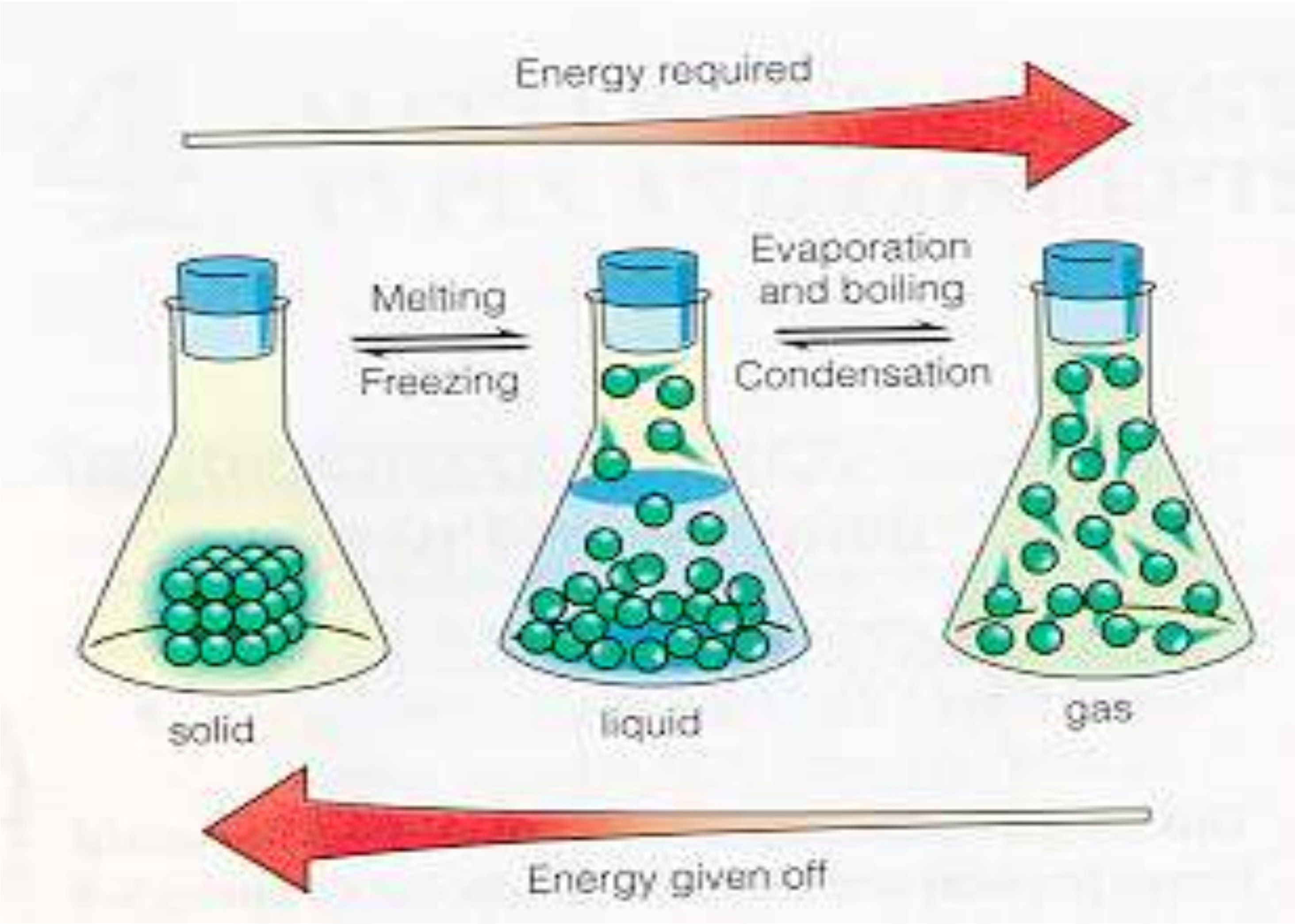


Properties of water

- Surface tension (allows boats to float)
- High specific heat (acts as a heat sink)
- Universal solvent (dissolves polar/charged solvents)

- Quick review:
- Define transpiration

Physical changes → change of state



Increasing entropy

- Melting (s→l)
- Evaporation (l→g)
- Sublimation (s→g)

- Energy required

Decreasing entropy

- Condensation
- Freezing
- Deposition

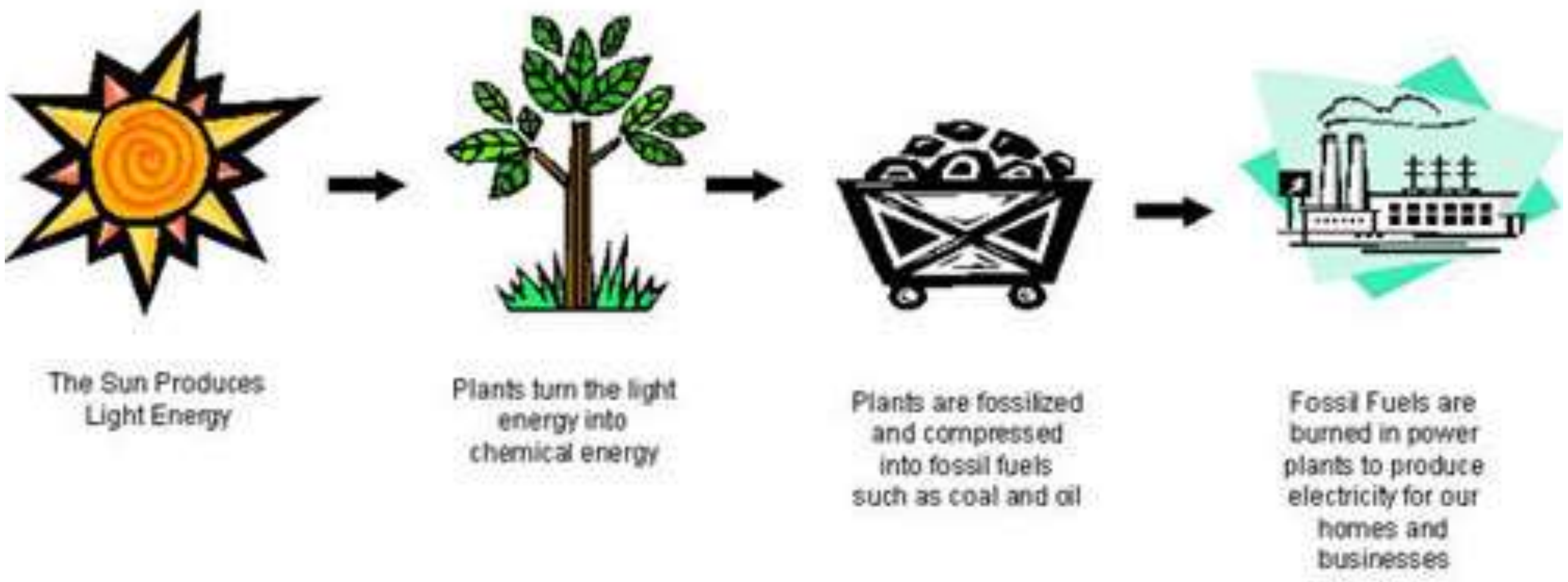
- Energy released

2 types of compounds

- Organic (contain C and H)
  - Hydrocarbons (methane, propane, gasoline, diesel, alcohols…)
  - Carbohydrates (sugars)
  - Fats (lipids)
  - Proteins
  - Nucleic acids (DNA and RNA)
- Inorganic (everything else)
  - Salts
  - Acids and bases

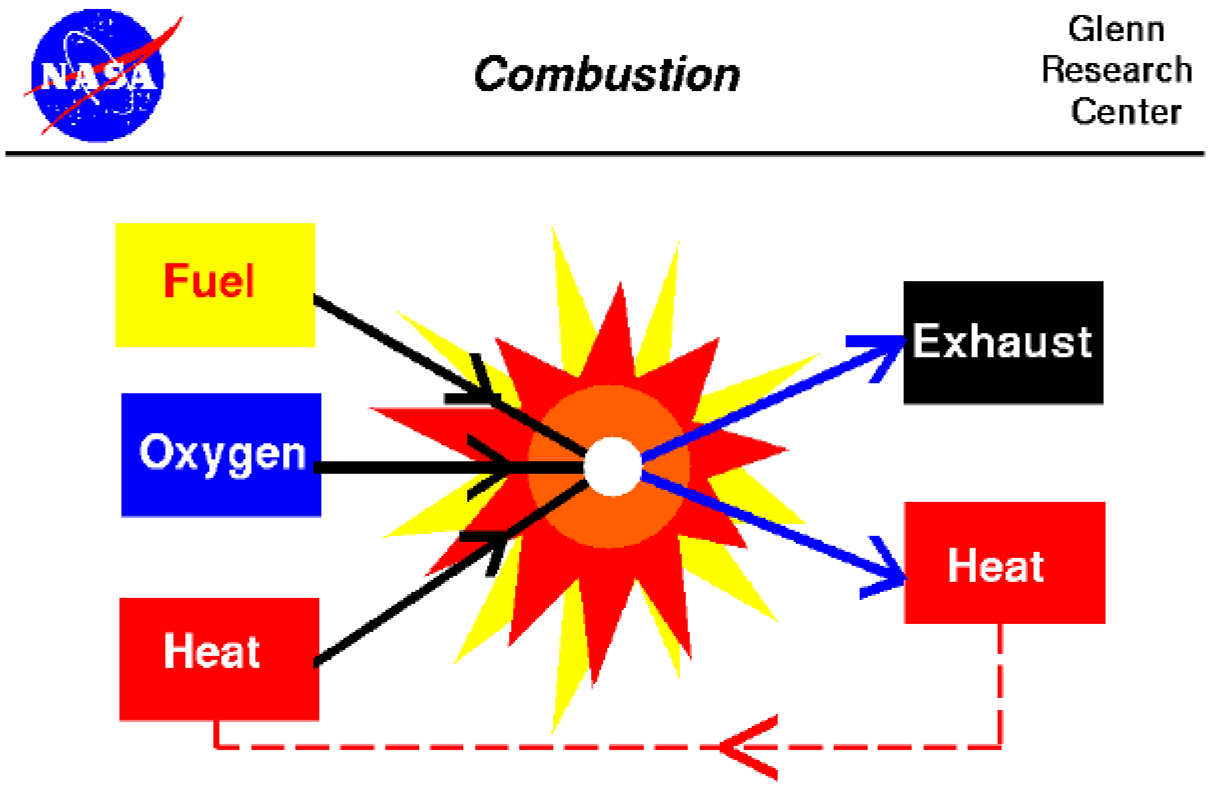
  - Review what is an acid?

Chemical bonds = potential energy



Break bonds → Release energy

- Combustion = breaking bonds → releases heat and light energy



Organic compound = lots of energy

- Organic compounds found in living things
  - Carbohydrates (glucose, starch, cellulose…)
  - Proteins (enzymes, make up organisms)
  - Lipids (fats and oils)

BIOMASS

- Hydrocarbons (methane, butane, propane…)
- Alcohols (methanol, ethanol…)
- Coal, oil, natural gas

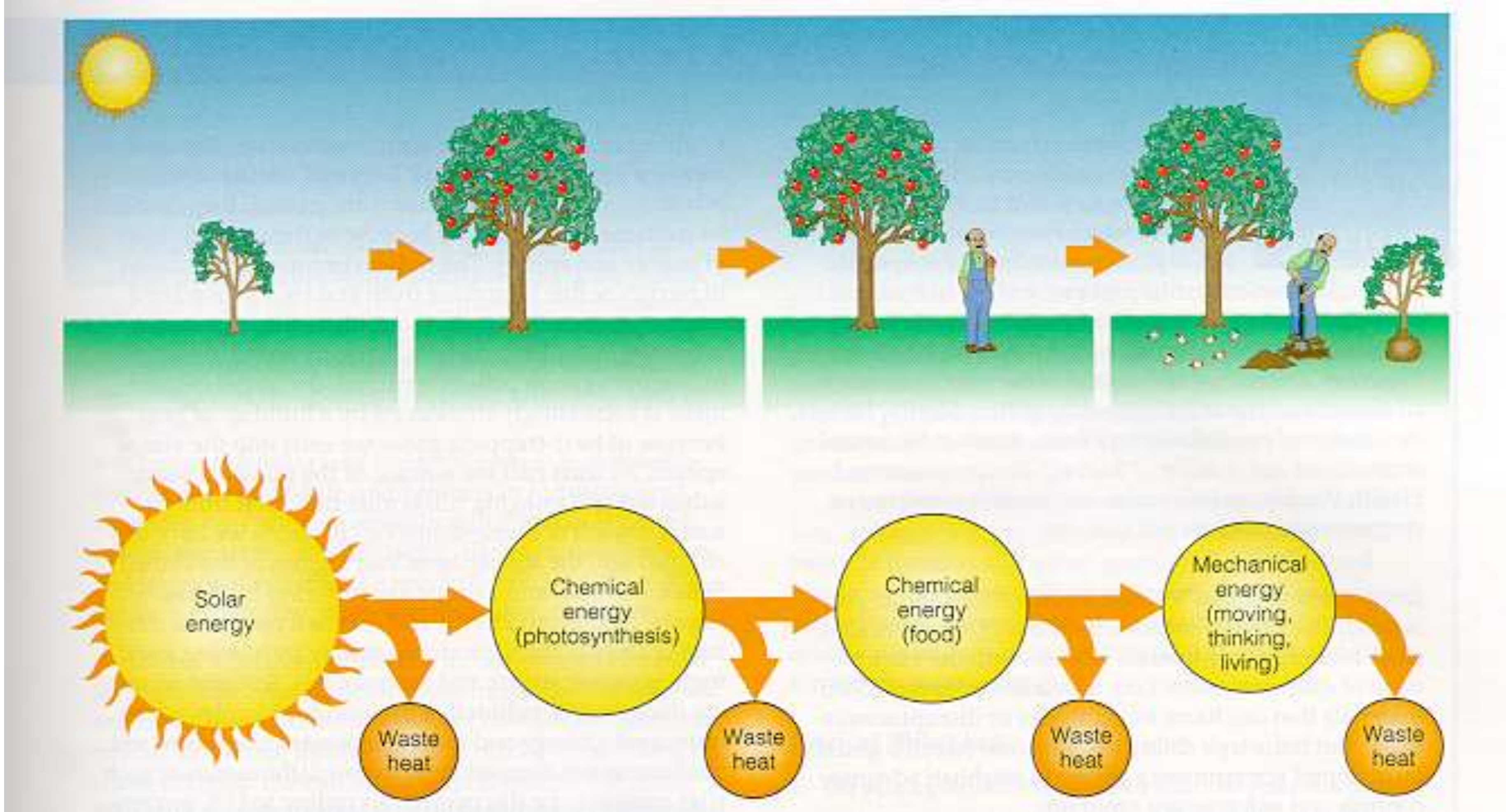
Fuels from biomass

Energy Laws

- First law of thermodynamics
- Energy can not be created or destroyed

- Second law of thermodynamics
- All energy transformations lose energy (usually as heat)
- No energy transformation is 100% efficient
- Systems go spontaneously in the direction of increased entropy = decreased order

10% rule = 90% loss at each trophic level



Energy efficiency = % energy →work

- Energy efficiency = useful energy out / total energy in x 100
- Less than 50% for most systems

Plants capture sunlight energy → glucose energy

- Only ~ 1% efficient

- C3 plants = most efficient
- C4 plants incorporate carbon faster in sunny dry regions (corn, sugar…)
- CAM plants are adapted to arid regions (ex: cactus)

Energy Laws and Energy Efficiency

Student activity worksheet

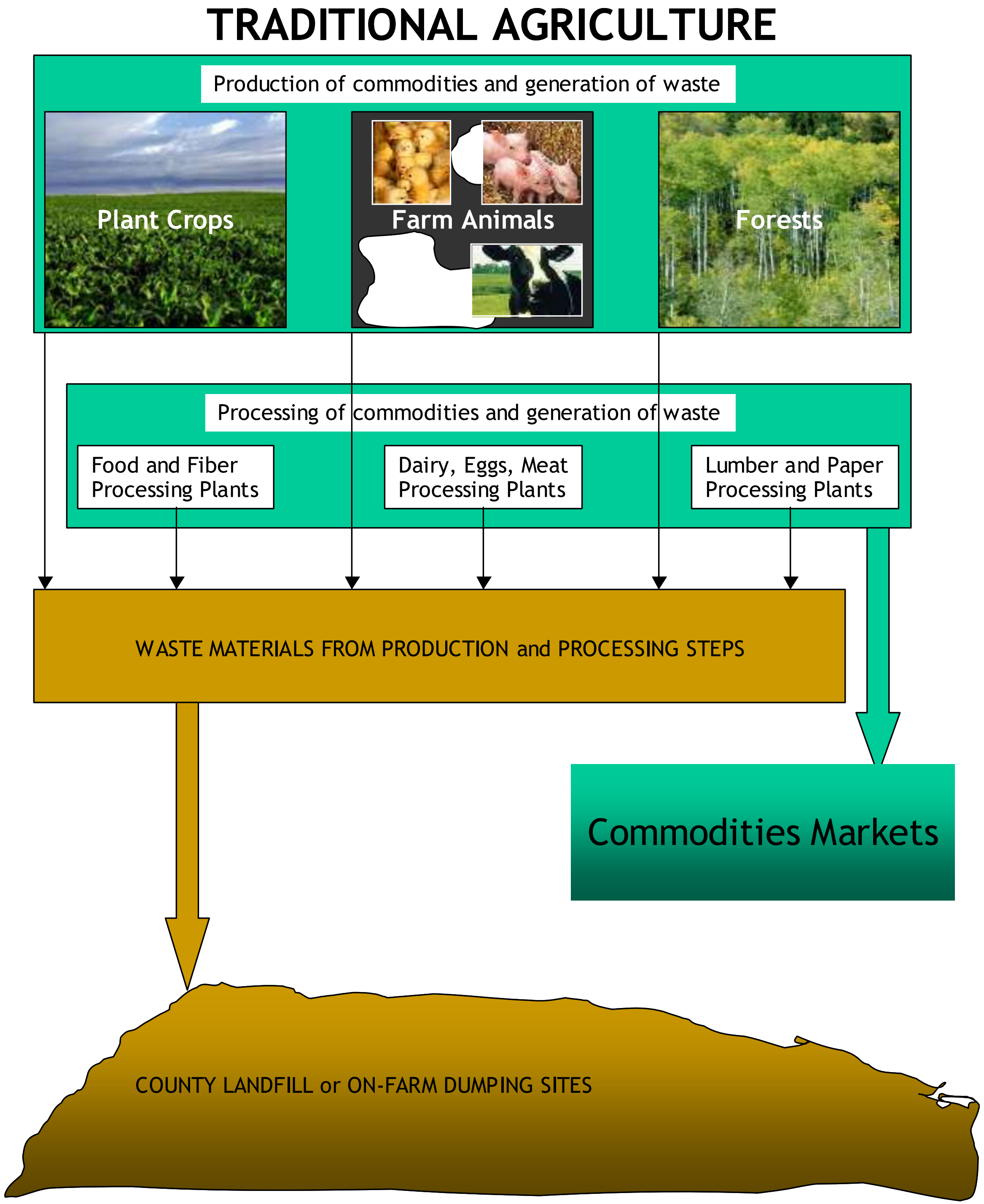
TABLE 15.1 Examples of First- and Second-Law Efficiencies

Energy (end use)	*First-Law Efficiency (%)*	*Waste Heat (%)*	*Second-Law Efficiency (%)*	*Potential for Savings*
Incandescent light bulb	5	95		
Fluorescent light	20	80		
Automobile	20–25	75–80	10	Moderate
Power plants (electric); fossil fuel and nuclear	30–40	60–70	30	Low to moderate
Burning fossil fuels (used directly for heat)	65	35		
Water heating			2	Very high
Space heating and cooling			6	Very high
All energy (USA)	50	50	10–15	High

Whole systems

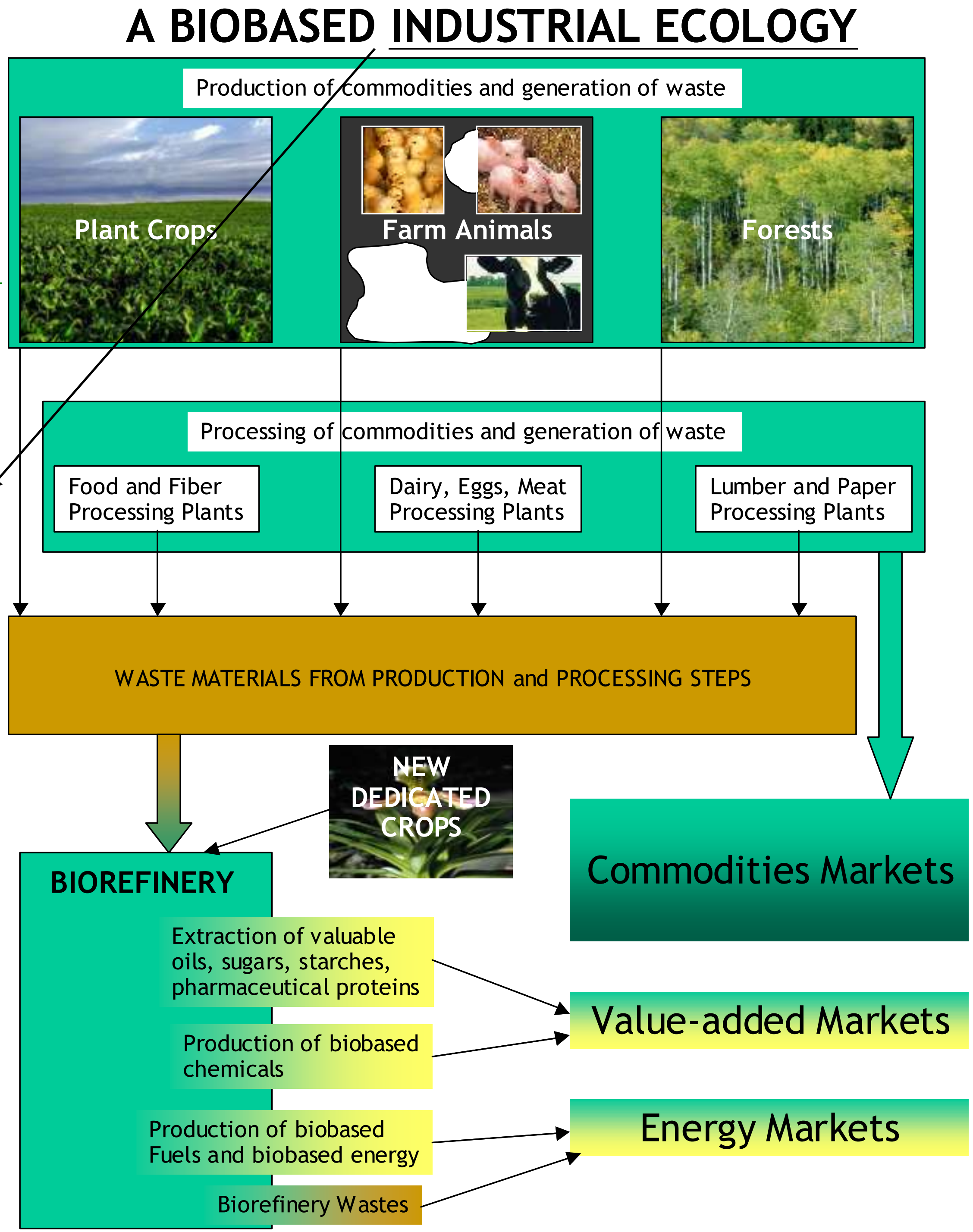
- When comparing energy products or system it is important to consider the whole system

Current systems = linear



Systems Approach

<u>Industrial Ecology</u>: a system model that uses the waste stream of one process as a feedstock for the next process all along the value-added chain

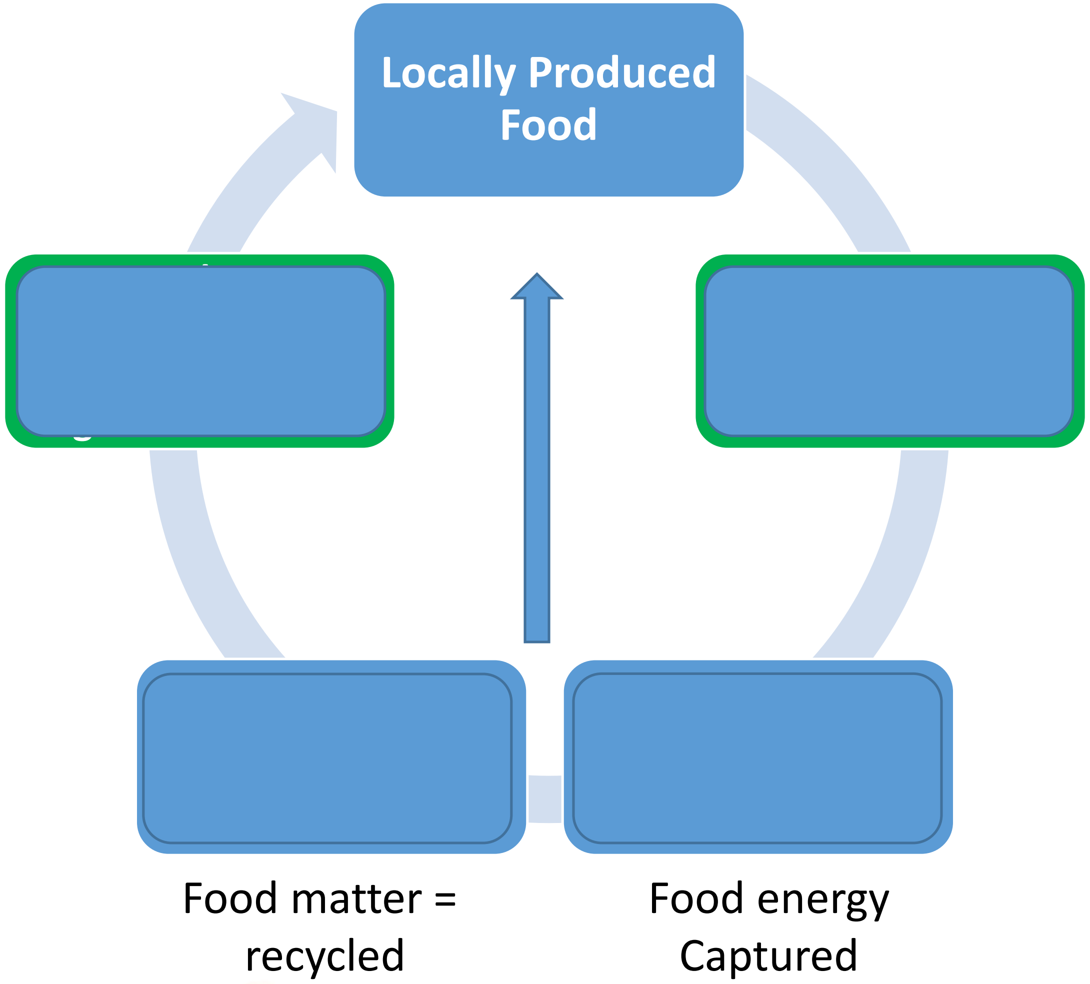


Current food waste system is linear and unsustainable

NOW

Trucks → Food → transfer station → landfill

Anaerobic Digester Plan = whole system



Recycles matter and Captures wasted energy

Pace Energy and Climate Center
PACE LAW SCHOOL
Northeast Bioenergy and Bioproducts (NBB) Educational Tools and Training
This project is supported by AFRI Competitive Grant no. 2011-67009-30055

Composting recycles nutrients energy still lost

Types of energy inputs humans need

- Food
- Transportation
- Heating
- Electricity

Earth ship = house as a whole system

Measuring Energy

- There are 4 units which are commonly used:
  - Calories, Joules, Btu’s, Watts

- REMBER – kilo = thousand (10^3), mega = million (10^6), giga = billion (10^9)

Calories (cal)

- Energy it takes to raise one gram of water one ºC
  - Measures food energy
  - 1 kilocalorie (Cal) = 1000 calories

Joules (J)

- Joules (J): Measure work (4.18 Joules = 1 calorie)

British Thermal Unit (btu)

- Amt. of heat needed to heat 1 pound of water 1ºF
  - Used to measure heat value of firewood and other fuels in North America

Electrical power is measured in watts (W)

- ex: a 2MW wind turbine is capable of producing 2MW at any given time

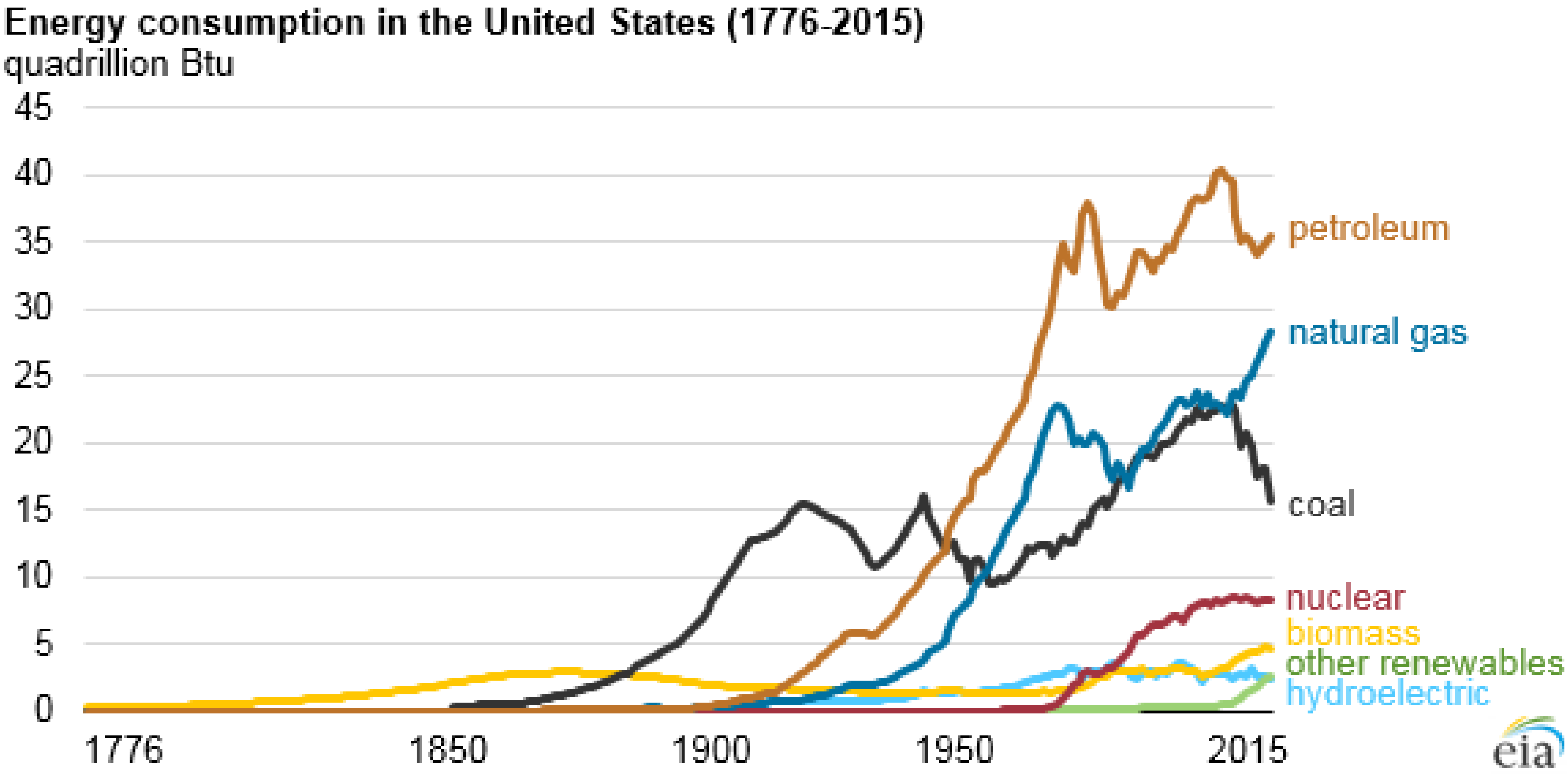
Electrical energy is measured in watt hours (wh)

- ex: the maximum amount of energy you can get from a 2MW turbine in one hour = 2MWh

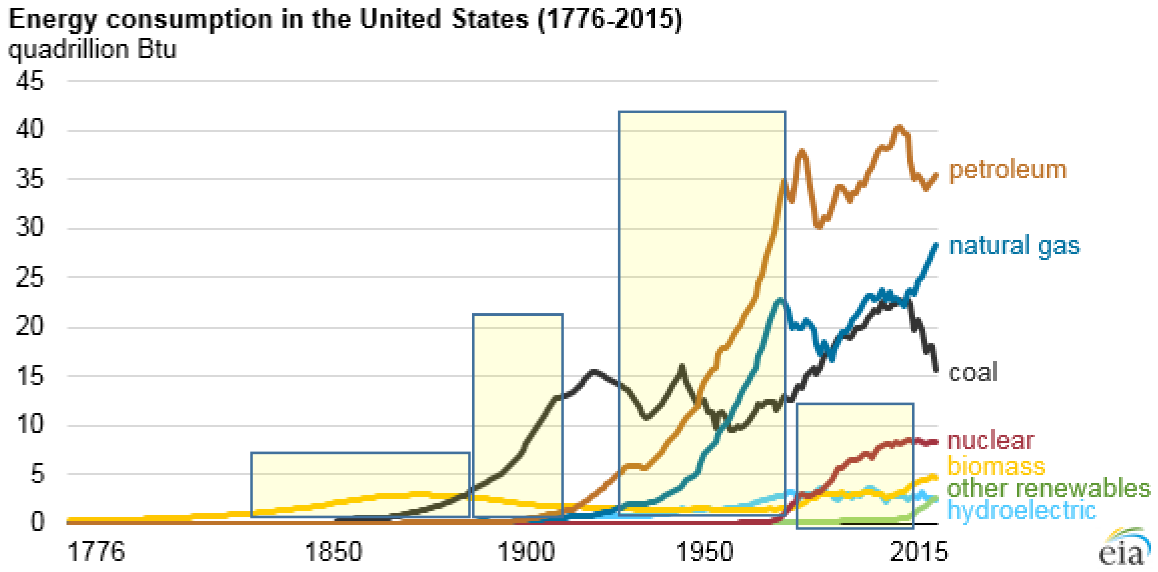
Calculating Energy Used

- Energy to lift an object to a height (E=mgh)
  - E(J) = mass(kg) x gravity(9.8m/s^2) x height(m)
- Heat (E=mcΔT)
  - E(J) = mass(g) x specific heat constant(J/g˚C) x change in temp(˚C)
- Electrical energy (E=Pt)
  - E(J) = power (kilowatts) x time (hours)
- Chemical energy of gasoline
  - E(J) = 37 x10^6 J/L x number of L of gasoline burned

Energy Consumption in the US



Energy Timeline



- Pre-1885 = Wood is primary energy source for cooking, heating, light, trains and steamboats
- 1885-1950 = Coal was the most important source of fuel (**1/2 ton of coal → as much energy as 2 tons of wood**)
- 1951-present = Oil has become the most widely used energy source (**automobiles inc. demand for oil)**
- 1957 = first commercial nuclear power plant began operating → electricity (Calder Hall, England) (1st in Us = 1959 in Il.)

Sources of Energy

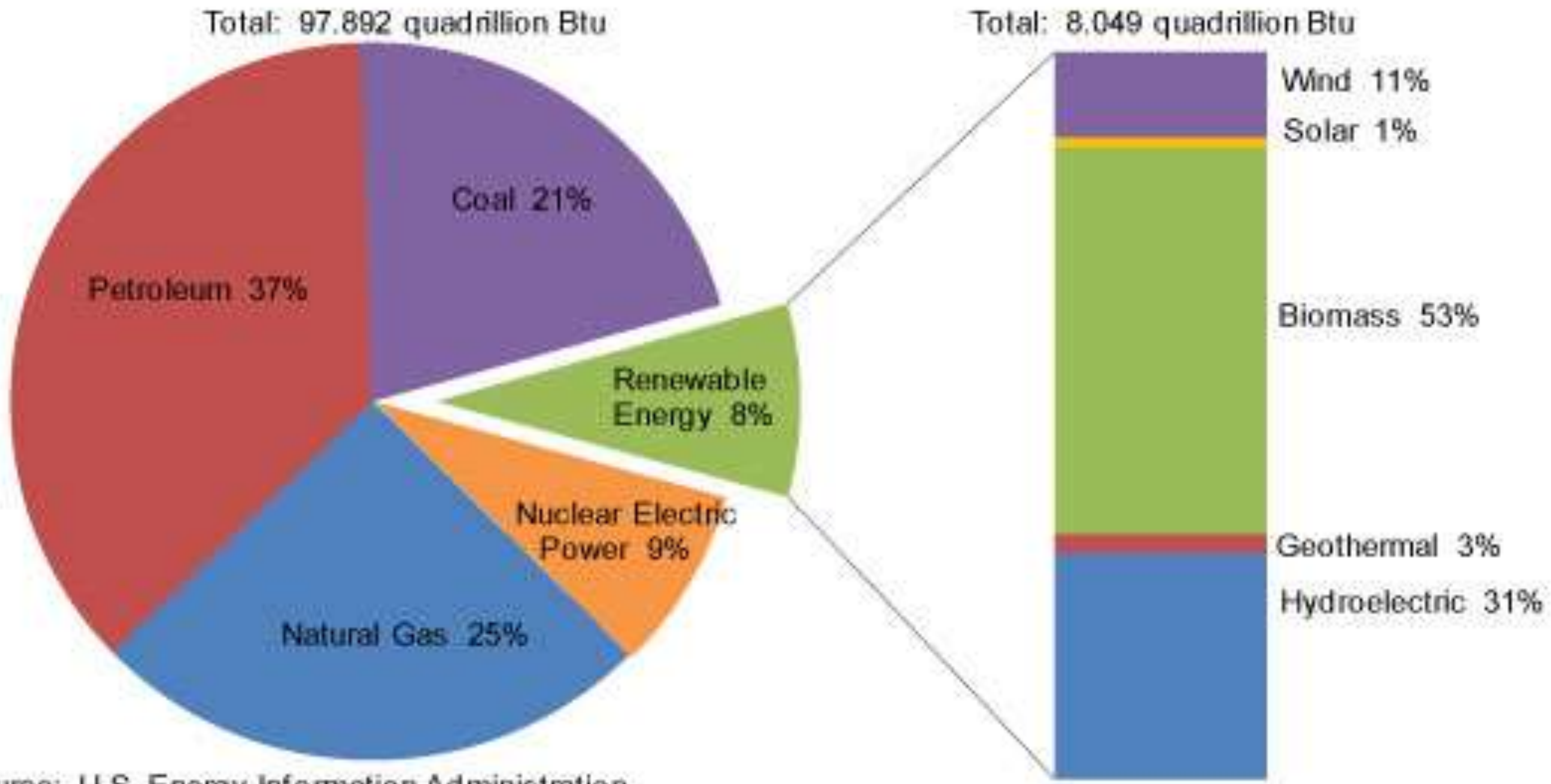
Non-Renewable

- Fossil fuels (Peat, Coal, Oil, Gas)
- Uranium (nuclear)

Renewable

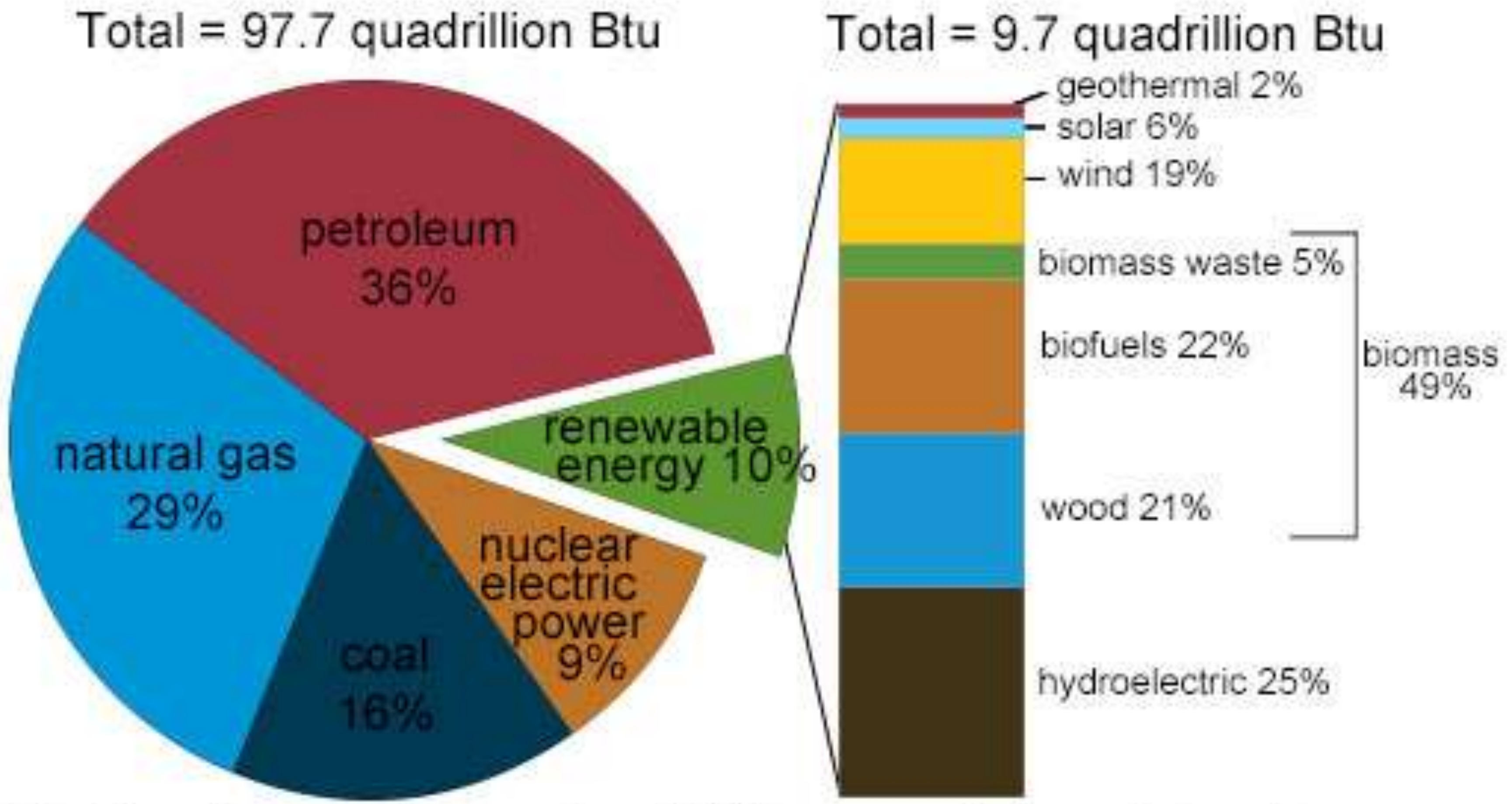
- Solar
- Wind
- Geothermal
- Biomass (wood, charcoal, ethanol…)
- Hydro
- Ocean (wave and tidal)

Figure 1. Renewable energy consumption in the nation's energy supply, 2010



Source: U.S. Energy Information Administration

U.S. energy consumption by energy source, 2015



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 2016), preliminary data

What happened to each

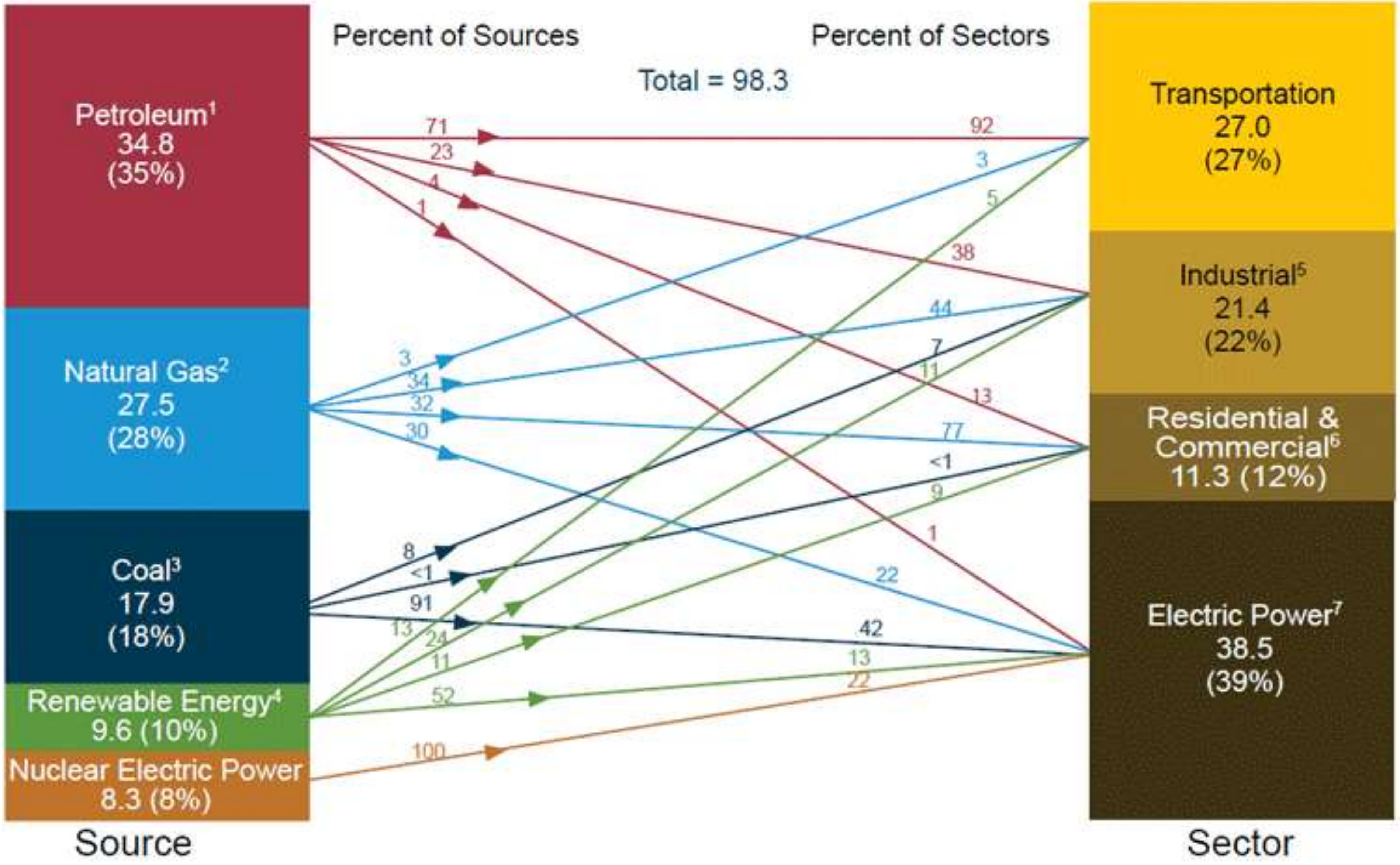
- Coal
- Decrease from 21% → 16%
- Natural gas
- Increase from 25% → 29%
- Renewables
- Increase from 8% → 10%

Which renewable sectors grew the most and why?

- Increase in wind and solar
- Incentives (ex: Production tax credits)

Primary energy consumption by source and sector, 2014

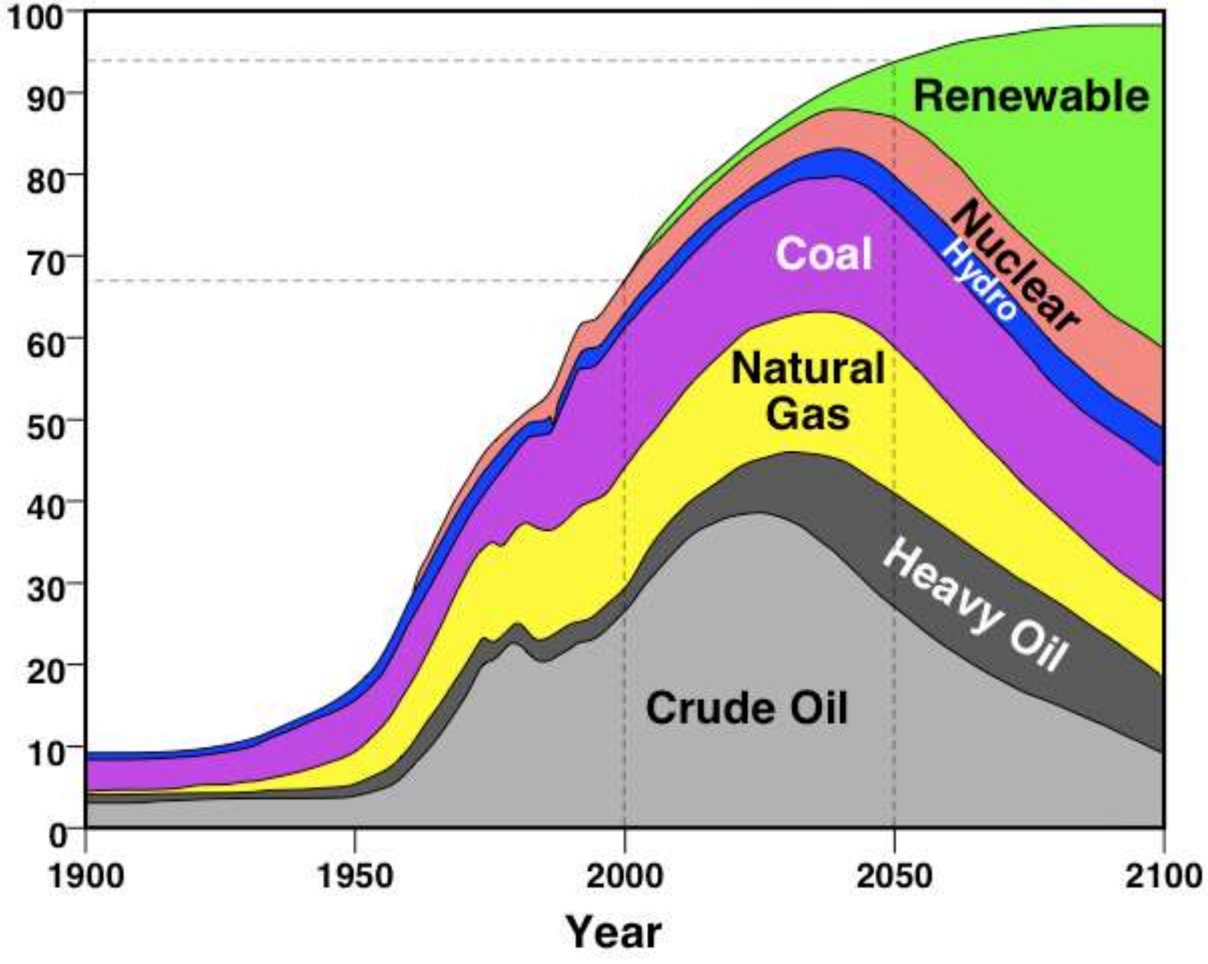
quadrilion Btu



Where does most of the oil go

- Transportation (cars)
- Industry (plastics)

http://www.geo.cornell.edu/eas/energy/the_challenges/peak_oil.html



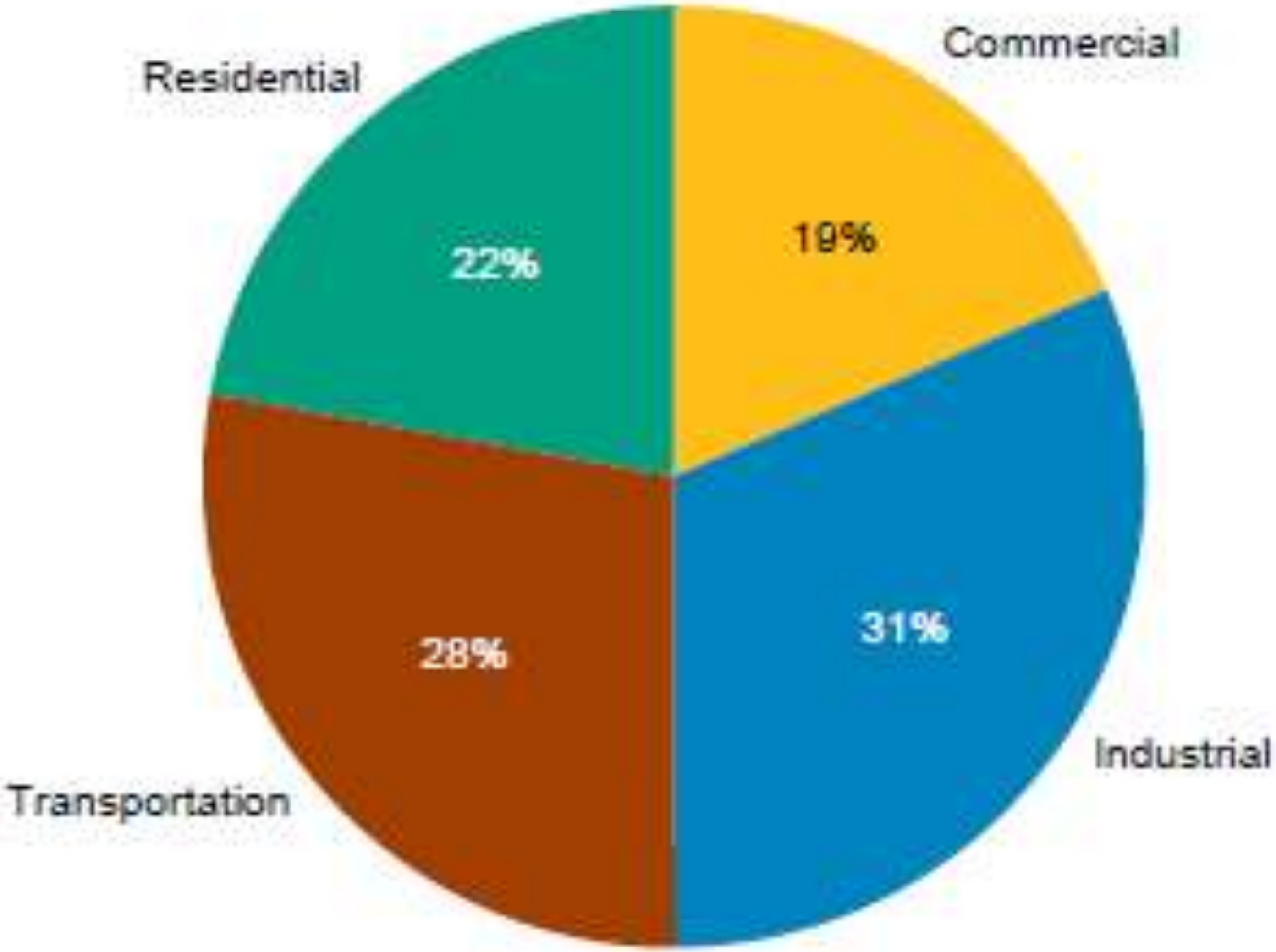
Oil supplies are depleting
what is the best way to decrease our need for oil?

- Alternative forms of transportation
- Decrease use of plastic

Nuclear → electricity and thermal pollution
What is a more efficient whole systems approach?

- Co-generation
- Use waste heat to heat buildings

End-Use Sector Shares of Total Consumption, 2011



Residential and commercial Energy Consumption

- Heating, cooling, running appliances
- **<u>Hot water and space heating = most energy intensive</u>**

Heating options

- **<u>Nonrenewable</u>**
- Natural gas
- Oil and kerosene
- Both → air pollution
- Ex:
- (<u>global warming, acid rain, smog</u>)

- **<u>Renewable</u>**
- Biomass
  - Wood fuels can → deforestation & air pollution
  - Ethanol and crop based fuels can → increase burden on farmable land & some air pollution

Most sustainable options

- Geothermal heat exchange
- Smart building design and passive solar

Energy Conservation

- Weatherization programs offer low income families help in permanently reducing energy bills by weatherizing

- Low flow shower heads cut down on hot water consumption

- Recycling can decrease energy consumption
  - <u>Bauxite → Al </u>(requires 20x's more energy than recycling)
    - recycling Al → 95% less air pollution
  - Iron ore → steel
    - Recycled steel uses 33% less energy

Lighting


photo credit: National Renewable Energy Laboratory

- Incandescent bulbs = 5-10% efficient
  - 90% energy → waste heat

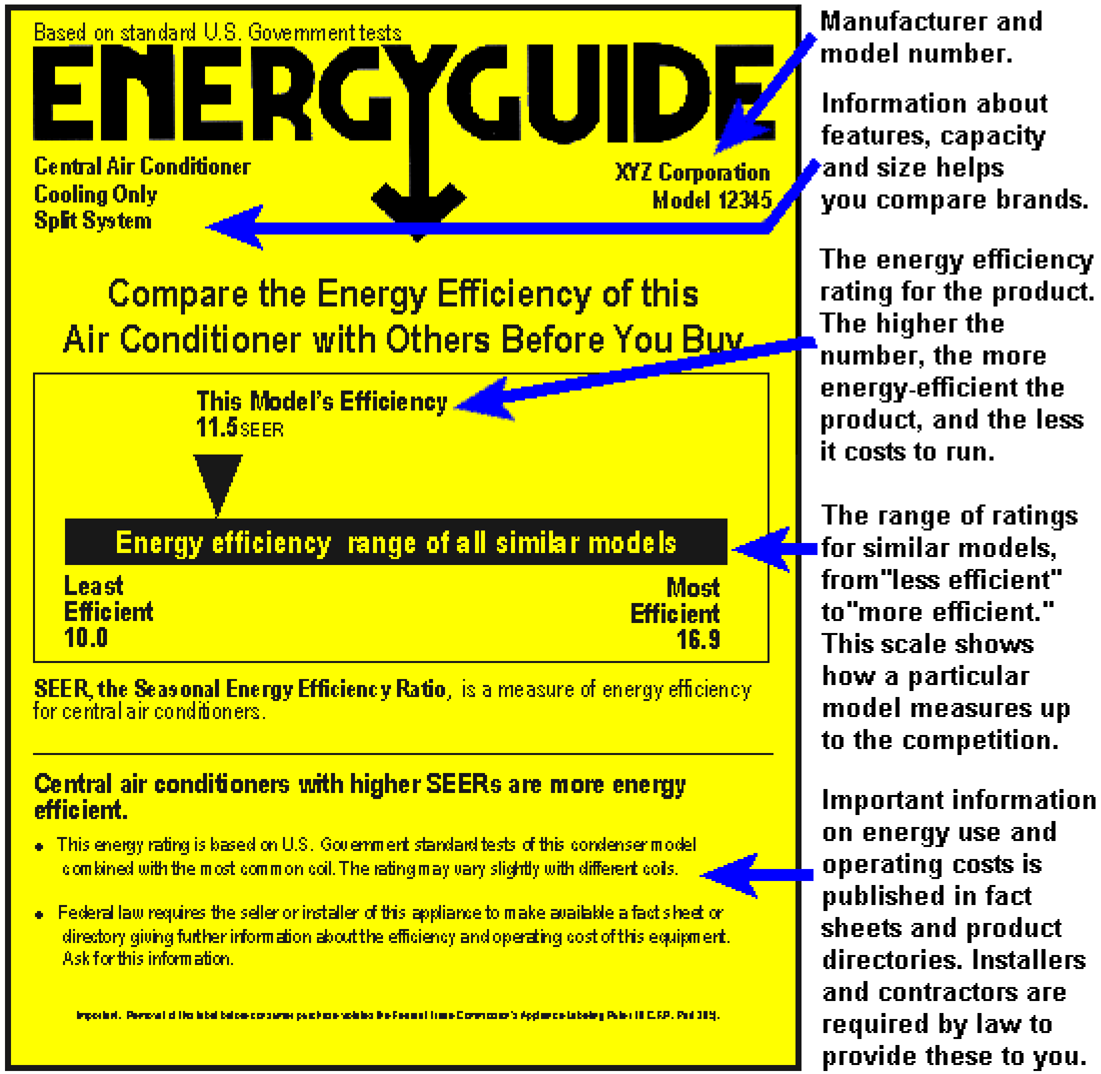
- Compact fluorescent = more efficient and last longer but contain small amounts of Hg
  - (BUT less electricity = less coal burning = less Hg emissions)

- LED lighting (ex: Christmas tree lights) = last longer and more efficient than CFL’s (less energy) but more expensive

Appliances

- 1990 **National Appliance Energy Conservation Act → strict efficiency standards**

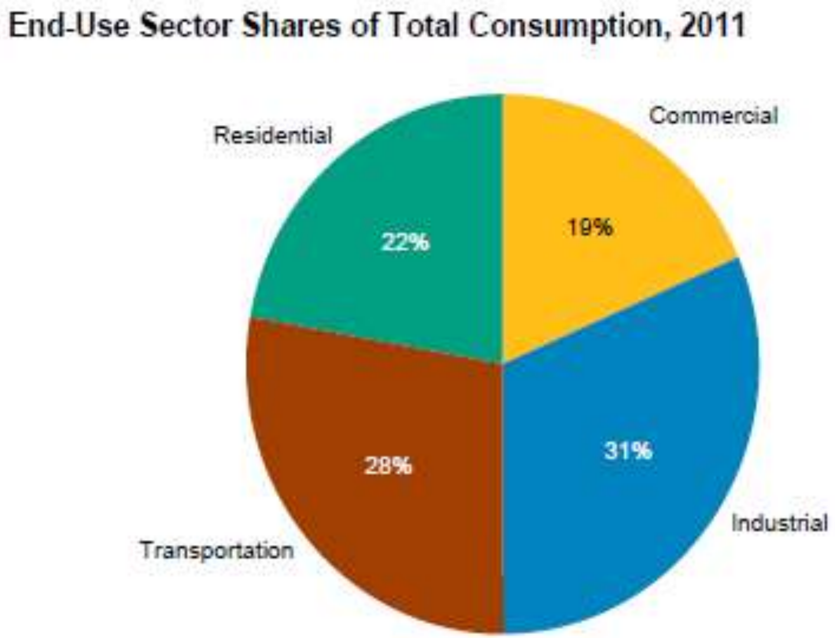
- Look for - Energy efficiency ratings (EER) - to compare appliances



Energy Star Program = government program → identifies products that are significantly more efficient than standard models

Ex: <u>front loading washing machines (40% less water and 60% less energy</u>

Industrial Energy consumption



Energy – intensive industries:

- Oil refining
- Steel (less energy to recycle)
- **Aluminum** (made from **bauxite**) (**recycling requires 95% less energy**)
- Paper (recycling dec. solid waste and tree harvesting, but uses = amounts of energy)
- Chemical manufacturing many chemicals come from petroleum
- Food industry → organic wastes (potential fuel source)

Ways to decrease industrial consumption

- **Cogeneration increases efficiency**
  - **1 fuel → heat and electricity**
- **Recycling** can **decrease** industrial energy **consumption**
- Can burn wastes → fuel
  - (BUT → air pollutants)

Cogeneration → District Heating in Finland

- District heating warms 44% of the buildings in Finland

- 72% of district heat was produced by CHP (cogeneration electrical plant) in 1993.

- Other industries produce heat that is fed into the system (computer networks, sewage treatment plants, paper industry…)

Transportation

- Most of our oil consumption → transportation
- Most oil imported
  - Domestic production mainly **Alaska** (**very fragile ecosystems due to slow decomposition and low species diversity**)
- Per capita consumption = per person
  - US Population ~ 325 million
  - World population ~ 7 billion

4 problems with burning fossil fuels

- Depletes nonrenewable resource
- → CO_2 → global warming
- → SOx and NOx → acid rain
- → particulates → smog

Alternatives

- Hybrids (2 motors – electric and gasoline)
  - More efficient, still use gas
- Electric
  - Pollution switches from dispersed source to a point source (power plant → emissions)
  - Must ask where electric power is coming from (US currently 60% coal, 23% nuclear)
- Ethanol = produced from biomass (corn, sugar cane, wood pulp…) Fermentation (anaerobic respiration) → alcohols but bacteria use lots of the energy
  - Note: **plants are only 1% efficient** at converting light → chemical energy.
  - Cleaner burning than gasoline
  - Greenhouse emissions offset by plant growth → fuel
  - Growing crops for fuel requires energy and land
- Hydrogen fuel cells (need H source and energy to isolate H)

Electricity is a secondary energy source why?

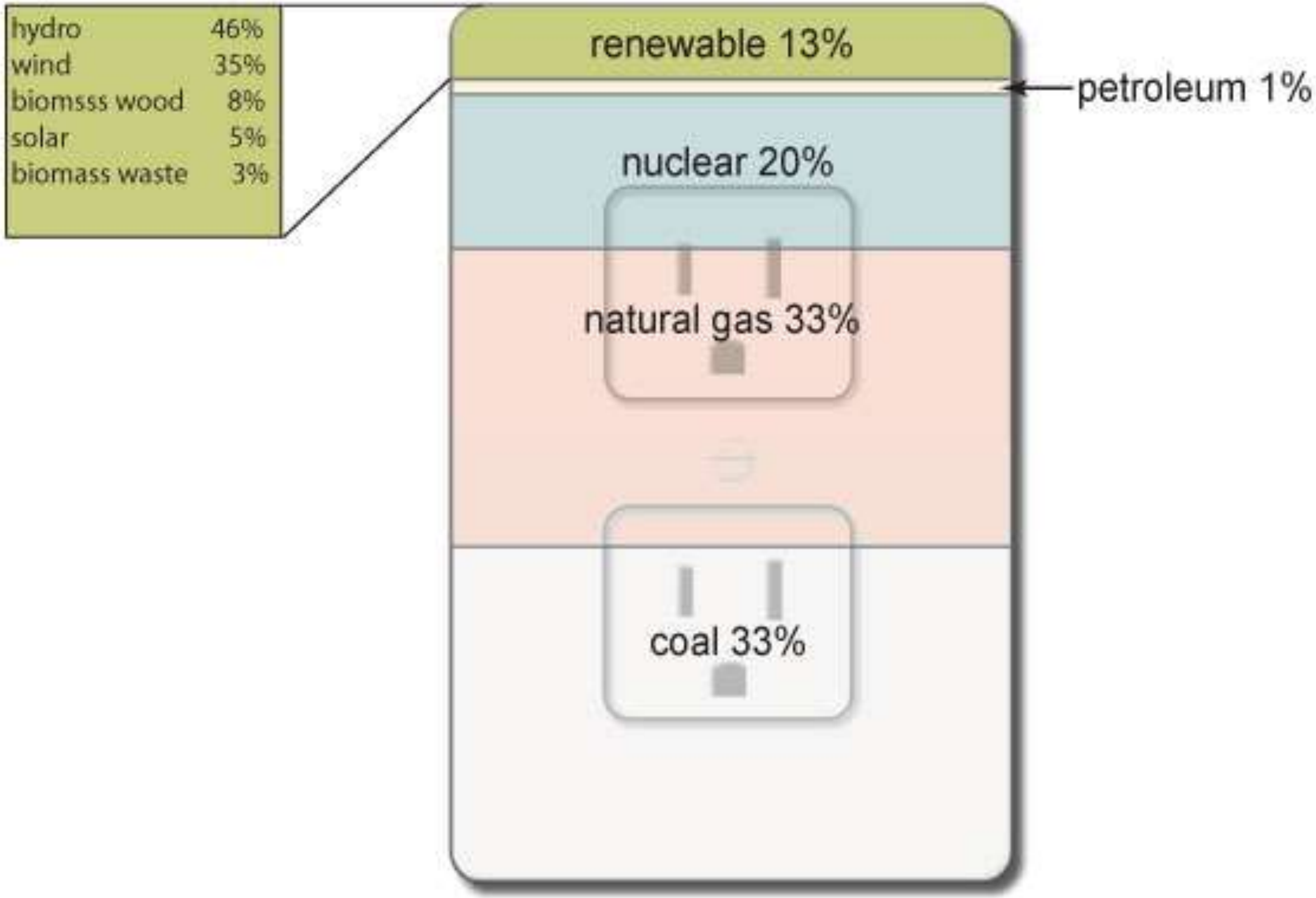
- Need energy → electricity
- Every energy conversion = loss = decrease in efficiency

Technologies→ electricity

- Photovoltaic (pv) cells
- Batteries (lead acid, cadmium, lithium-ion)
- Hydrogen fuel cells
- Each rely on chemical reactions and properties → electron flow

- Steam generators
- Wind turbine
- Water powered turbine
- Each rely on spinning a coil of wires around a magnet

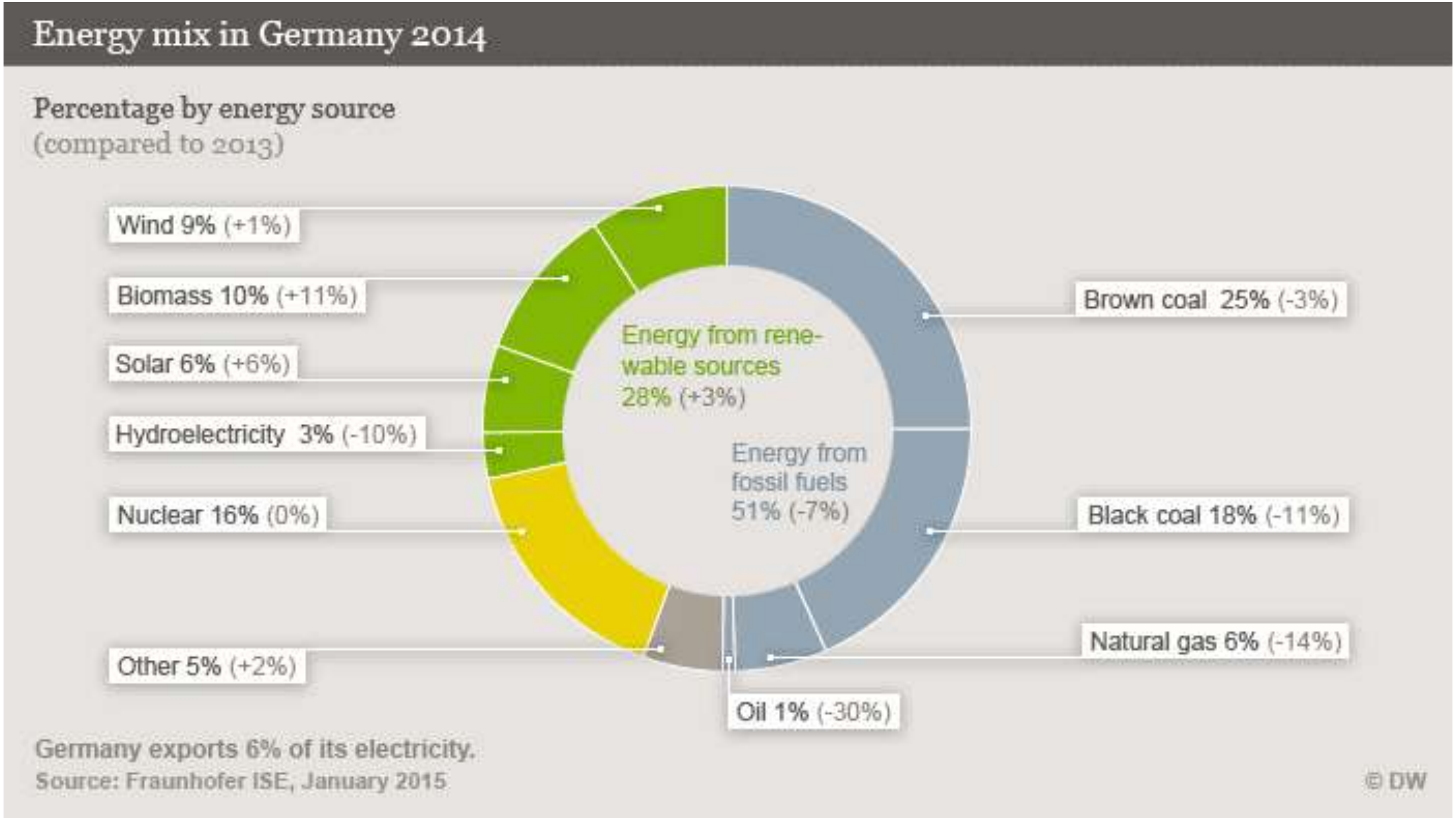
Sources of U.S. electricity generation, 2015

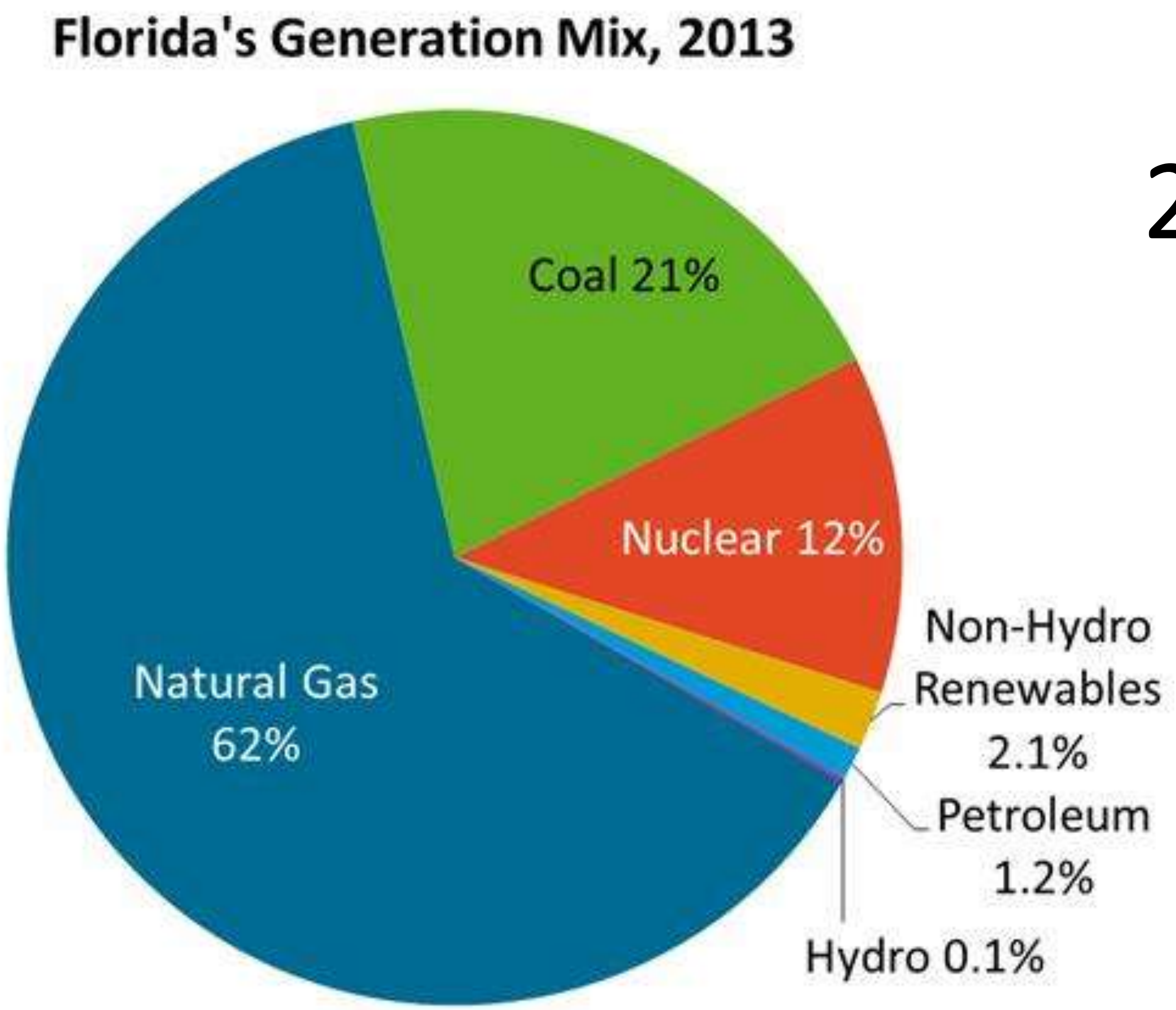


Source: U.S. Energy Information Administration, *Electric Power Monthly*, February 2016. Preliminary data for 2015

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

Renewables → 28% Germany's electricity (2014)



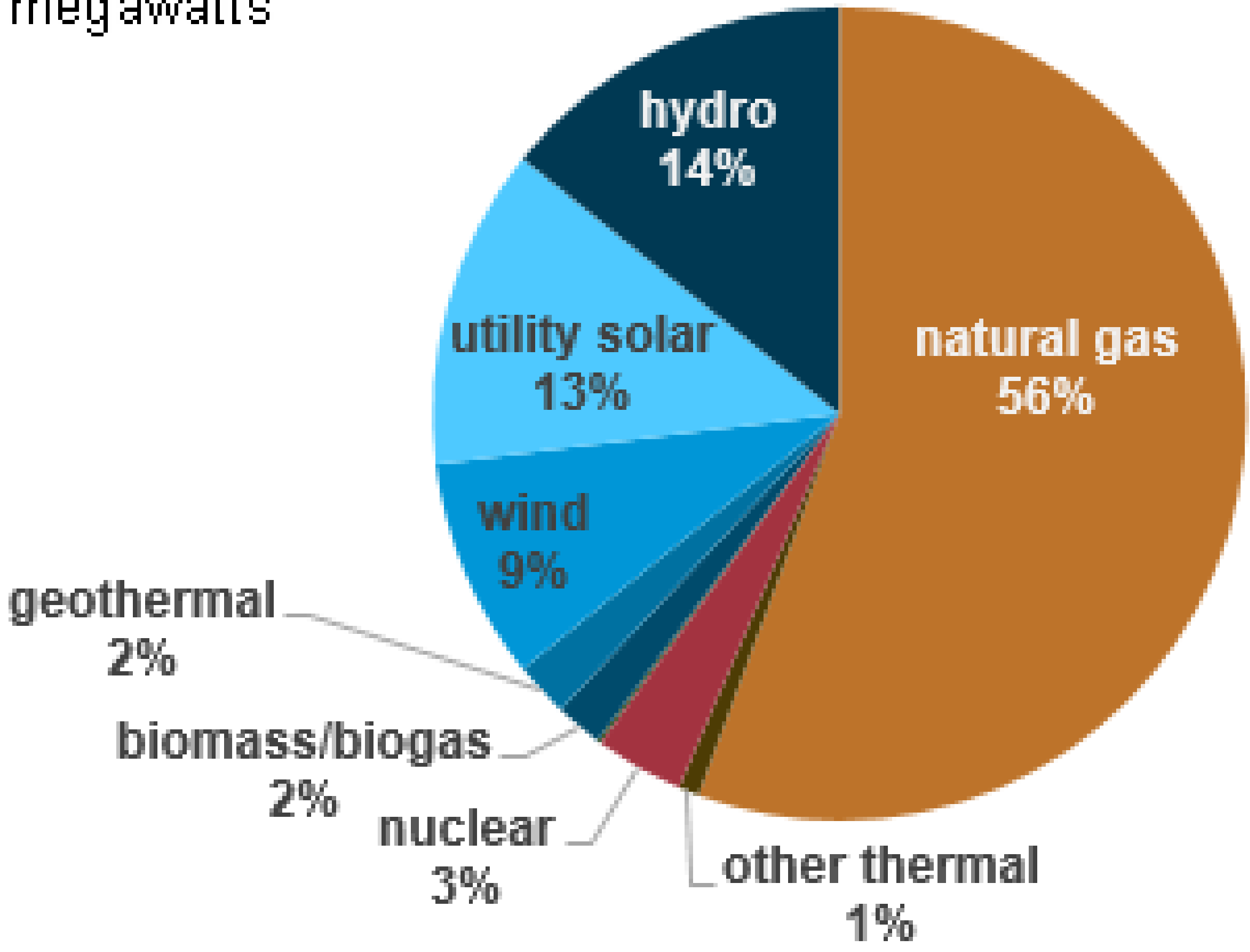

Florida's Generation Mix, 2013
Coal 21%
Nuclear 12%
Non-Hydro Renewables 2.1%
Petroleum 1.2%
Hydro 0.1%
Natural Gas 62%

2.2%

Net summer capacity in California Independent System Operator, June 2016

megawatts

total = 63,397 megawatts

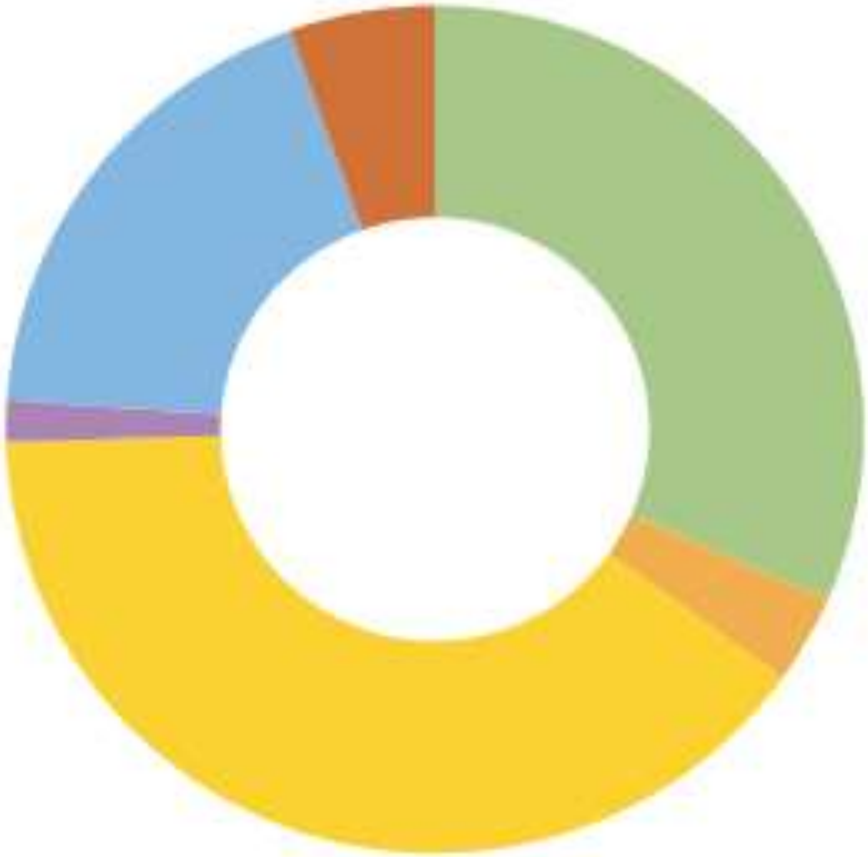


eia

40%

Sources of Electricity in New York

- **Nuclear** 31.6%
- Coal 3.4%
- Natural Gas 39.6%
- Hydroelectric 18.4%
- Renewable and Other 5.5%
- Oil 1.6%



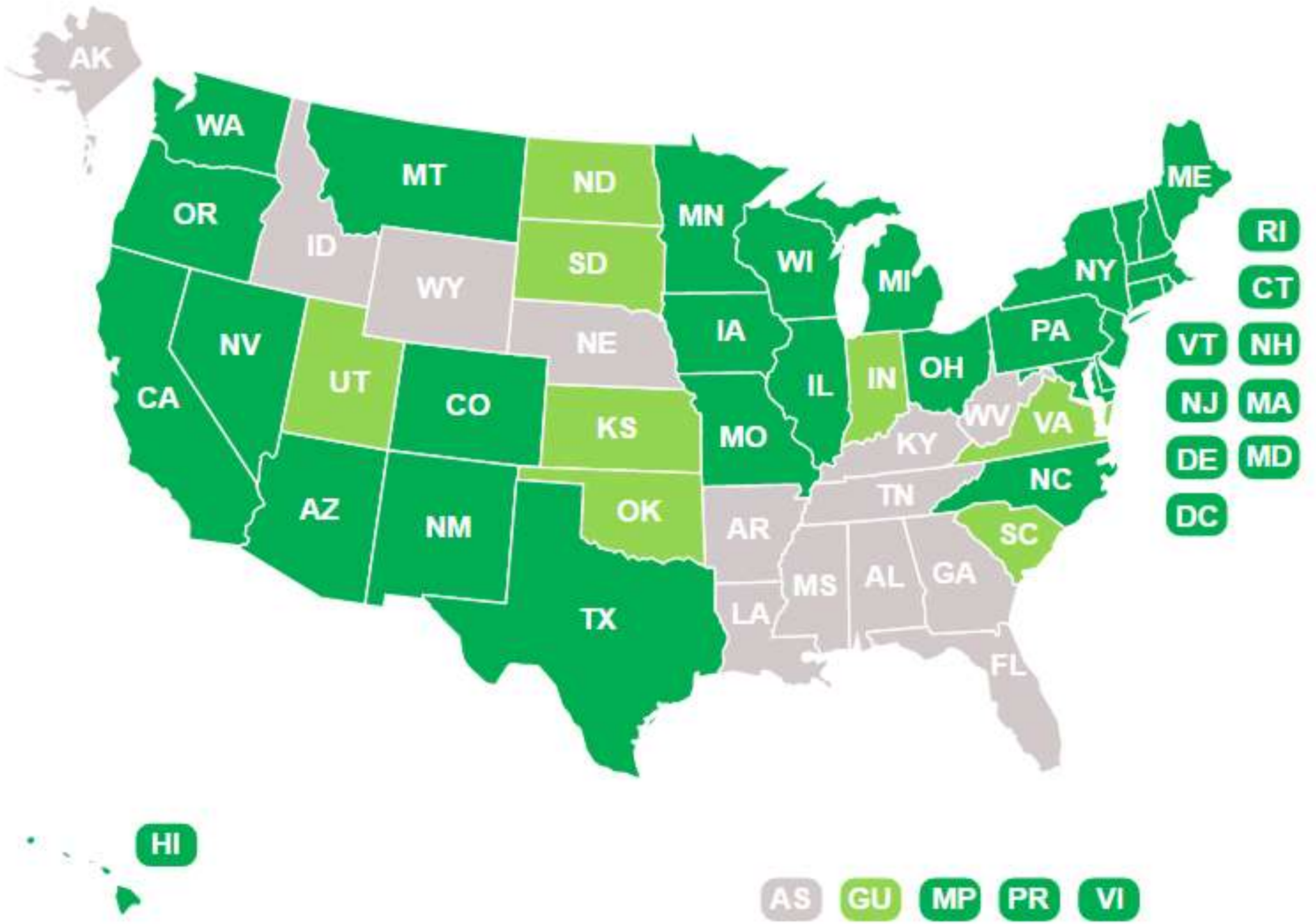
Source: U.S. Energy Information Administration, 2014

23.9%

What is necessary → states and governments transition to renewable electric generation?

- Renewable energy portfolios and standards
- Renewable energy credits (RECs)
- Production tax credits
- Economic Incentives

States and territories with Renewable Portfolio Standards	States and territories with a voluntary renewable energy standard or target	States and territories with no standard or target



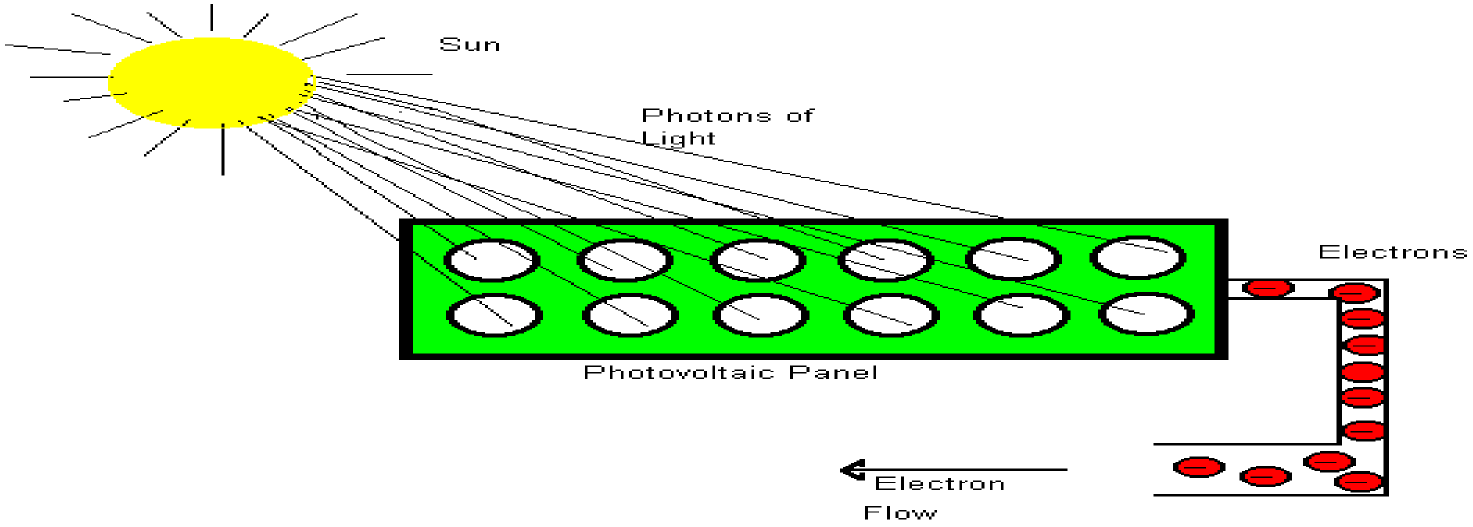
Florida does not have a renewable portfolio standard

California	Renewables Portfolio Standard	33% by 2020 40% by 2024 45% by 2027 50% by 2030	2013 amendment allows the California Public Utilities Commission to adopt additional requirements.	Cal. Public Utilities Code §399.11 et seq.; Cal. Public Resources Code §25740 et seq.; CA A 327 (2013)

New York	Renewable Portfolio Standard; Reforming the Energy Vision (REV)	29% by 2015; 50% by 2030 (REV- *currently in process*)	Distributed Generation: 8.4% of annual incremental requirement.	NY PSC Order Case 03-E-0188; 2015 New York State Energy Plan

Photovoltaics

- Requires a semi-conductor (Si)
- Creates a direct current (DC) which can
  - Be stored in batteries
  - Or converted to a conventional alternating current (AC)
  - Or used to split water (electrolysis) → Hydrogen gas (stored fuel for fuel cells)
- Typical PV cell has a 15-20% efficiency



Batteries

- Electrochemical reaction → flow of electrons
- REDOX reactions
- Electrons flow from negative (anode) terminal to positive (cathode)

Photovotaics and batteries → DC current

- Direct current
- Electrons flow in 1 direction

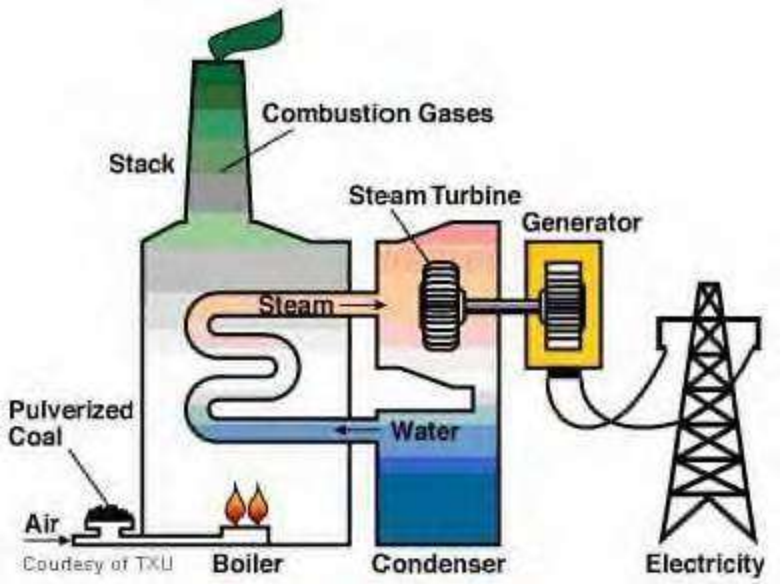
NiCd battery

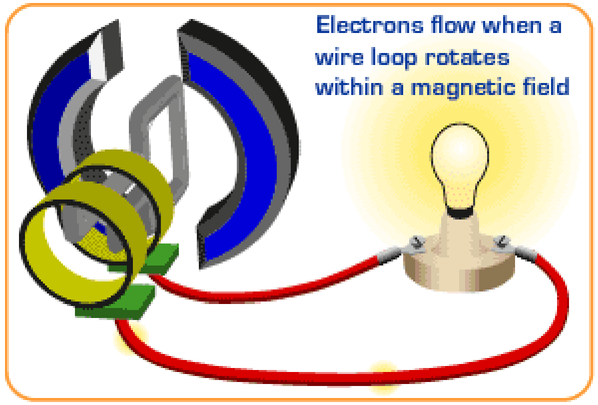
- Cathode = nickel oxide
- Anode = cadmium compound
- Electrolyte = potassium hydroxide (alkaline = strong base)
- Pros = rechargable
- Cons = Cd is toxic heavy difficult to dispose safely

Lithium-ion battery

- Cathode = lithium-cobalt oxide ($LiCoO_2$) or, in newer batteries, from lithium iron phosphate ($LiFePO_4$).
- Anode = graphite (carbon)
- Electrolyte = varies from one battery to another
- Pros =
- Most energy dense battery on the market today
- Cons =
- Less toxic but can overheat and catch on fire

Turbine - Generator





- Steam turns turbine
- Turbine spins wire loop in a magnetic field
- → flow of electrons

9 ways → turn a turbine → electricity

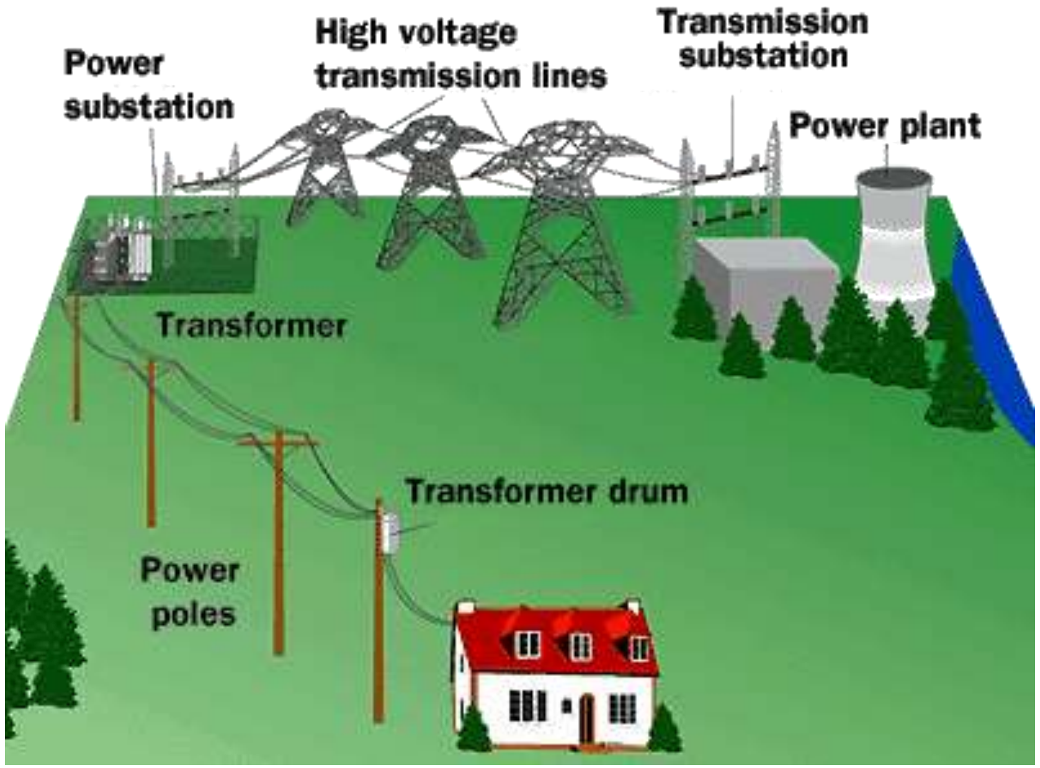
- Nonrenewable
  - Nuclear reaction
  - Coal
  - Natural gas
  - oil
- Renewable
  - Wind
  - Hydro
  - Solar thermal generation
  - Biomass (wood, biogas…)
  - Geothermal

Most powerplants →AC current

- Alternating
- Advantage = easier to step up or step down current with transformers

Electric power transmission

- AC current is converted to high voltage (10^6volts)
- Higher voltage = more efficient = less energy loss



Transformers increase and decrease voltage

- Voltage is decreased to about 1000 volts at a substation for transmission
- Then down to 120 volts in homes