Renewable Energy Production

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Alabama Solar Association

Updated 2017

Alabama Solar Association

- Visit us at **www.AL-Solar.org**
- We are a volunteer organization
- We promote all things solar, energy conservation, and living green
- We sponsor speaking and demonstration events for the public
- We'd love to have you join us, dues are minimal ($24/yr)
- Barring that, give us your e-mail address and we will keep in touch

What Is Renewable Energy?

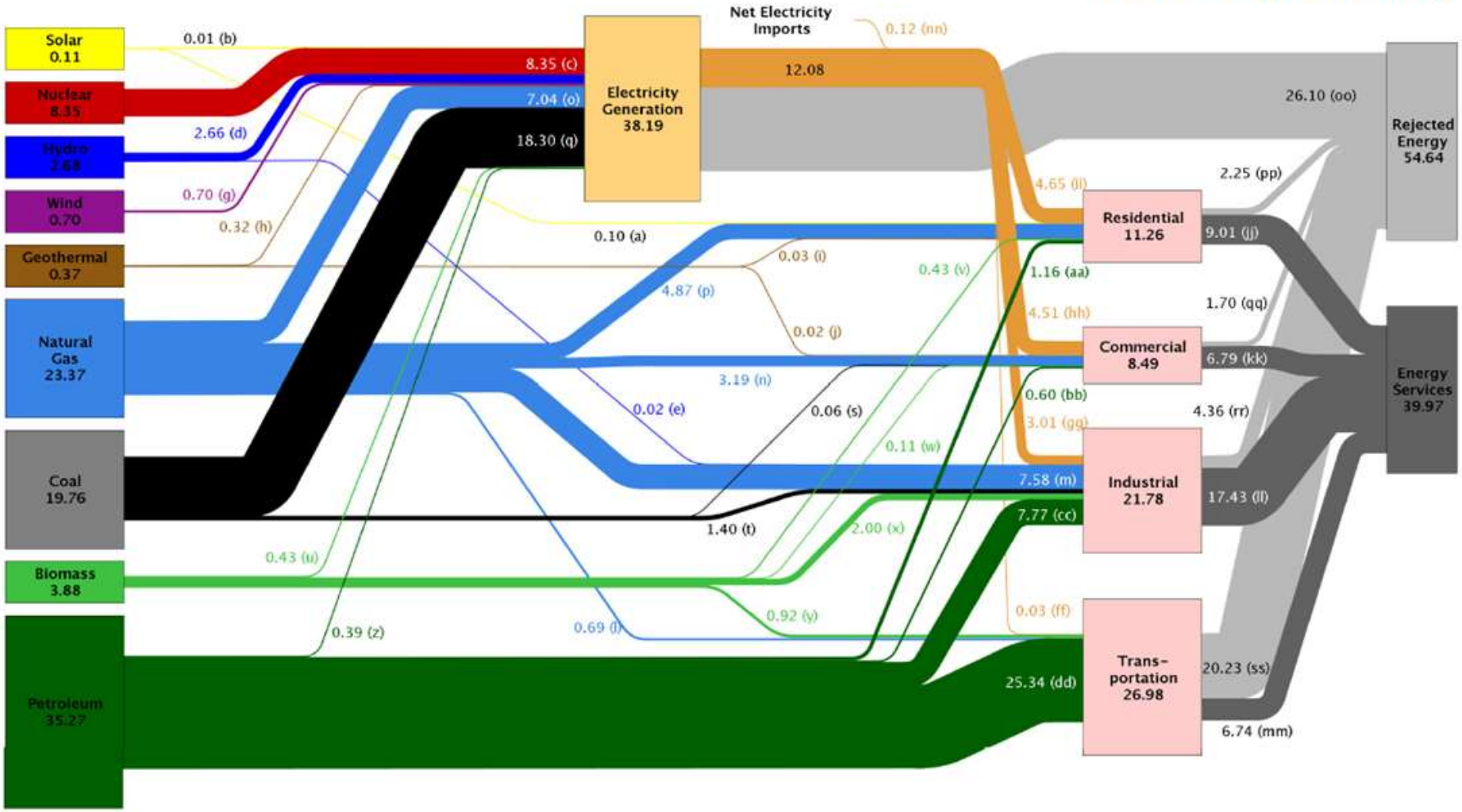
- Renewable energy is derived from natural processes that are replenished on a short time scale
- Energy derived from crops or even trees, water flow, the sun, geothermal sources, wind, etc.
- Renewable energy replaces conventional fuels in 4 areas, electricity generation, hot water/space heating, motor fuels, and rural (off-grid) energy
- Renewable energy contributes about 17% of the 55.4 Terrawatts (10^{12} Watts) of power used
- Before coal (mid-1800's), almost all energy was renewable

Renewable Power Sources

- Biomass (like trees and switchgrass)
- Hydropower (like hydroelectric dams)
- Biofuels (like 10% ethanol gasoline)
- Wind (wind turbines)
- Solar (like photovoltaics)
- Geothermal (like geysers)
- Ocean power (tidal generators)

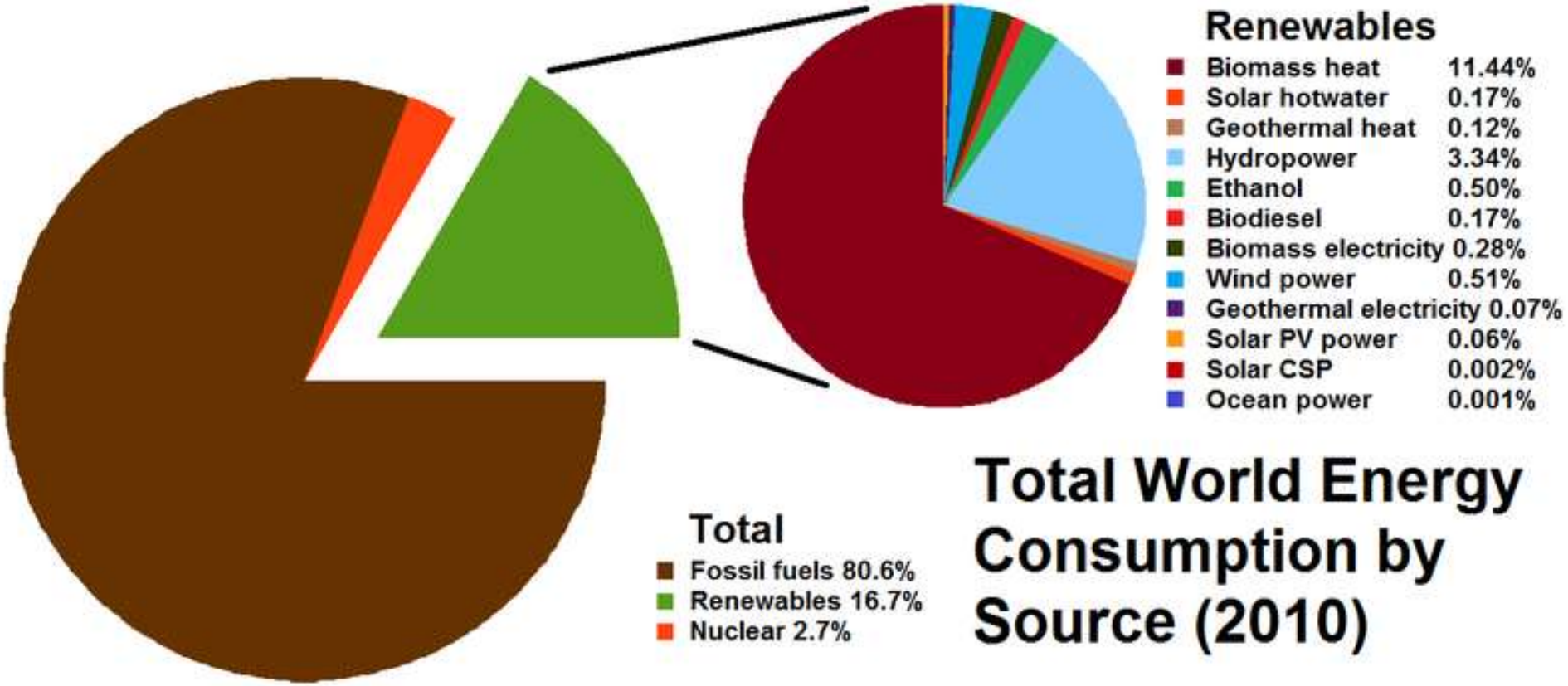
Estimated U.S. Energy Use in 2009: ~94.6 Quads

Lawrence Livermore National Laboratory



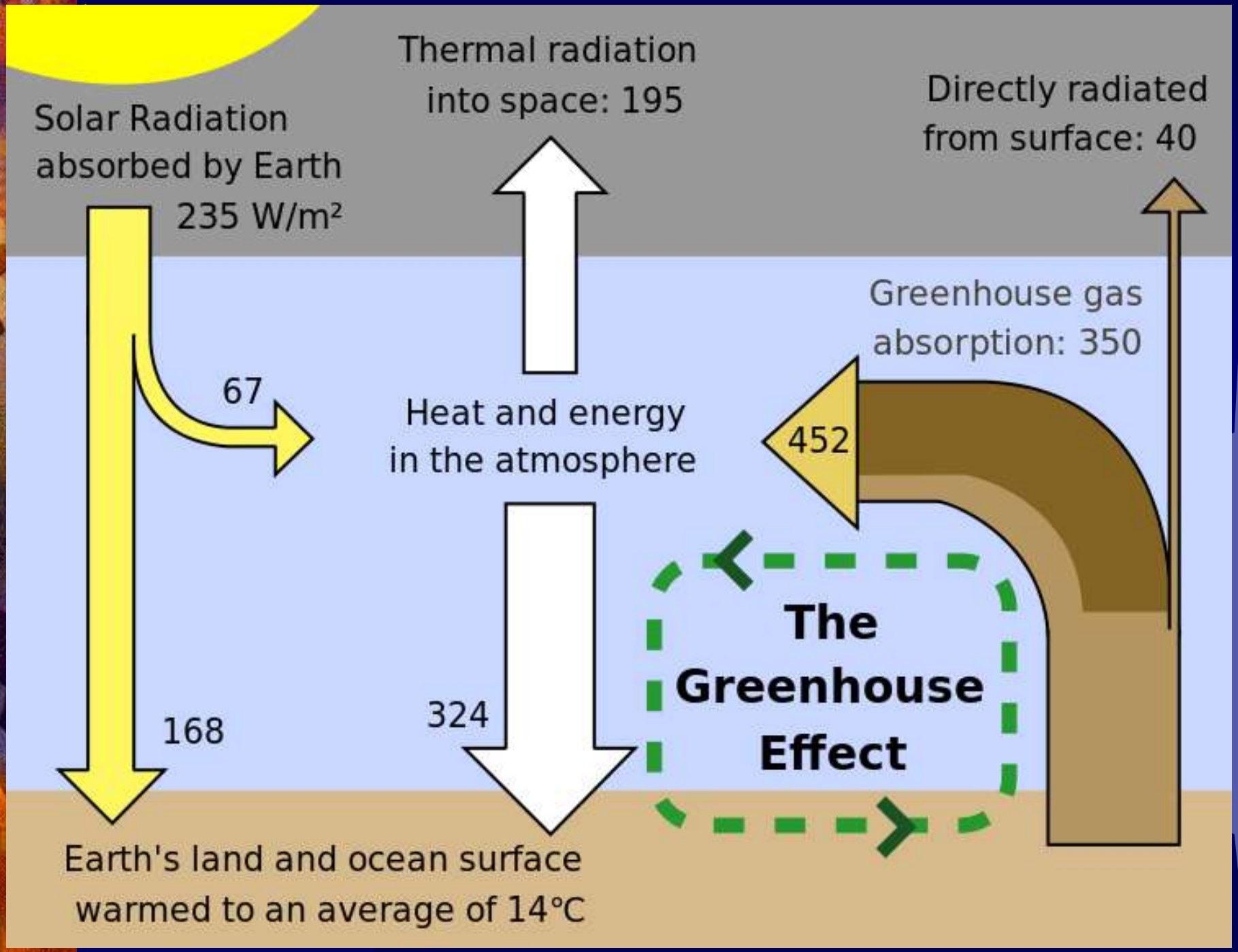
Source: LLNL 2010. Data is based on DOE/EIA-0384(2009), August 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports flows for non-thermal resources (i.e., hydro, wind and solar) in BTU-equivalent values by assuming a typical fossil fuel plant "heat rate." The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Here's Where Renewables Fit In

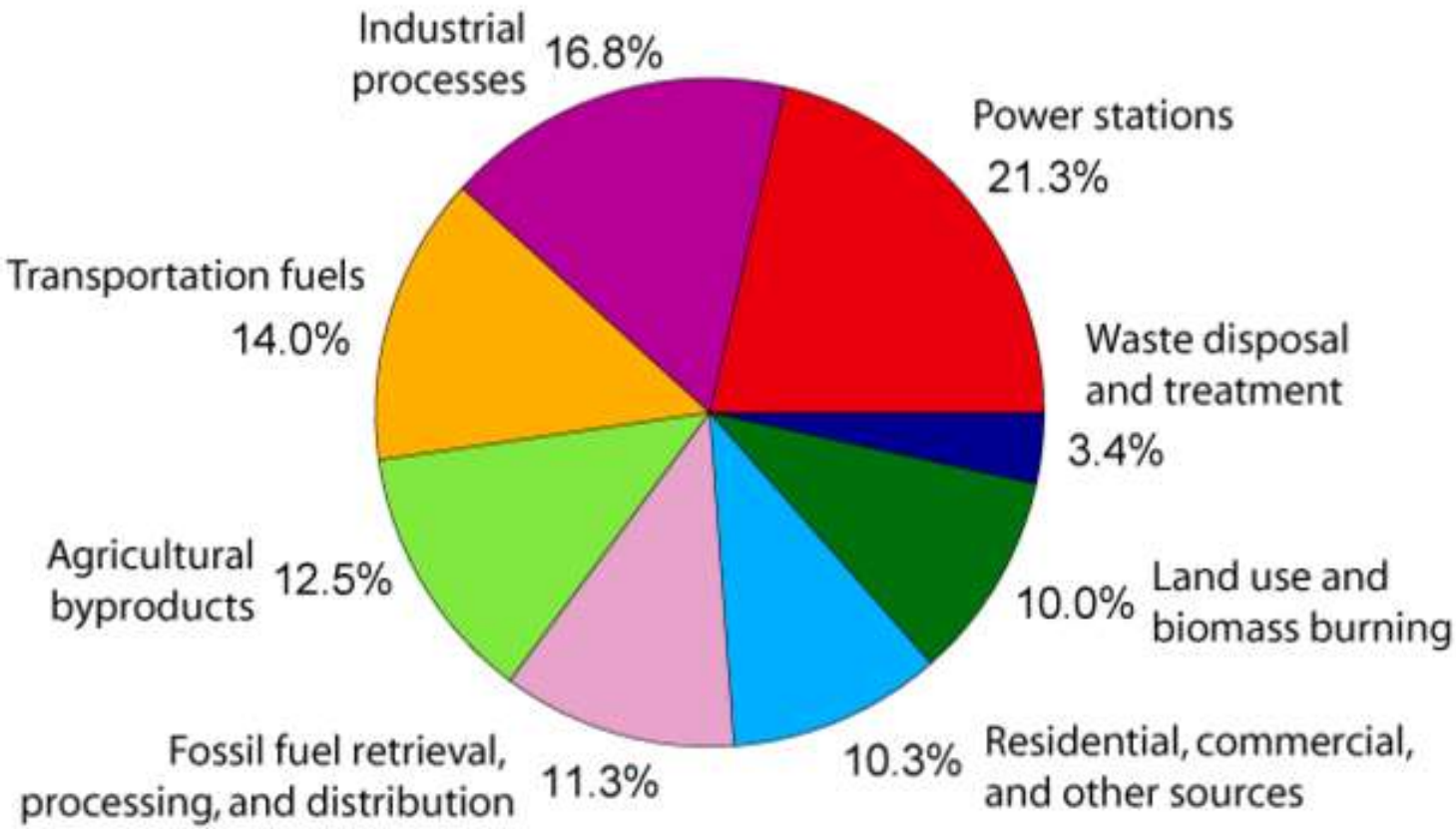


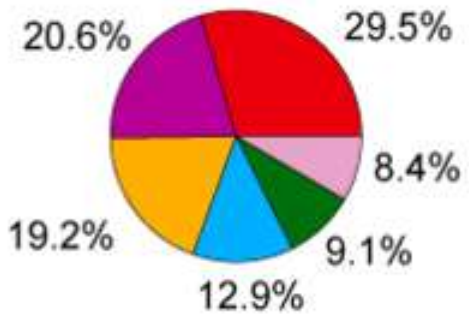
Renewable Energy Is Important

- Fossil fuels (coal, oil, and natural gas) and deforestation effects have increased the concentration of carbon dioxide (CO_2) by 40% since the beginning of the industrial revolution
- CO_2 is considered a major contributor to global warming (after water vapor and clouds)
- Renewables recycle the CO_2; fossil fuels produce CO_2 that cannot be recycled for millions of years
- Oil prices trend upward as reserves dwindle

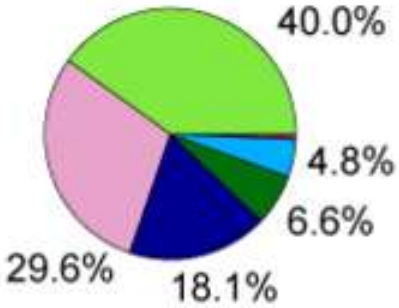

Thermal radiation
into space: 195
Directly radiated
from surface: 40
Solar Radiation
absorbed by Earth
235 W/m²
Greenhouse gas
absorption: 350
67
Heat and energy
in the atmosphere
452
The
Greenhouse
Effect
324
168
Earth's land and ocean surface
warmed to an average of 14°C

Annual Greenhouse Gas Emissions by Sector

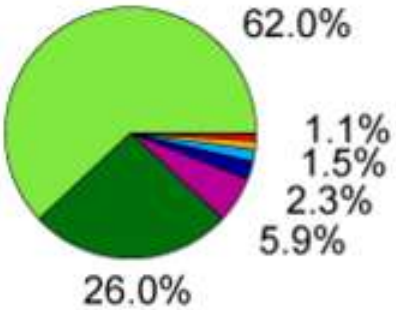




Carbon Dioxide
(72% of total)



Methane
(18% of total)

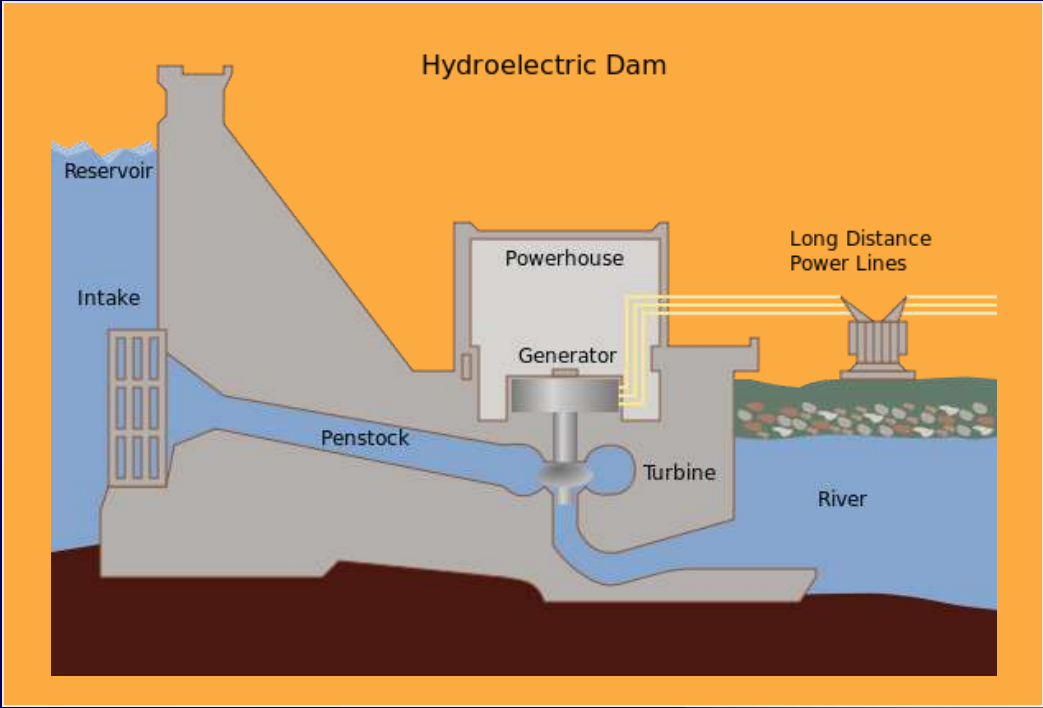


Nitrous Oxide
(9% of total)

Biomass

- Biomass includes trees, yard clippings, municipal waste, etc.
- Biomass energy is 71% of renewable energy
- Biomass is used mostly for heat
- Wood burning is a big application
- Some cities burn trash for heat and power (Huntsville does this)

Hydropower



- Hydroelectric power is second only to biomass as a renewable energy source
- Water being 800 times denser than air can produce much more energy
- Hydro power comes not just from dams, but also run-of-the-river, tidal, and ocean swell systems

3 Gorges Dam, China

3 Gorges Dam Facts

- Generation capacity – 22,500 MW
  - 32 main turbines – 700 MW each
  - 2 smaller turbines – 50MW each (power the plant itself)
- Estimated cost = $28 Billion USD
- Raises the water level behind the dam by 110 meters
- Increased the Yangtze River shipping capacity
- Displaced 1.3 million people

Hoover Dam

- Built for $49 Million
- Completed in 1936
- 2,080 MW capacity
- Concrete gravity-arch

Tidal Energy Production

- This is the Rance, France tidal power plant
- 240 MW power production

Other hydropower

Technologies to Generate Power from the Ocean

Ocean energy overview

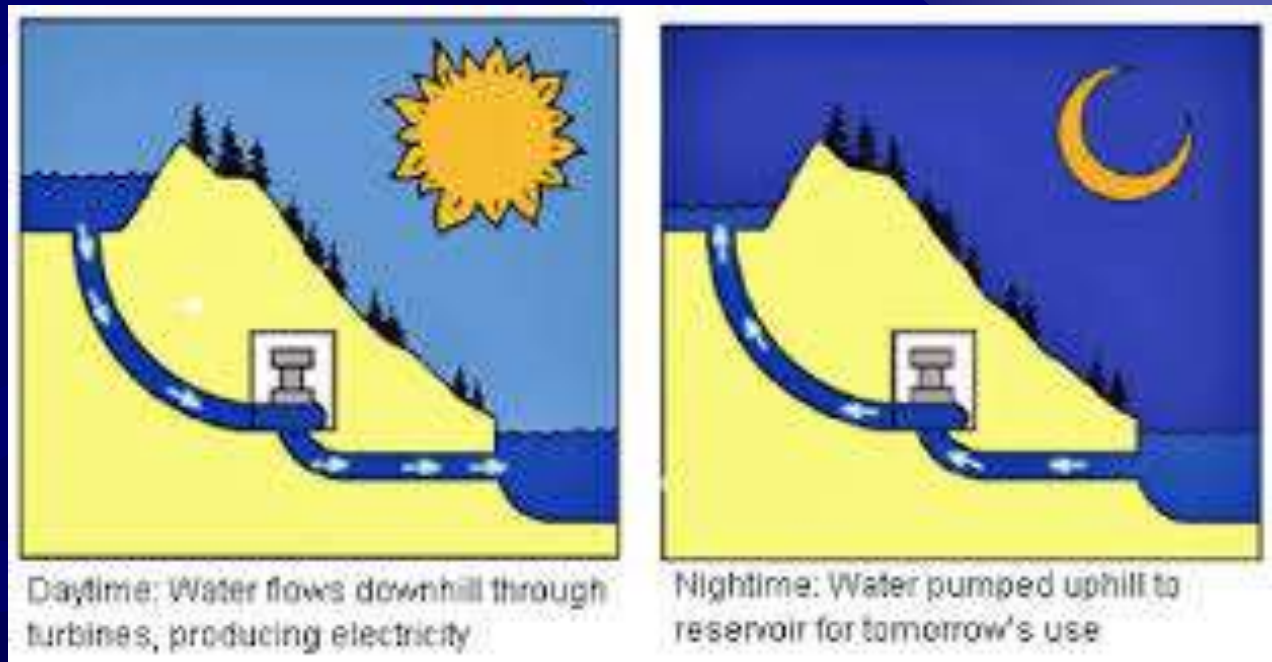
	Tidal Barrage	Tidal Stream	Wave	Thermal Gradient	Salinity Gradient
					
Energy source	▪ Tidal range (using conventional hydro technology)	▪ Tidal currents ▪ Ocean currents	▪ Ocean waves	▪ Temperature gradient between the sea surface and deepwater	▪ Difference in salt concentration at fresh-water/ sea-water interface
Example technologies	▪ Ebb generation ▪ Flood generation	▪ Horizontal Axis ▪ Ducted Rotor ▪ Vertical Axis ▪ Hydrofoil	▪ Attenuator ▪ Oscillating Water Column (OWC) ▪ Point Absorber ▪ Overtopping	▪ Different Ocean Thermal Energy Conversion (OTEC) processes	▪ Pressure-retarded reverse osmosis and associated conversion technologies
Maturity of installed devices	▪ Mature: plants in operation	▪ Pre-commercial: full-scale proto-types (~1MW)	▪ Testing: part-scale proto-types (<1MW)[1]	▪ Demonstration: first small-scale devices (<250kW)	▪ Concept: first pilot device (<5kW)
Exploitation potential	▪ Environmental concerns limit further exploitation (~300 TWh/a[2])	▪ Emerging exploitation, sites under development (~800 TWh/a)	▪ Mid-term potential (~8,000 TWh/a, economically viable)	▪ Long-term potential (~10,000 TWh/a[2])	▪ Long-term potential (~1,600 TWh/a[2])

Source: IHS Emerging Energy Research (2010), Siemens

1) OWC commercially available, 2) Global theoretical potential

Hydro As Energy Storage

- Pumping water uphill to a storage reservoir allows storage of energy
- TVA's Raccoon Mountain Pumped Storage Plant in Tennessee is an example



Biofuel

- The 25 billion gallons of biofuel produced in 2009 displaced 17 billion gallons of gasoline (about 5% of world gasoline production)
- Includes bioethanol (alcohols), biodiesel (oils), and biogasses (less common)
- Bioethanol comes from sugar and starch crops (corn in US, sugarcane in Brazil)
- Biodiesel comes from vegetable oils, animal fats, or recycled greases

What Are Biofuels Made From?

Camelina plantation

Straw plantation

Short rotation coppice willow harvesting

Algae

Jatropha

Food and kitchen waste

Biofuels Save On CO_2

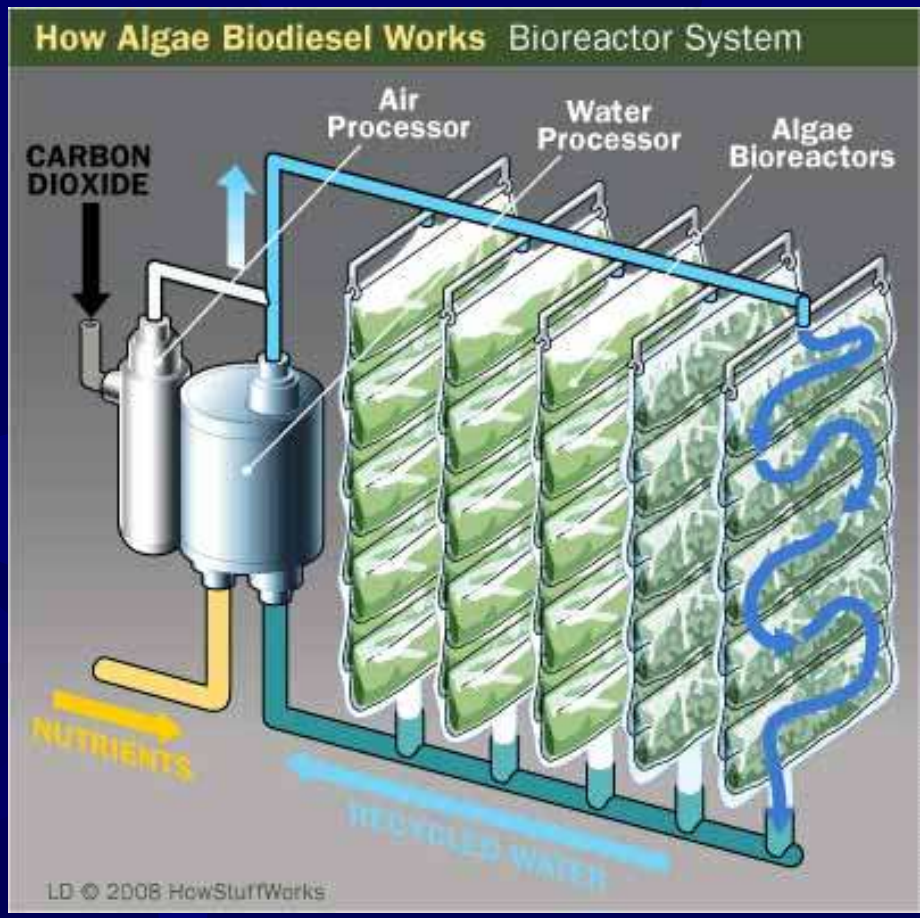
- The key idea is to reduce fossil fuel use
- Fossil fuels release CO_2 that has been stored for millions of years
- Biofuels reuse the CO_2 to create the biomass and release oxygen

Bioethanol

- US uses mostly corn to make bioethanol
- Brazil uses mostly sugarcane
- Commonly use 10% bioethanol in gasoline in US (some cars are now built to run on 85% bioethanol)
- Unfortunately, corn-based bioethanol saves only about 20% of GHGs over fossil-fuel gasoline (switchgrass would save about 85%)

Biodiesel

- Used mostly in Europe
  - Mostly from Palm oil
- The future is in algae
  - Gasoline releases 94 kG/MJ of CO_2, algae is at –183
  - Bioethanol would require 130 times the land area to produce the same energy



Wind Power

- Wind farms are most common in steady wind areas (offshore and at higher altitudes)
- Wind could potentially provide more electric power than we consume
- In 2012, globally we had 283 GW capacity
- Wind power capacity is growing at 30%/yr
- 14% of electricity consumed in Iowa comes from wind
- The picture is Shepard's Flat, OR (845 MW)

How Does Wind Power Fit In?

- Globally, there are about 50,000 wind turbines generating about 50 billion kWh of electrical power per year
- In the U.S. we generate about 25 billion kWh/yr from wind
  - That may sound like a lot, but it is about 2% of the total power generated
  - Experts say we could be generating up to 20% of our power from wind energy

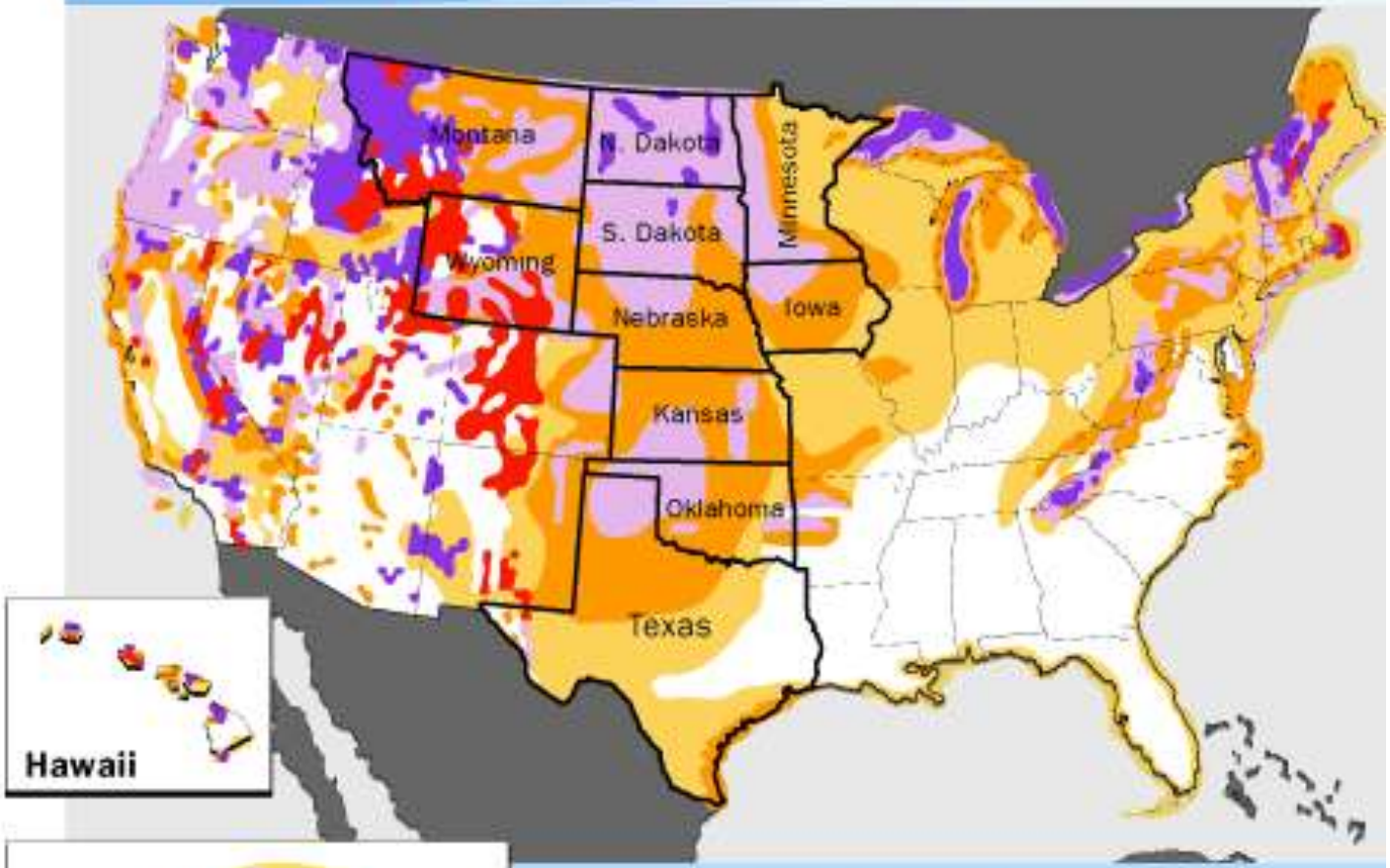
What About Wind Power For Your Home?

- Sizes range from several hundred to several kW capacity
  - Assumes 15 – 30 mph wind
  - Requires 3 – 9 mph wind for startup
  - Operates up to 50 – 70 mph
- A typical 2 kW system cost

Turbine & charge controller	$3,500
Pole	800
Inverter	1,000
Batteries, Labor	?

Most of Alabama does not even have marginally useful winds

How Wind Power Works Wind Strength



Wind Power Class	Resource Potential	Wind Speed at 50 m (mph)
1	Marginal	12.5 - 14.3
2	Fair	14.3 - 15.7
3	Good	15.7 - 16.8
4	Excellent	16.8 - 17.9
5	Outstanding	17.9 - 19.7
6	Superb	19.7 - 24.8

Top-10 states for wind-energy potential factoring in environmental and land-use exclusions

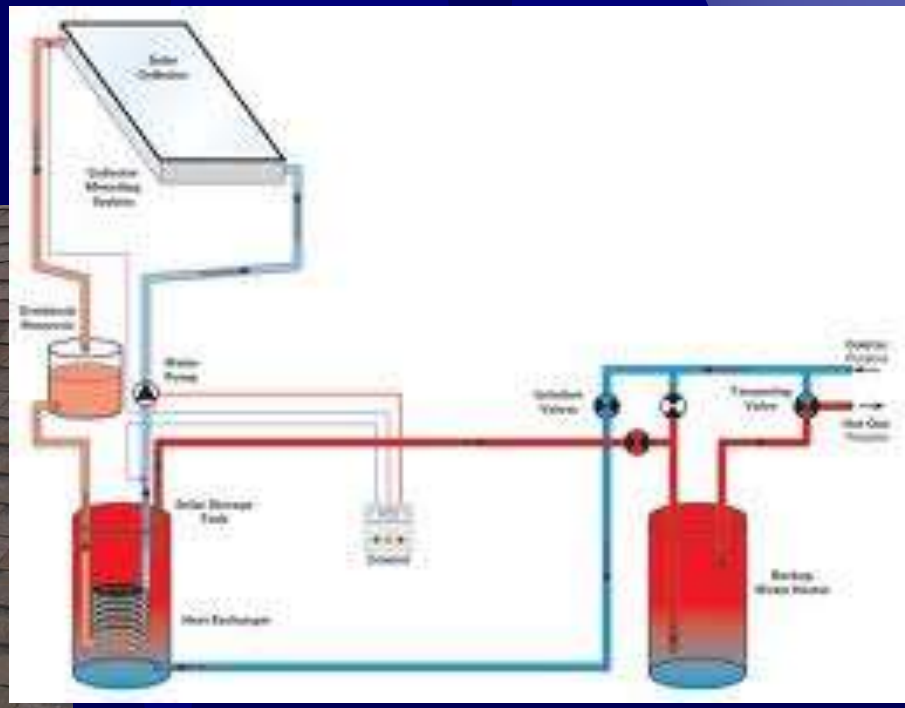
 Sources: American Wind Energy Association, U.S. DOE National Renewable Energy Laboratory

Solar Energy

- About 0.6% of US energy used comes from solar hot water heating, solar Photovoltaics (PV) or solar Concentrated Solar Power (CSP)
- This energy production is increasing fast. Solar power generation has increased over 300% in from 2010 to 2012
- 14,626 megawatts of solar was installed in 2016 alone (mostly by utilities), an increase of 95% over 2015

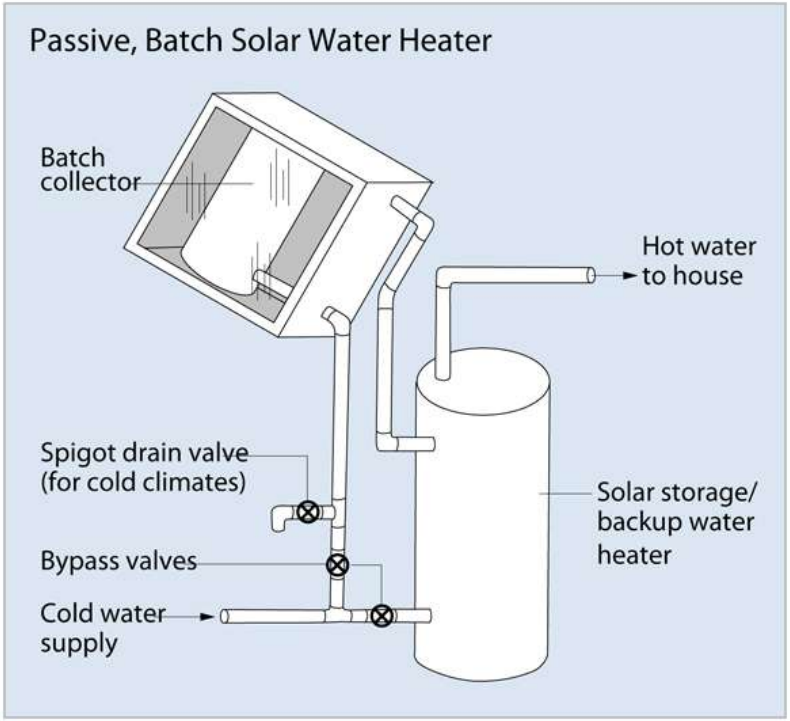
Solar Hot Water

- China produces 70% of the world's solar hot water heaters (180 GWth)
- Israel also has a high per-capita production of hot water from solar



Solar Hot Water 2

- This is an example of a thermosiphon system (more popular in Israel and maybe China)

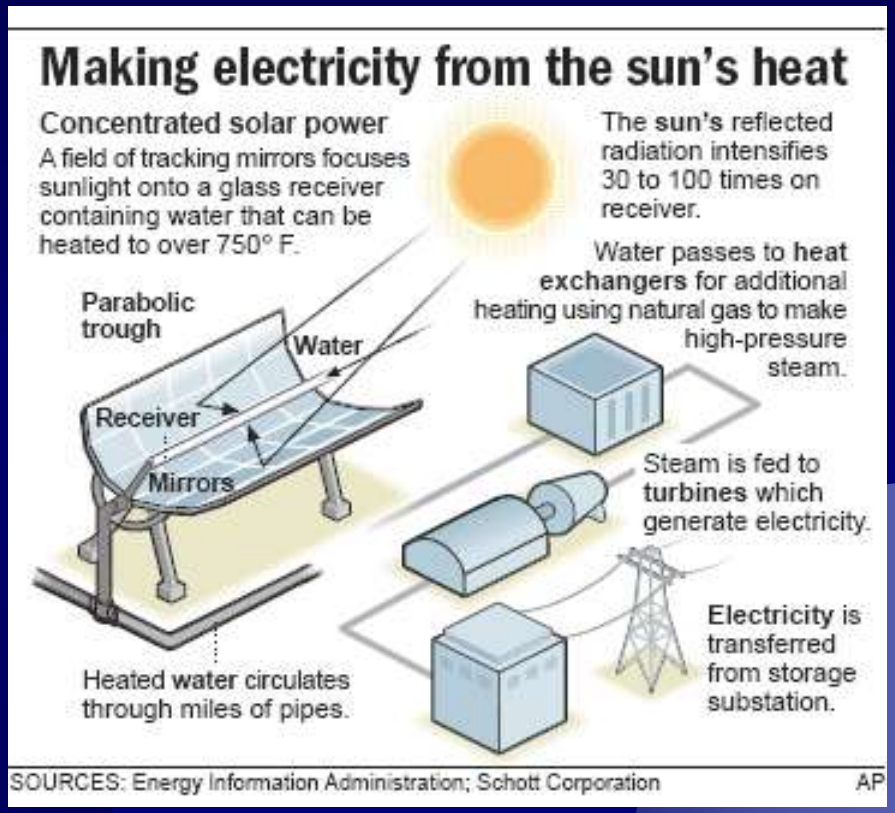


Solar From Home

Solar From Parking Lots

PV Commercial

Concentrated Solar Power



Concentrated Solar Power 2

11 MW plant in Spain

19.9 MW, Seville, Spain

Geothermal Energy

Nesjavellir, Iceland geothermal plant

Summary of Renewable Energy

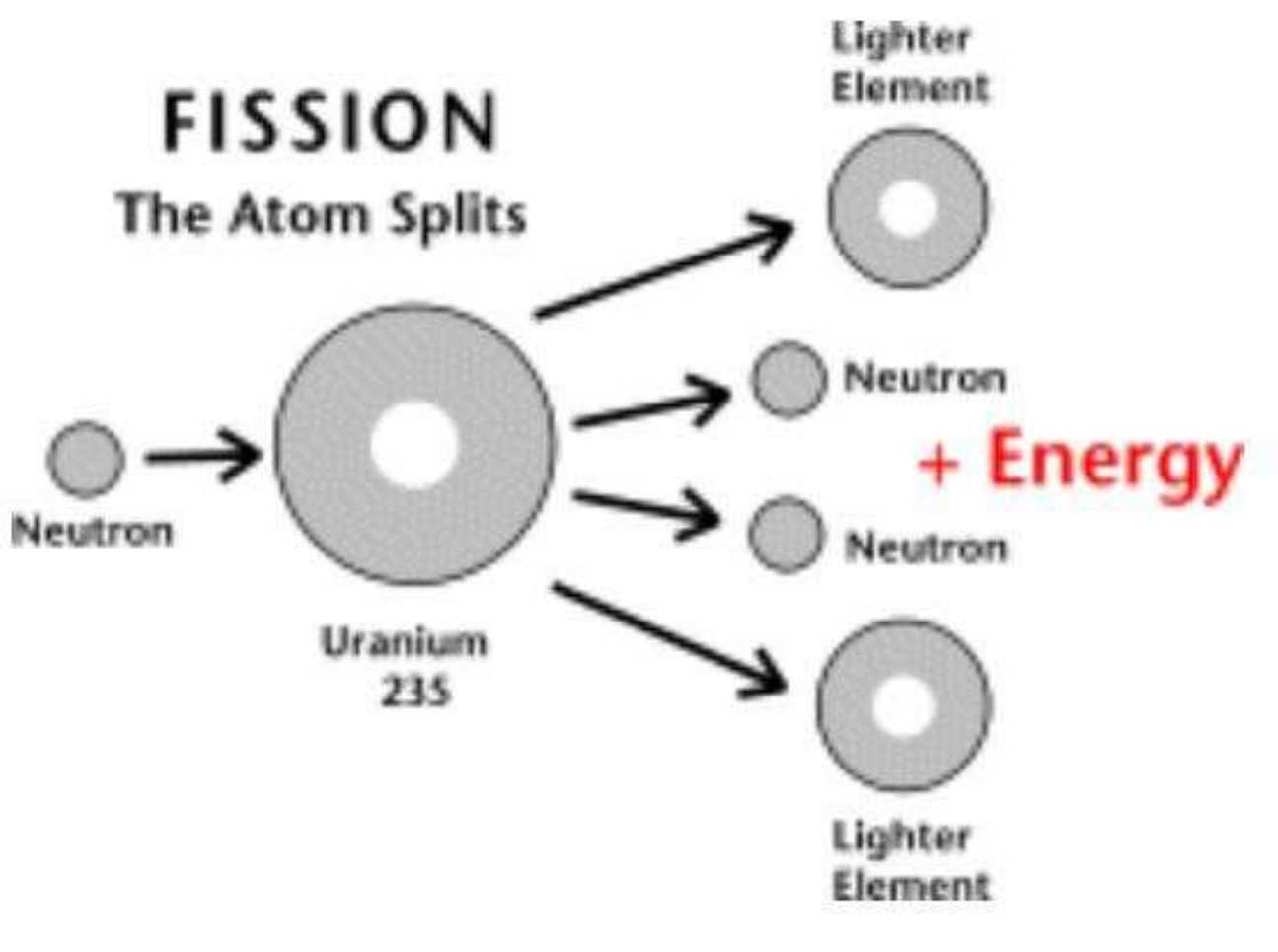
- Renewable energy is important to all of us
- The rising cost of finding the next barrel of oil indicates the need for other energy sources
- Renewable energy reduces the production of GHGs

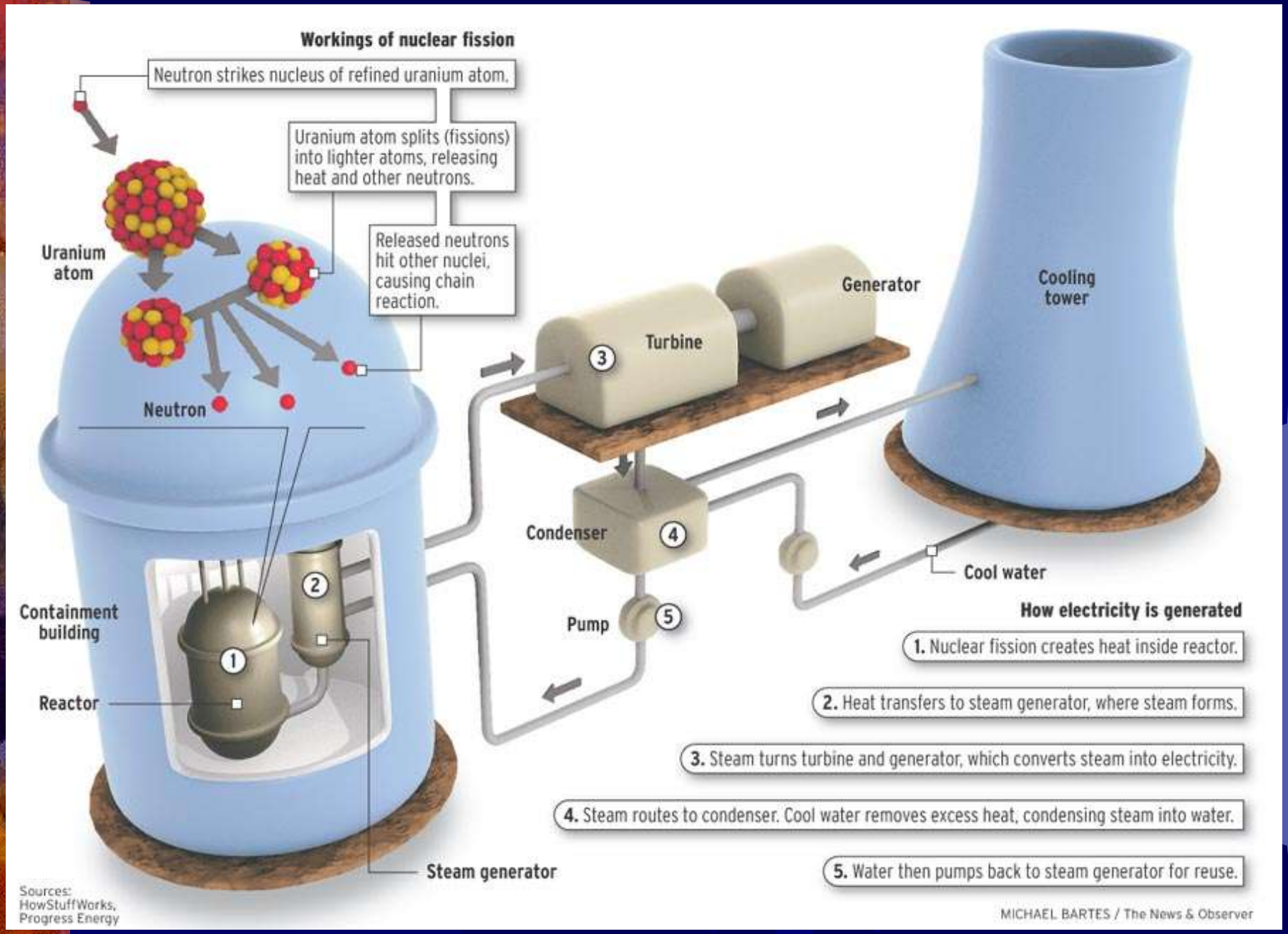
Where Does Nuclear Fit In?

Why Our Interest In Nuclear?

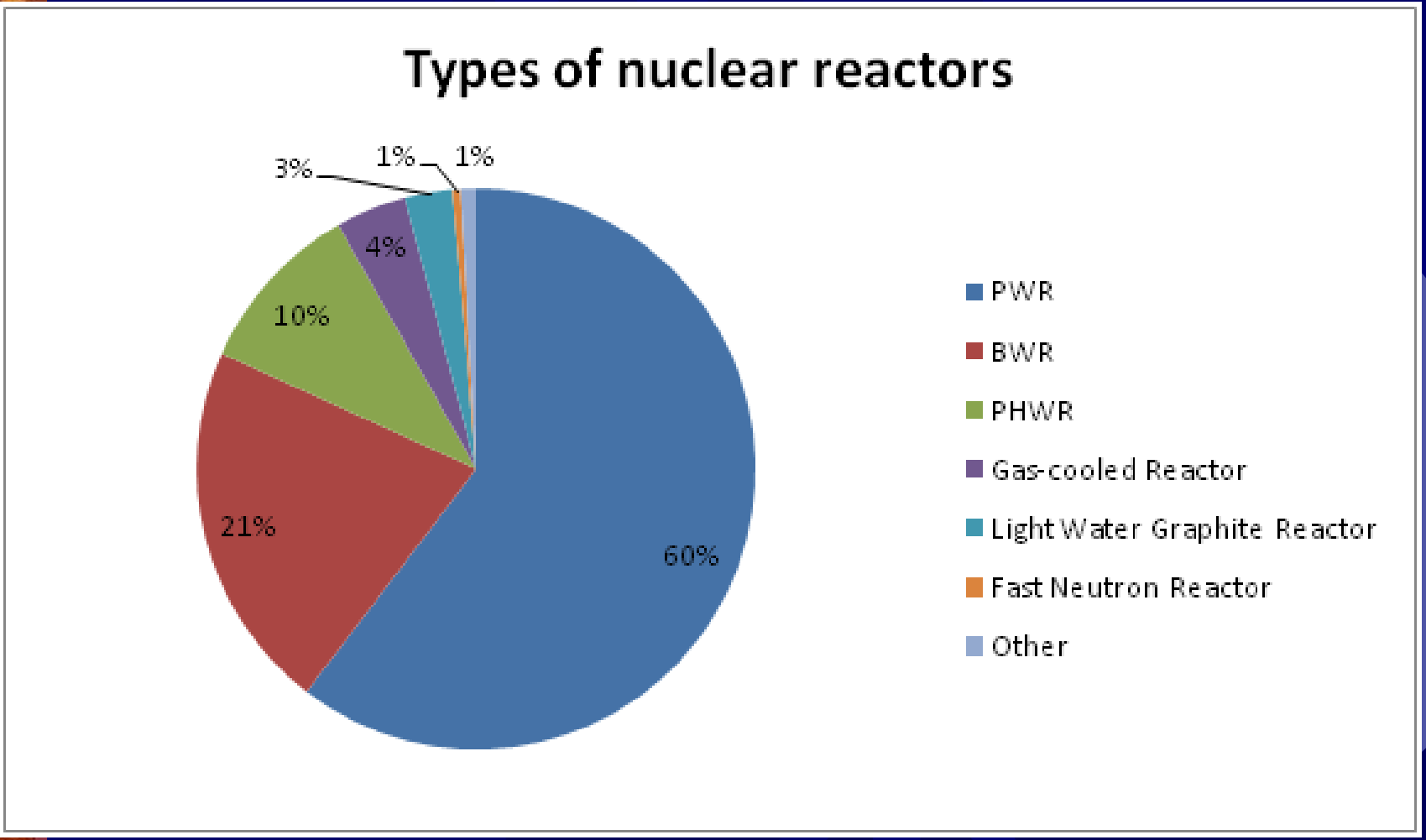
- Nuclear power produces virtually no CO_2
- Nuclear power runs night and day
- Although the fuel is not renewable, there is much available
- Nuclear power plants release less radiation than a coal power plant
- Nuclear power plants have long operating lives

Nuclear Fission

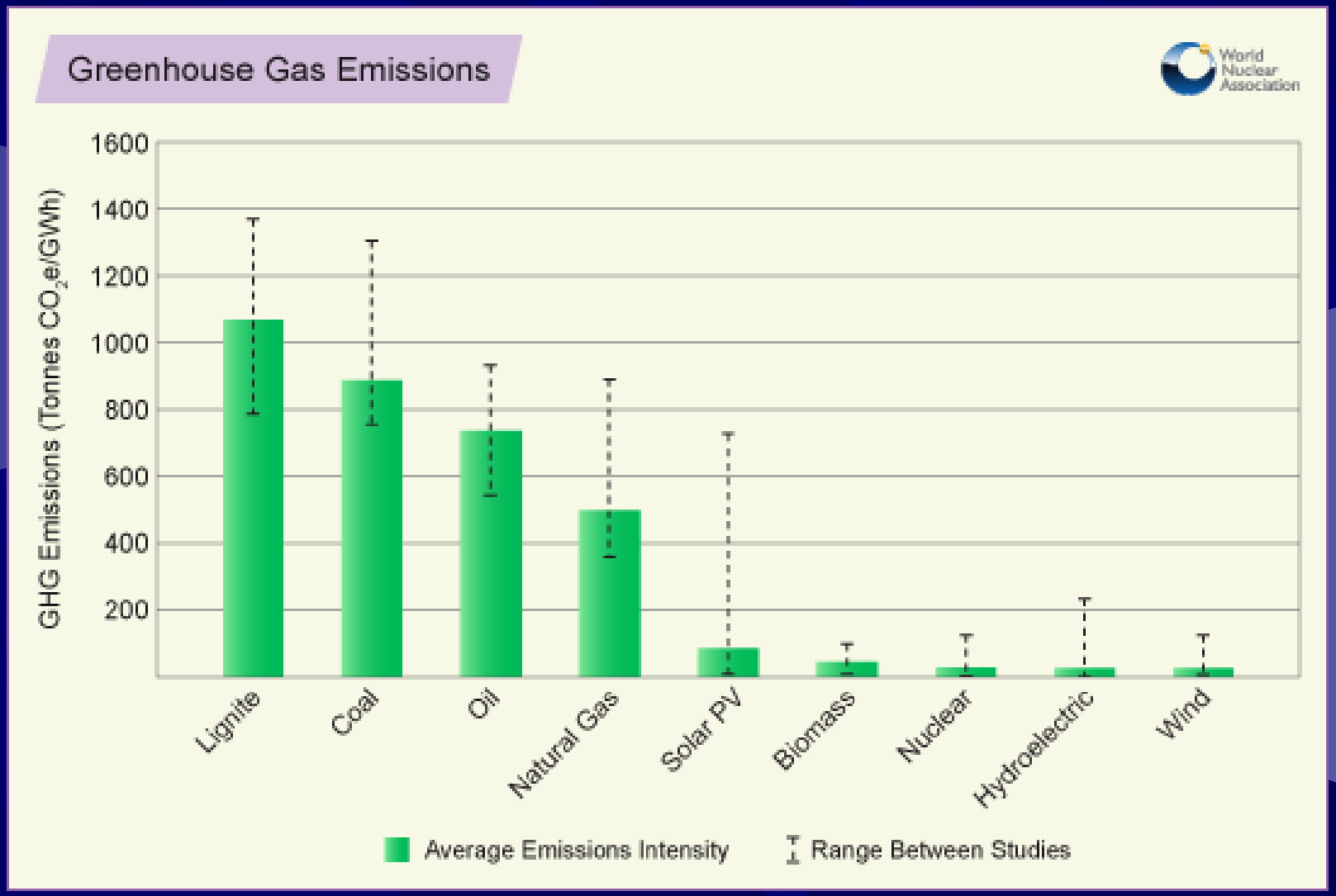



Workings of nuclear fission
Neutron strikes nucleus of refined uranium atom.
Uranium atom splits (fissions) into lighter atoms, releasing heat and other neutrons.
Released neutrons hit other nuclei, causing chain reaction.
Uranium atom
Neutron
Containment building
Reactor
Steam generator
Turbine
Generator
Cooling tower
Condenser
Pump
Cool water
How electricity is generated
1. Nuclear fission creates heat inside reactor.
2. Heat transfers to steam generator, where steam forms.
3. Steam turns turbine and generator, which converts steam into electricity.
4. Steam routes to condenser. Cool water removes excess heat, condensing steam into water.
5. Water then pumps back to steam generator for reuse.
Sources: HowStuffWorks, Progress Energy
MICHAEL BARTES / The News & Observer

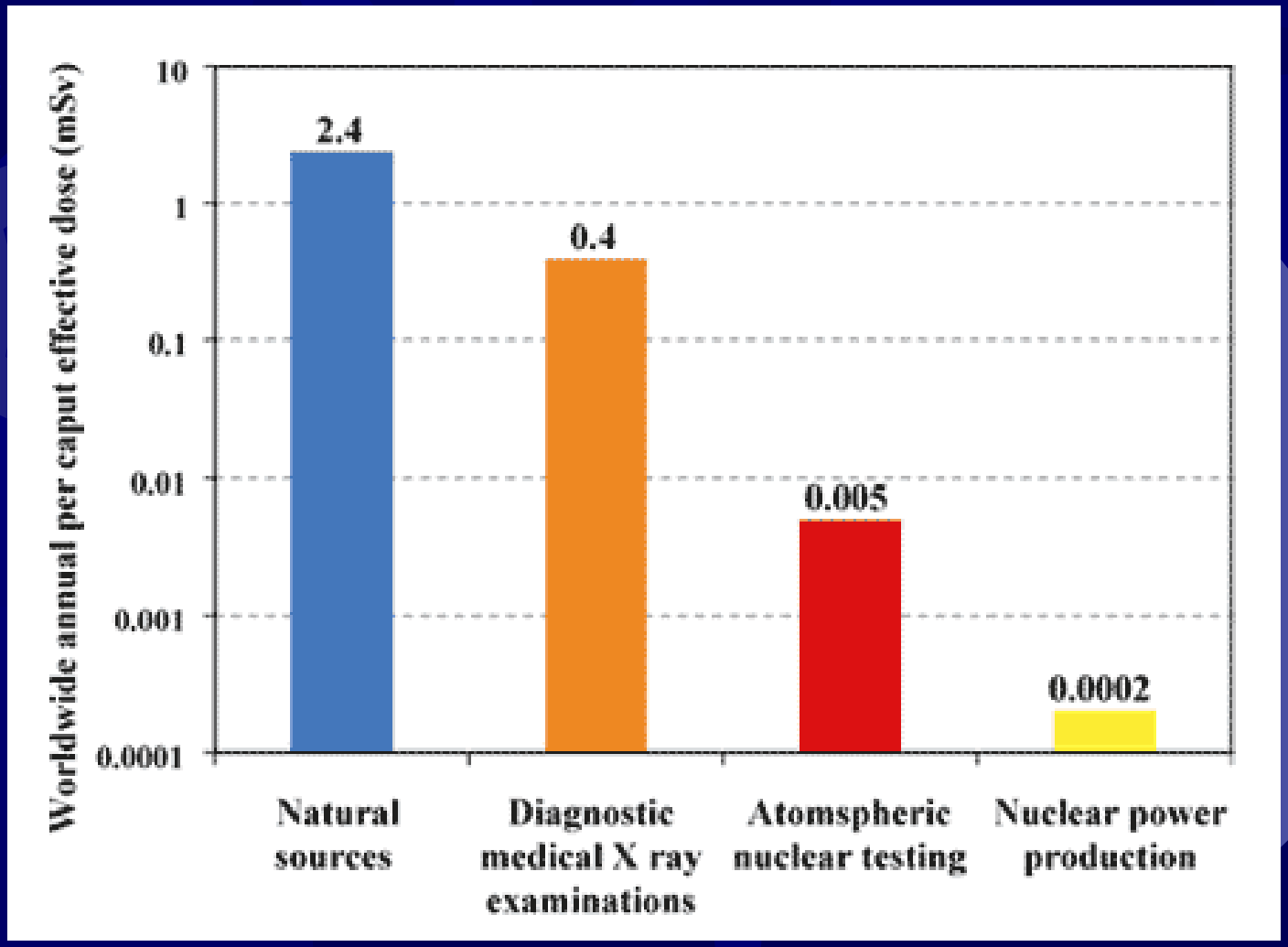
Reactor Types



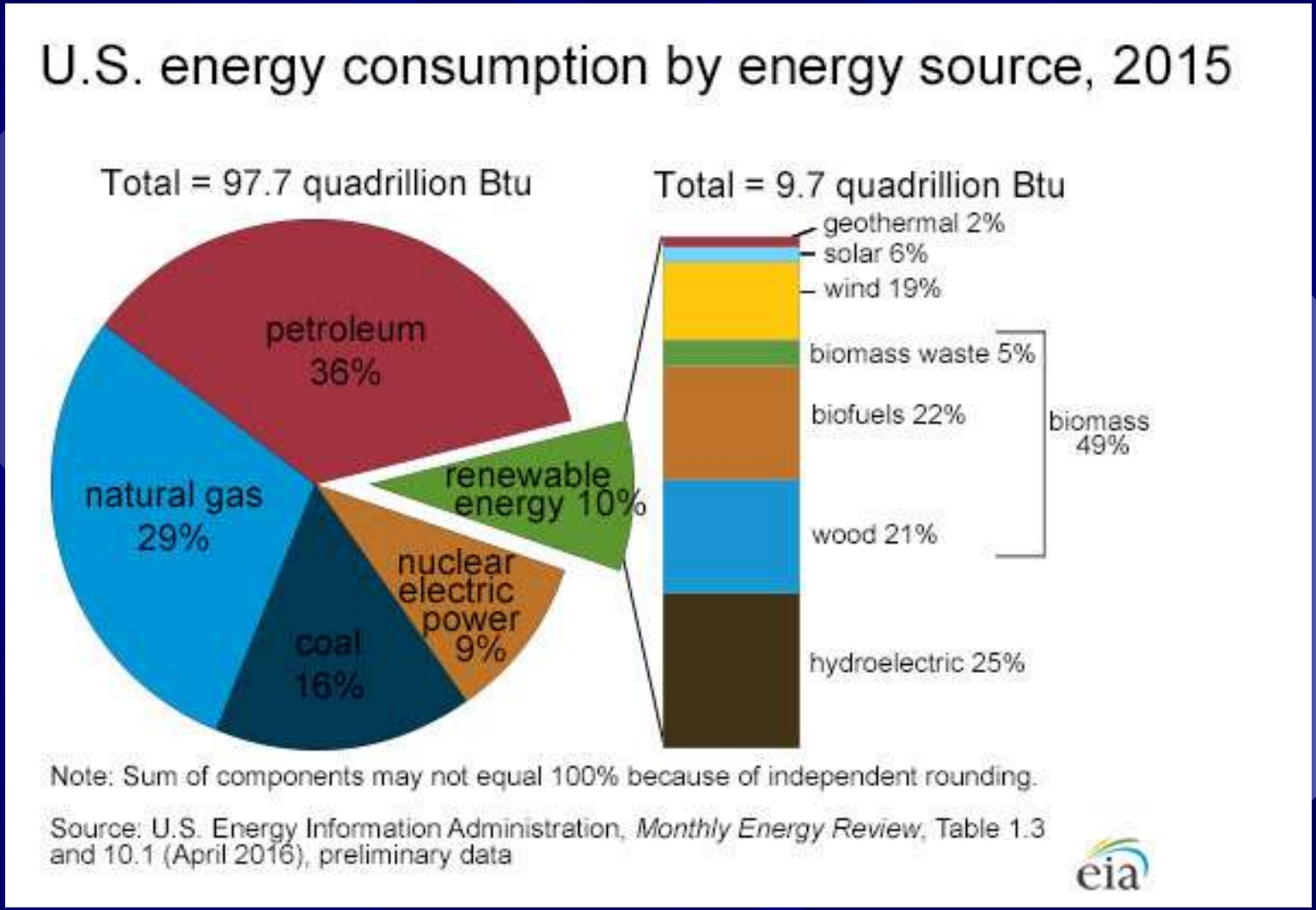
Nuclear (& PV & Wind & Hydroelectric) Produce Little GHG



Normal Operation Is Not A Threat

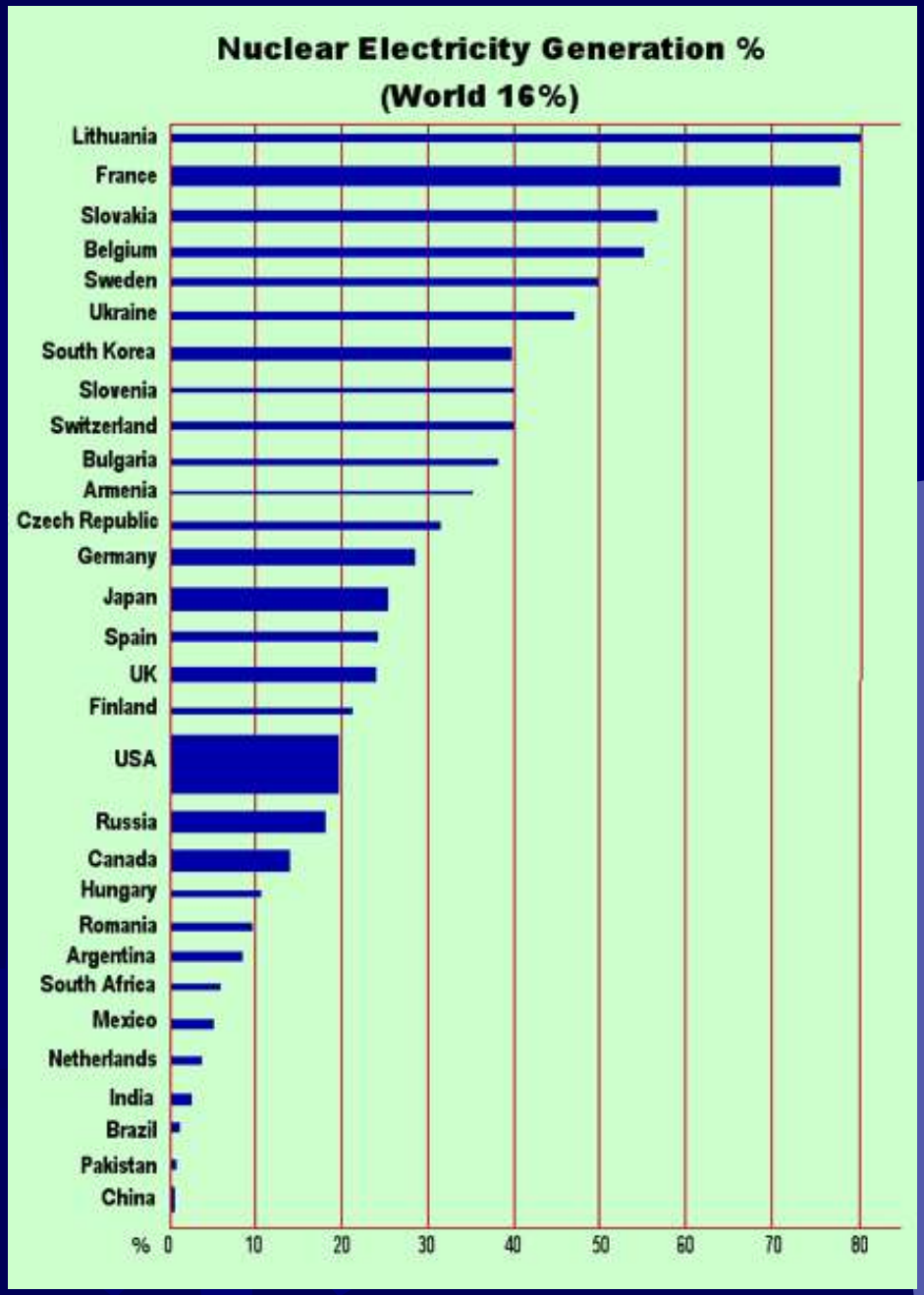


U.S. Energy Sources

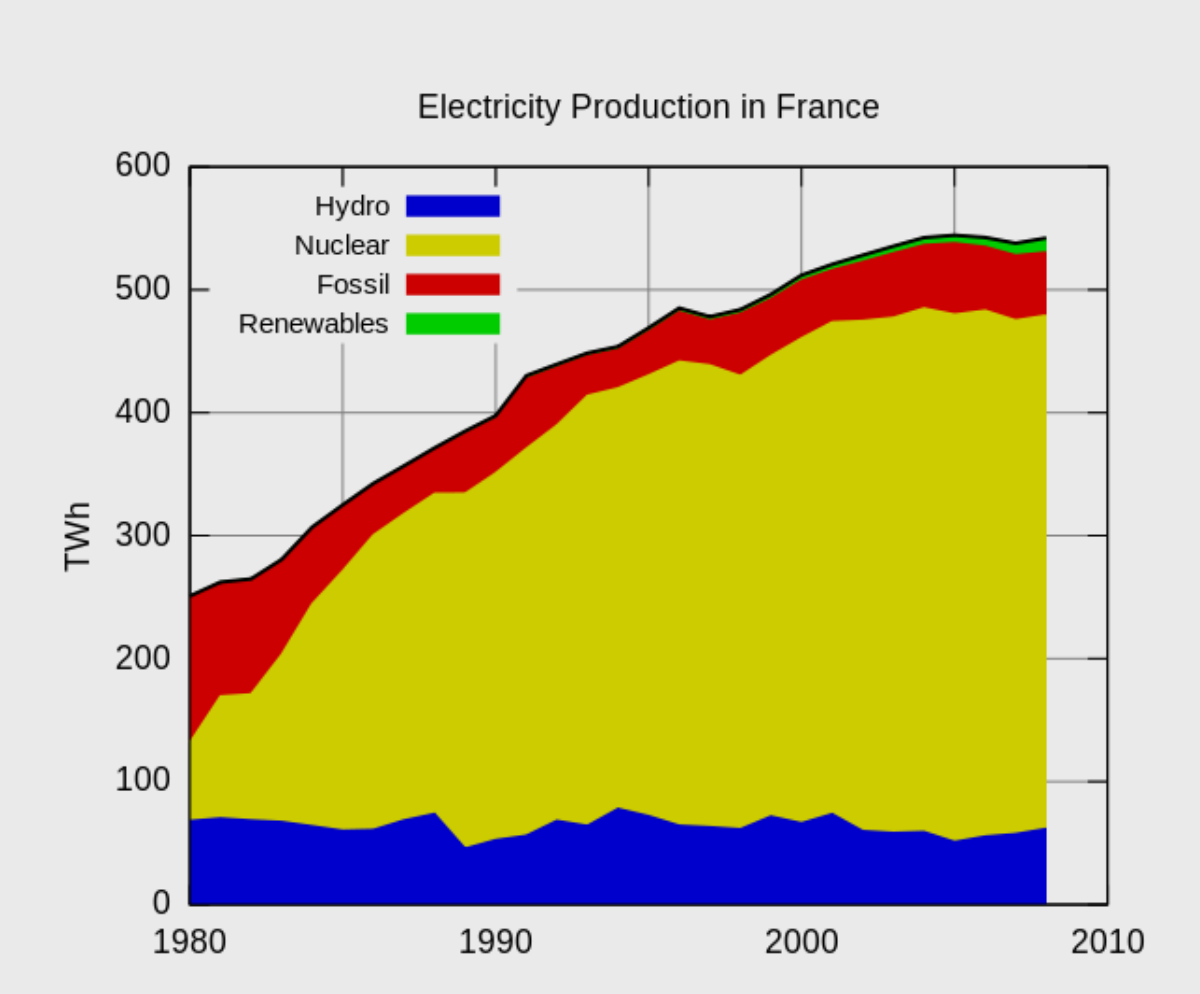


Nuclear Power By Country

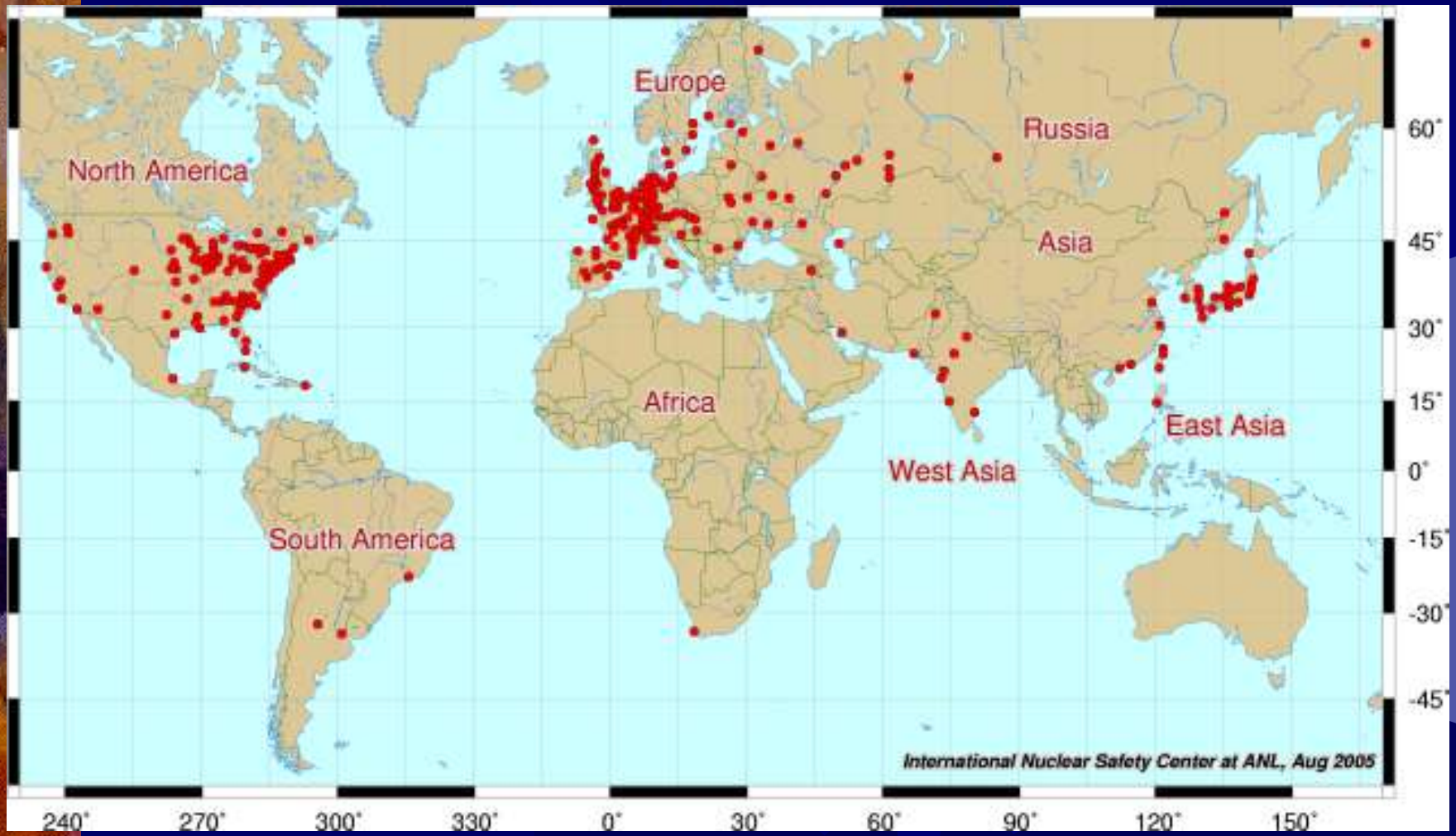
- Line length indicates %
- Line width indicates gross amount



France Is A Nuclear Power Model



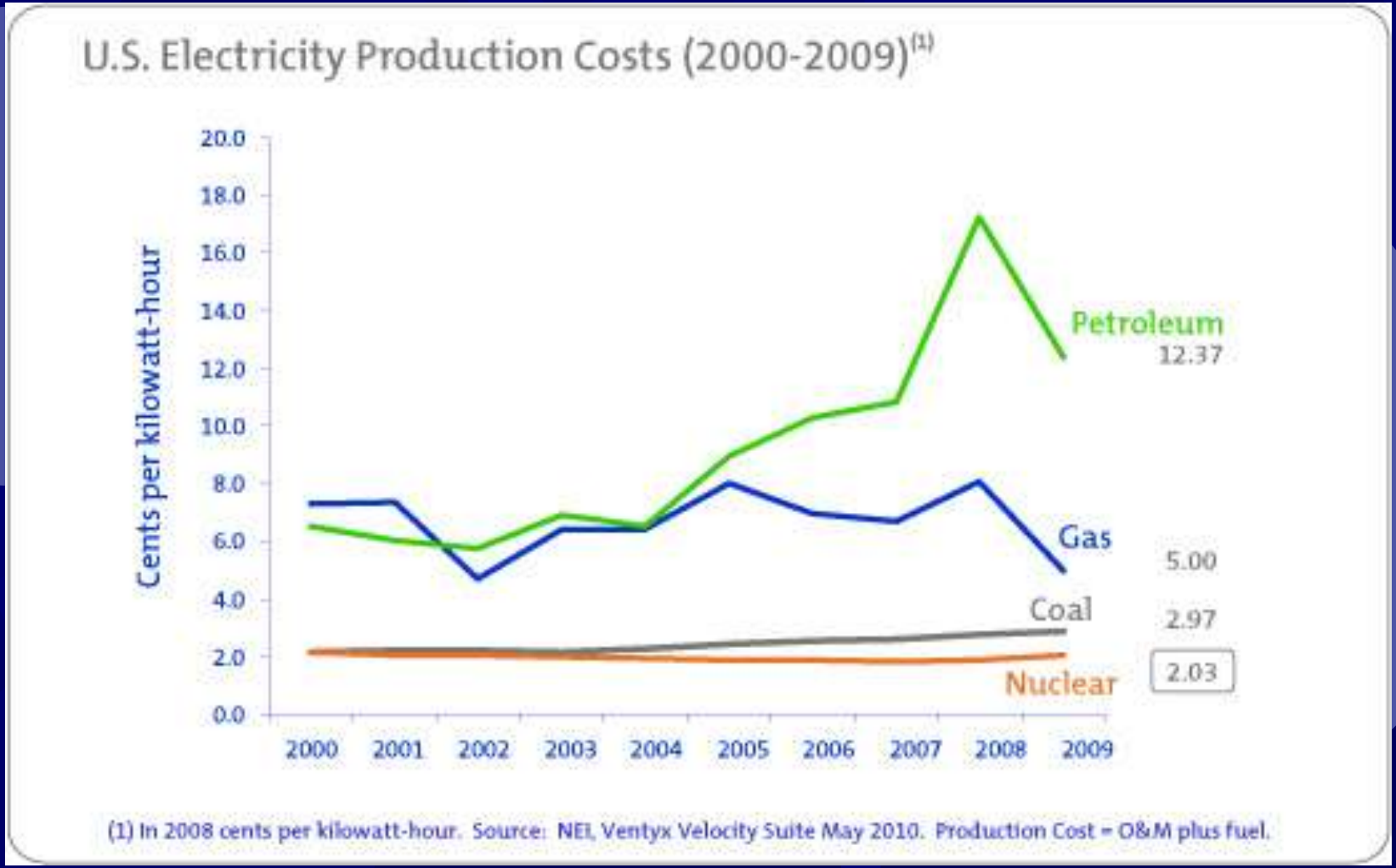
Where The Plants Are



Containment Vessels Make Them Safe

Birds Eye View

Nuclear Power Production Is Cheap




PROS
AND
CONS

Random Facts

- Nuclear fuel is typically enriched to 3% U-235
- Control rods are made from Indium, Boron, Cadmium, or rare earth elements
- Fuel rods have to be replaced every 3 to 4 years
- It takes about 10 years to build a nuclear plant
- Nuclear power plant lifetimes are planned at 60 years

More Random Facts

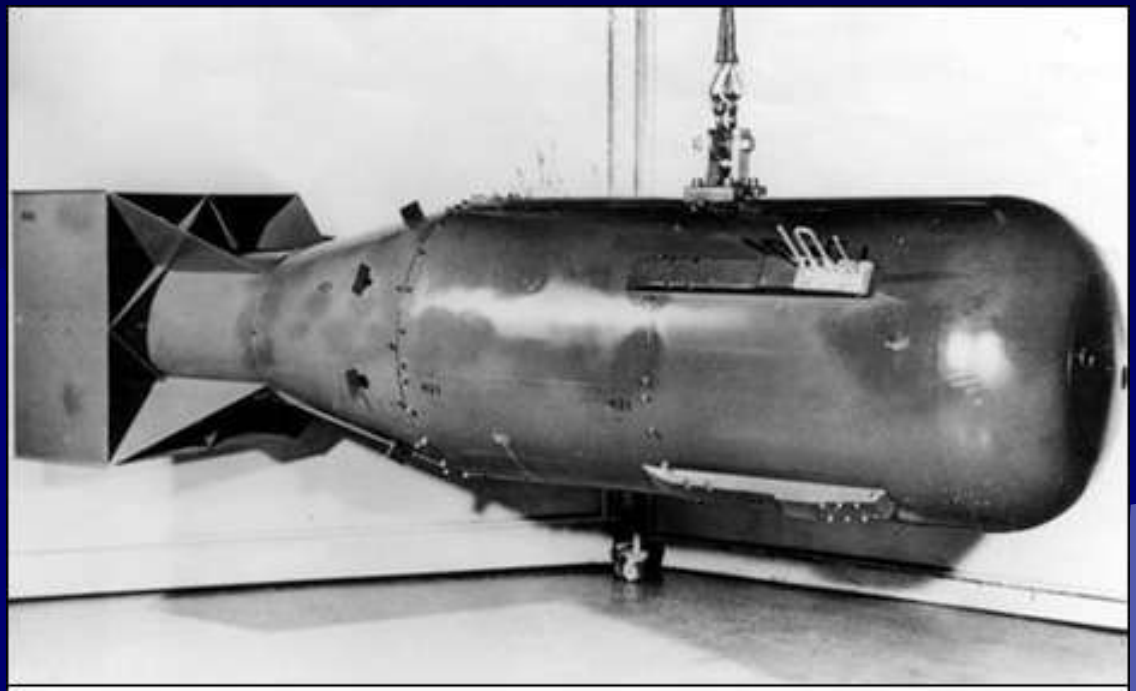
- There were 439 nuclear power reactors worldwide in 2007
- The U.S. produces the most nuclear energy
- Average capacity is about 1,000 MW per reactor (Browns Ferry has 3)
- The estimate to complete the Levy nuclear plant in FL grew to $24B and was ultimately canceled
- To power about 1.8 million homes would require about 1.7 sq. mi. for a nuclear plant or about 21 sq.mi. for PV
- Bellefonte has never been completed and has sat for 20 years. TVA said they were going to start it up, but didn't. It recently sold for about $120 M to a firm that says they will start it up.

What Are The Concerns?

- Radioactive waste
- Possible disasters
- Escalating costs
- Life cycle costs may be higher than competing sources

Little Boy

- Hiroshima



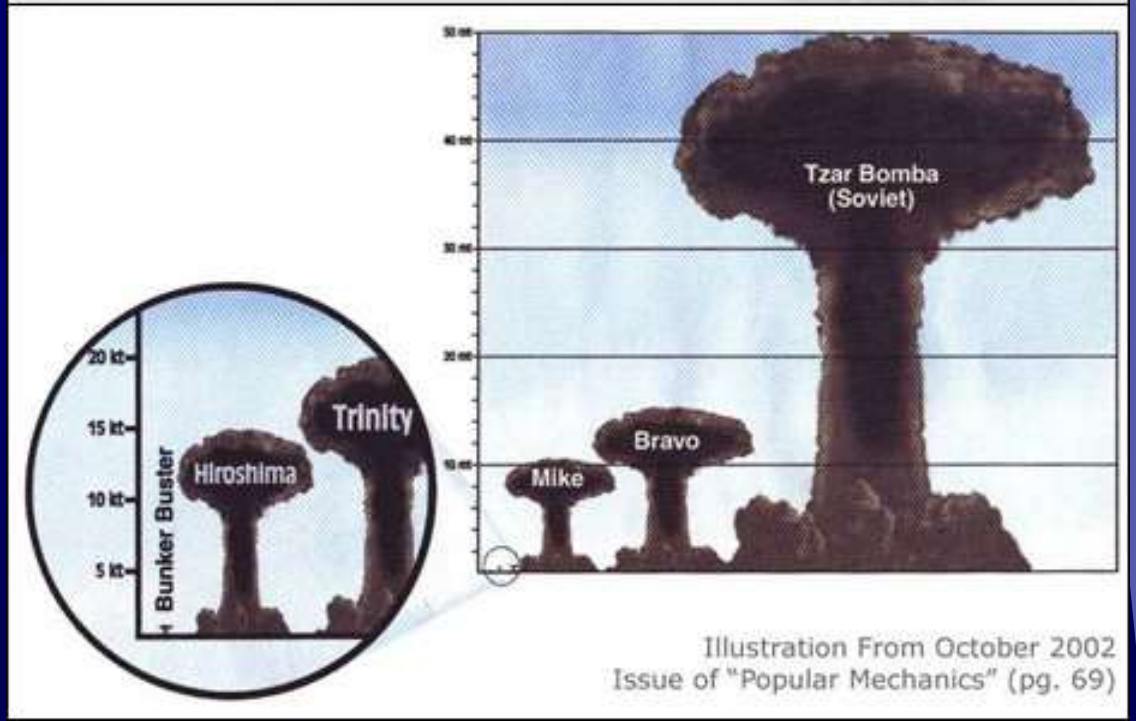
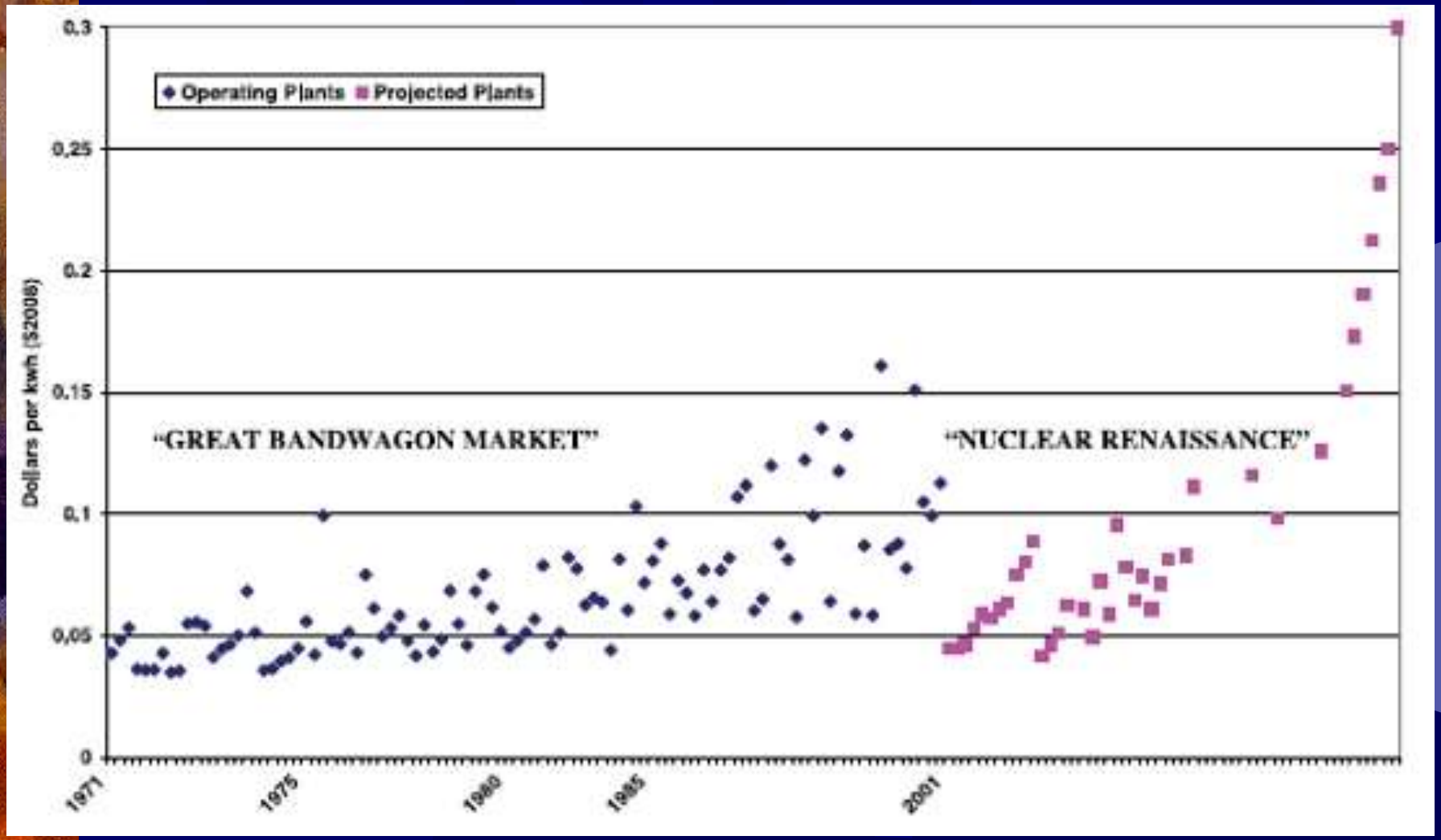


Illustration From October 2002
Issue of "Popular Mechanics" (pg. 69)

Nuclear Power Has Risks

- Human error (and natural disasters) can be devastating
  - Three Mile Island
  - Chernobyl
  - Fukushima
  - 1975 Browns Ferry fire

Costs of Nuclear Power Plant Costs Are Skyrocketing



Nuclear Power Plants Are A Huge Investment

Nuclear Waste

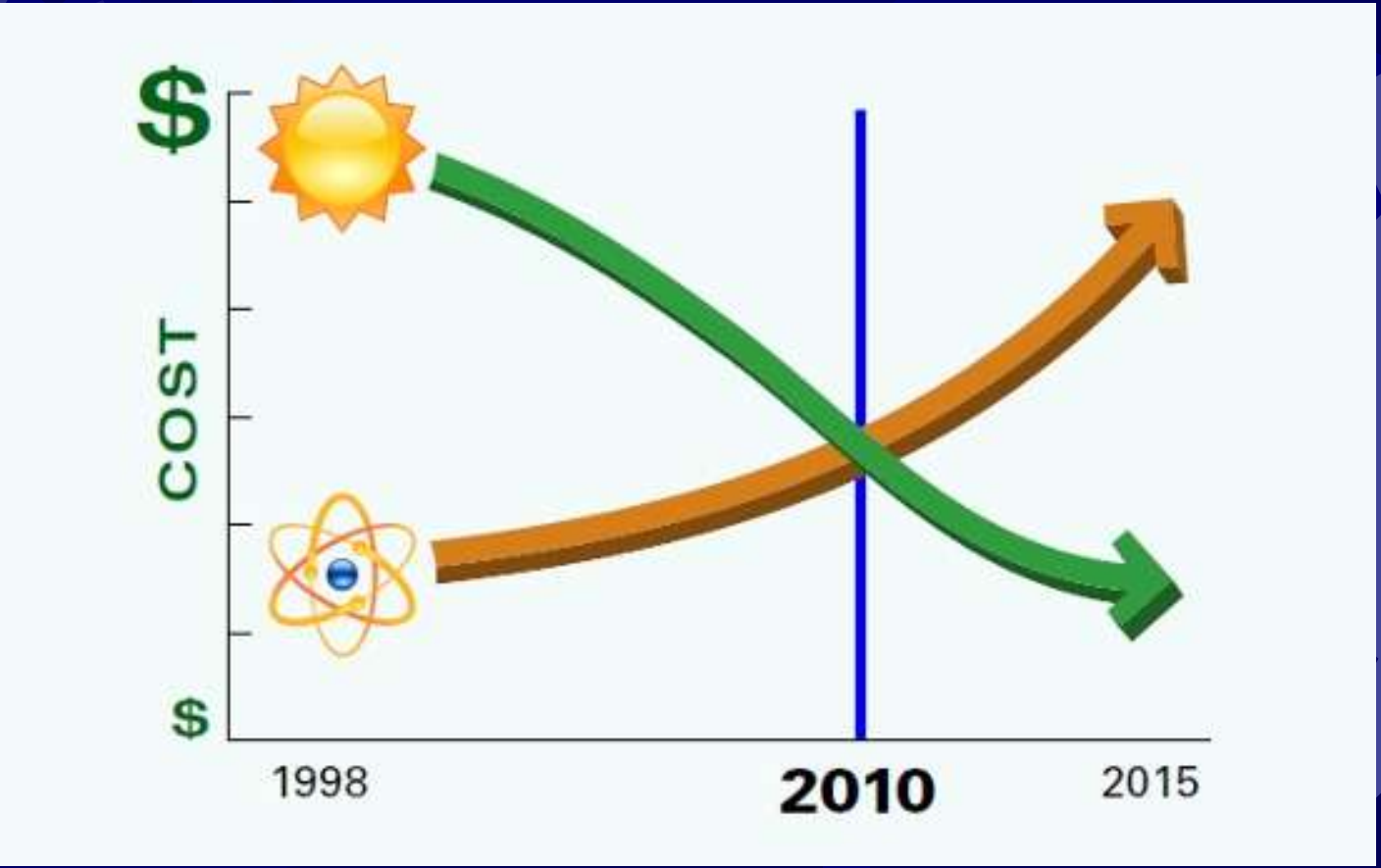
Spent fuel rods

Dry waste

Low level waste

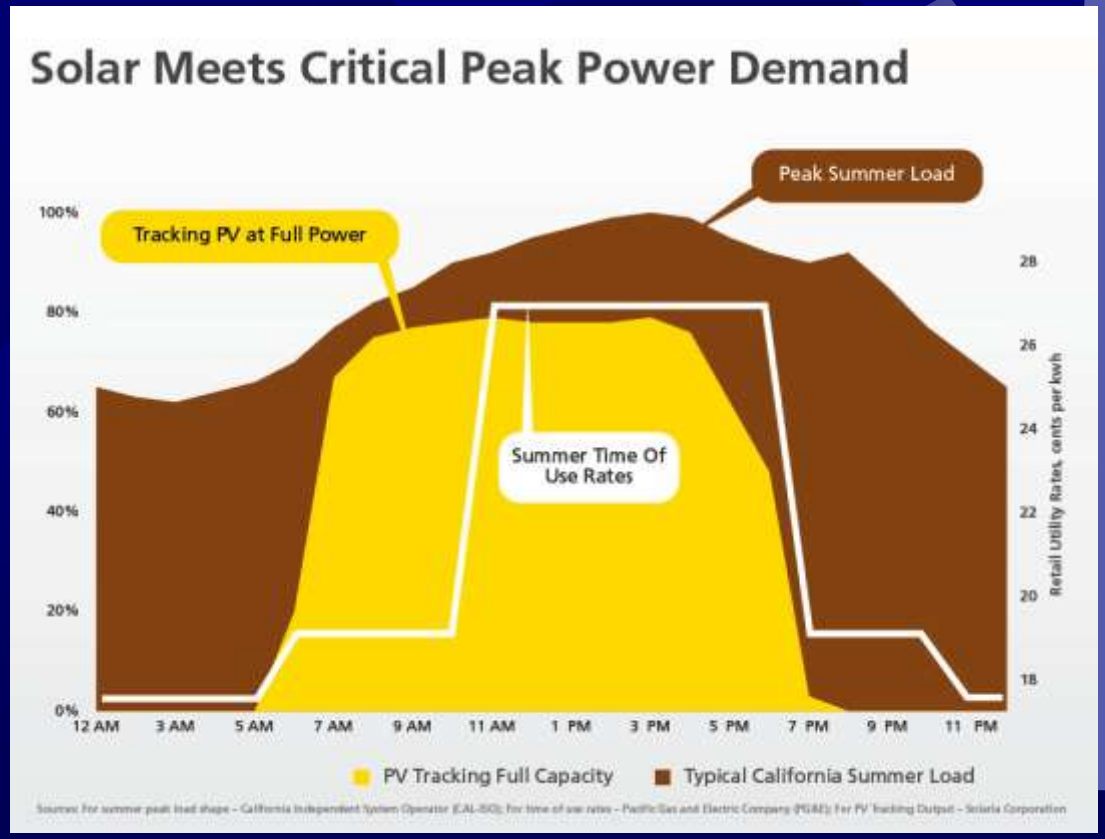
Solar May Now Be Cheaper Than Nuclear

- But it depends on how you count

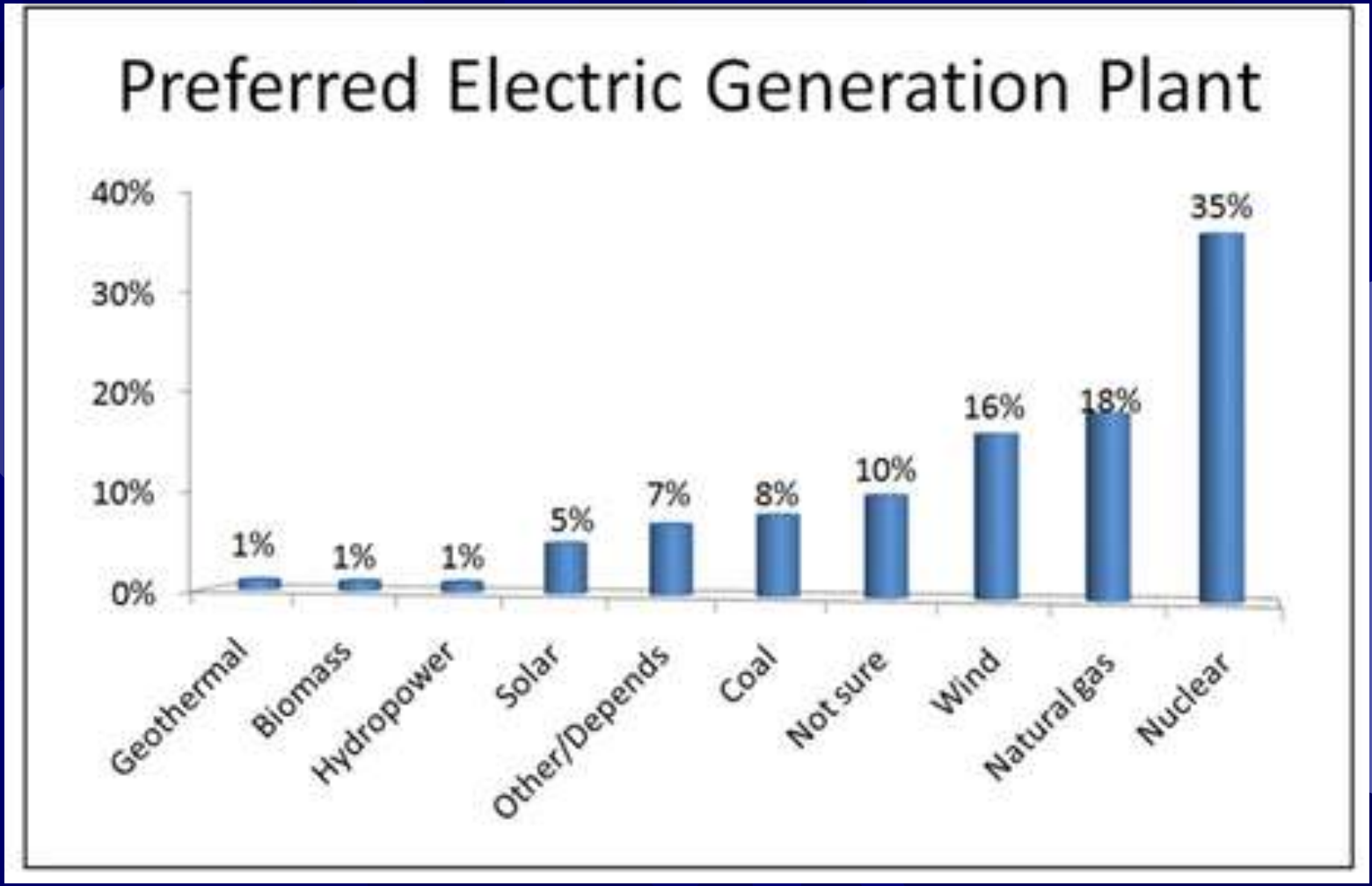


Solar vs. Demand

- Although solar generates only during daylight hours, that's when power is needed the most



Utilities Say They Still Like Nuclear



Summary of Nuclear

- Nuclear power releases very little GHG
- Nuclear energy is generated ‘round the clock
- Nuclear plant costs are increasing rapidly
- Nuclear power has radioactive waste to deal with
- Nuclear power involves significant risks
- Solar and wind energy sources also release little or no GHG
- Solar power may be less expensive (and much safer) than nuclear power
- There is room for both nuclear and solar power in our future