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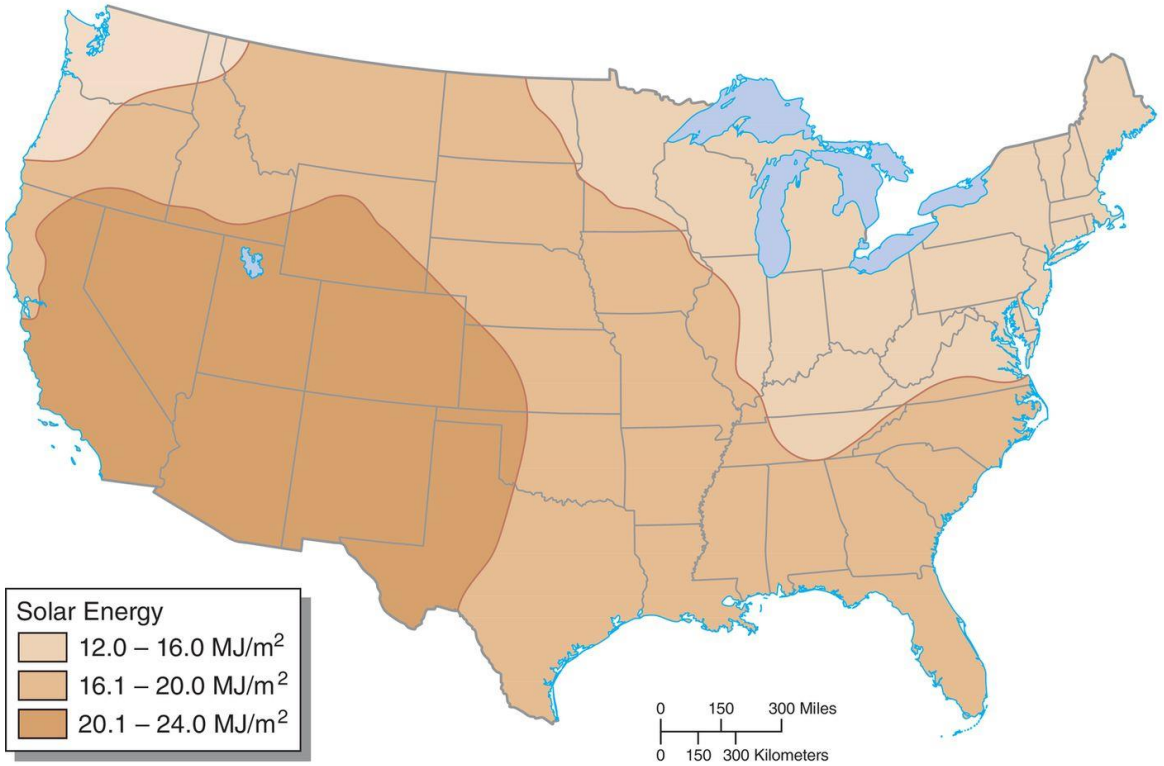
12 Renewable Energy and Nuclear Power

Overview of Chapter 12

- Direct Solar Energy
- Indirect Solar Energy
- Other Renewable Energy Sources
- Nuclear Energy
- Pros and Cons of Nuclear Energy
- Radioactive Waste
- Future of Nuclear Power

Direct Solar Energy

- Perpetually available
- Varies with latitude, season, time of day, and cloud cover

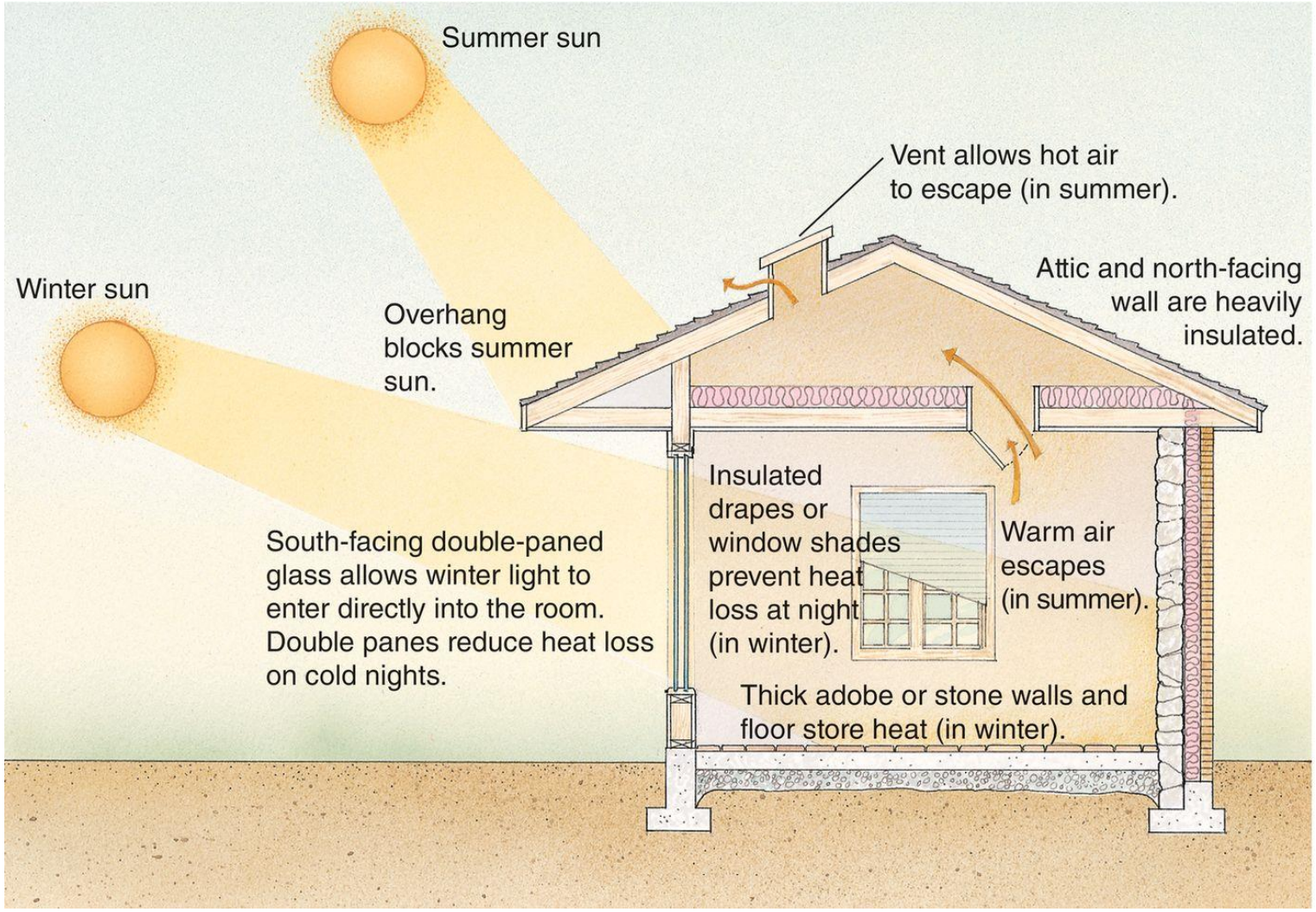


Heating Buildings and Water

- Passive solar energy
  - System of putting the sun's energy to use without requiring mechanical devices to distribute the collected heat
- Certain design features can enhance passive solar energy's heating potential
  - South facing windows (in N. hemisphere)
  - Well insulated buildings
  - Attic vents
  - Overhangs and solar sunspaces

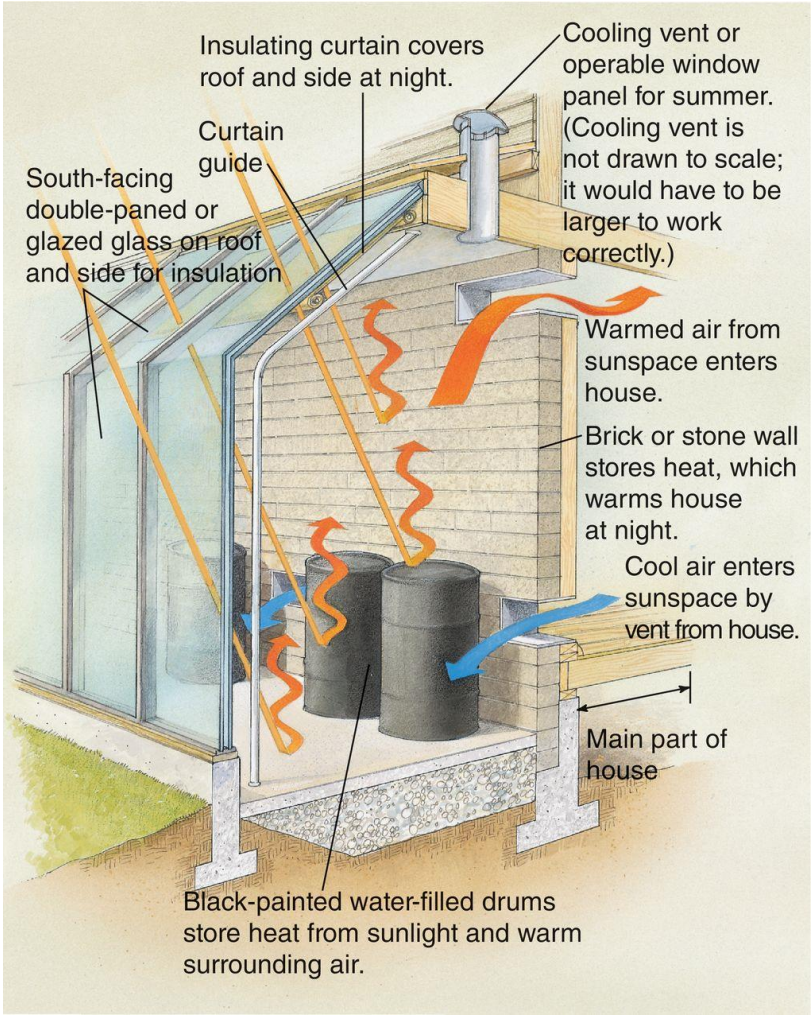
Altrendo Images/Getty Images

Passive solar heating designs



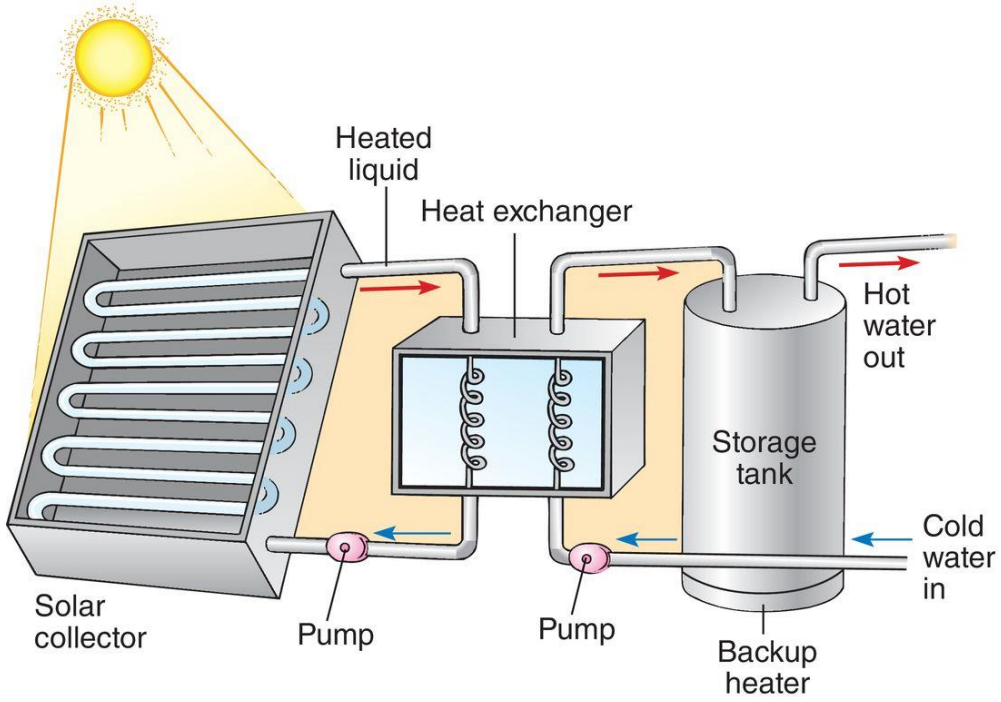
Solar Sunspace

- Utilizes passive solar energy to heat and cool homes
  - Using sun's energy without mechanical devices to distribute heat
- Can be added to existing homes



Heating Buildings and Water

- Active Solar Energy
  - System of collecting and absorbing the sun's energy, and using pumps or fans to distribute the collected heat



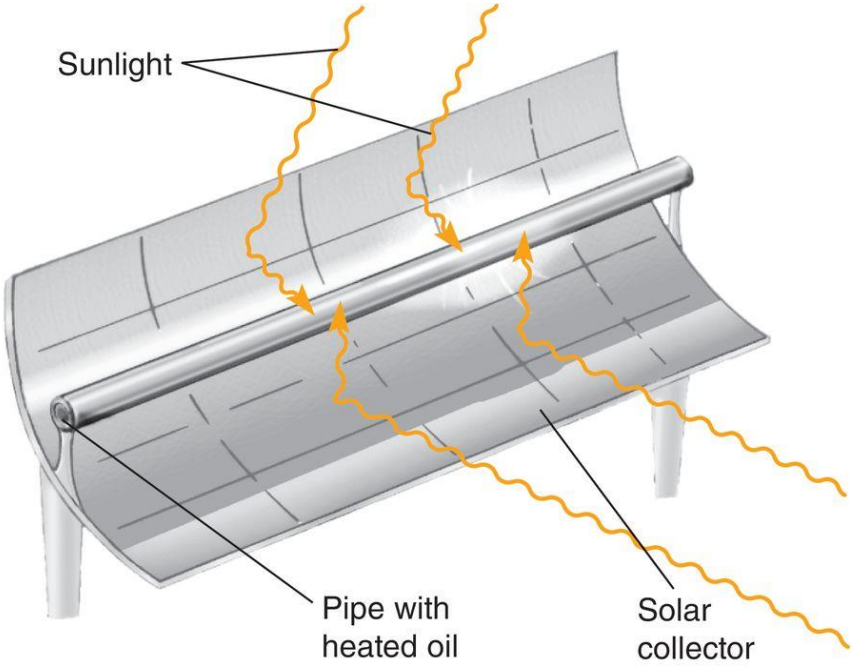
- Typically used to heat water
  - 8% of energy in the U.S. is used to heat water

Heating Buildings and Water

- Solar Thermal Electric Generation
  - Means of producing electricity in which the sun's energy is concentrated by mirrors or lenses to either heat a fluid filled pipe or drive a Stirling engine
  - More efficient than other solar technologies
    - No air pollution
    - No contribution to global warming or acid precipitation

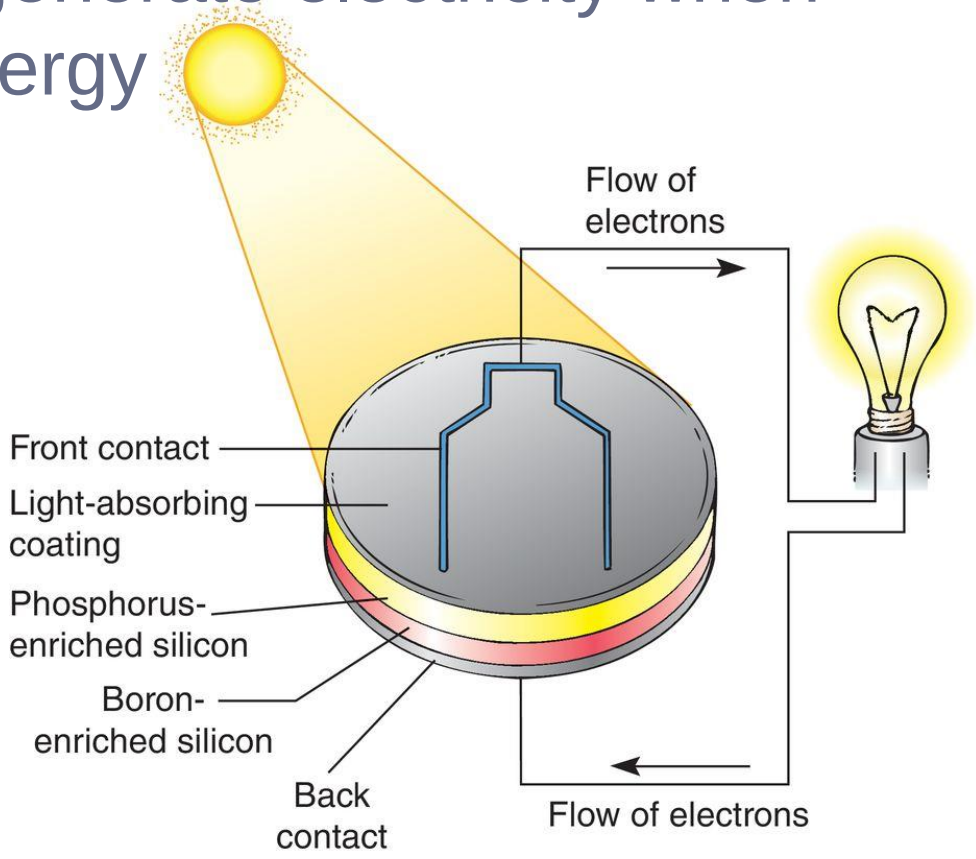
Solar Thermal Electric Generation

L. Lefkowitz/Taxi/Getty Images



Photovoltaic Solar Cells

- A wafer or thin film that is treated with certain metals so that they generate electricity when they absorb solar energy
- No pollution and minimal maintenance
- Used on any scale
  - Lighted road signs
  - Entire building



Photovoltaic Solar Cells

- More economical than running electrical lines to rural areas
- Can be incorporated into building materials
  - Roofing shingles
  - Tile
  - Window glass

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Cost of Electrical Power Plants

- Alternative power sources are becoming competitive with traditional power sources

Table 12.1 Generating Costs of Electric Power, 2010

Energy Source	*Generating Costs (cents per kilowatt hour)**
Hydropower	5–11
Biomass	6–9
Geothermal	5–10
Wind	4–6
Solar thermal	5–13
Photovoltaics (PV)	15–25
Natural gas	4–5
Coal	4–6
Nuclear power	2–14

*Electricity production and consumption are measured in kilowatt-hours (kWh). As an example, one 50-watt light bulb that is on for 20 hours uses one kilowatt-hour of electricity ($50 \times 20 = 1000$ watt-hours = 1kWh).
Source: Energy Information Agency.

Indirect Solar Energy

- Biomass
  - Plant materials, such as wood, crop wastes and animal waste, used as fuel
- Wind energy
  - Electric or mechanical energy obtained from surface air currents caused by solar warming of air
- Hydropower
  - Form of renewable energy reliant on flowing or falling water to generate mechanical energy or electricity

Biomass

- Contains energy from sun via photo-synthesizing plants
  - Oldest known fuel to humans- still used by half the world's population
  - Renewable when used no faster than it can be produced
- Can convert to biogas or liquids
  - Ethanol and methanol
  - Clean fuel

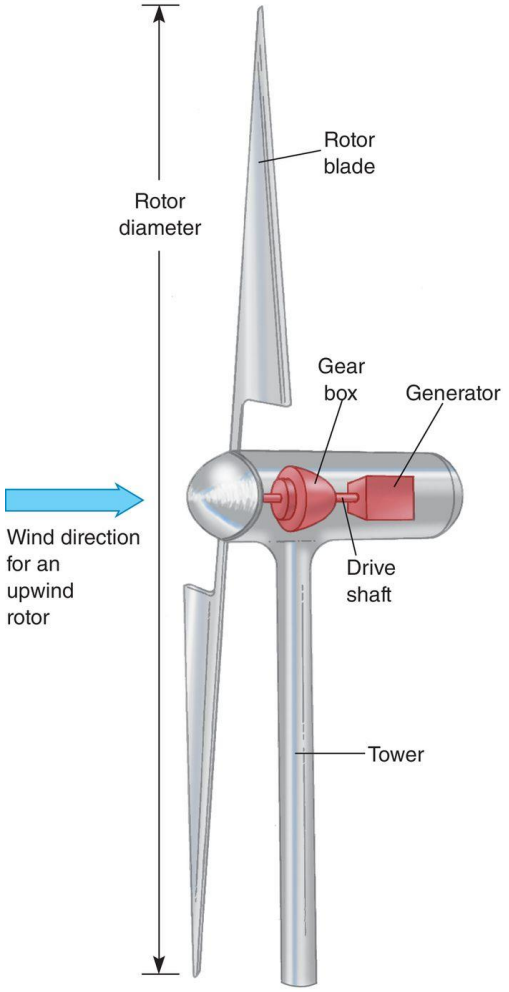
Robert E. Ford/Terraphotographics/Biological Photo Service

Biomass

- Advantages
  - Reduces dependence on fossil fuels
  - Often uses waste materials
  - If trees are planted at same rate biomass is combusted, no net increase in atmospheric CO_2
- Disadvantages
  - Requires land, water and fossil fuel energy
  - Bad air quality
  - Can lead to:
    - Deforestation
    - Desertification
    - Soil erosion

Wind Energy

- World's fastest growing source of energy
- Wind results from sun warming the atmosphere
  - Varies in direction and magnitude
- New wind turbines harness wind efficiently
  - Most profitable in rural areas with constant wind



Wind Energy

- Few environmental problems
  - Kills birds and bats
- No waste- clean source of energy
- Biggest constraints:
  - Cost
  - Public resistance (NIMBY)

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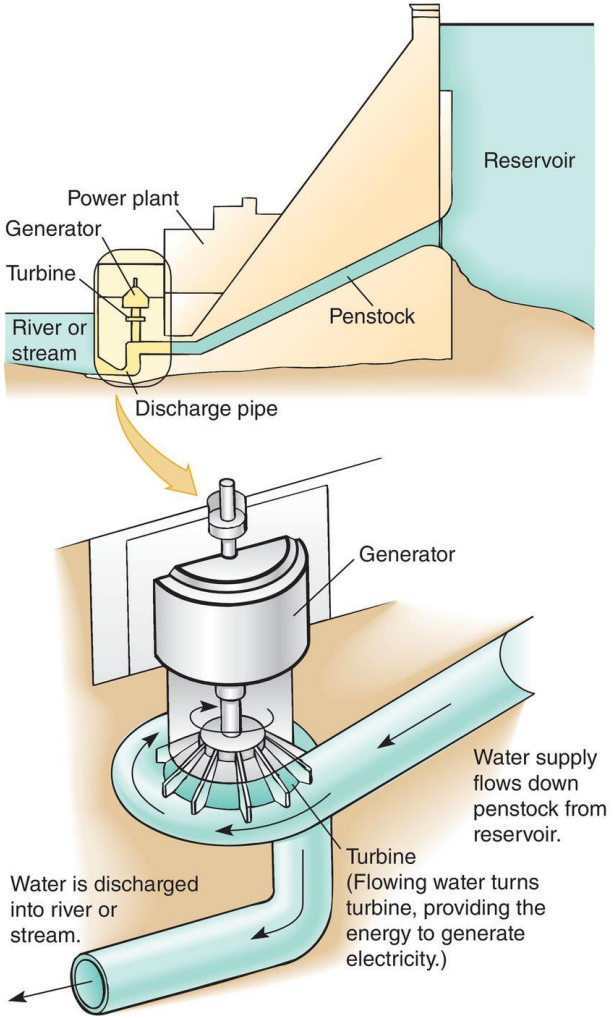
Hydropower

- Most efficient energy source (90%)
- Most widely used form of energy
  - 19% of world's energy
- Traditional hydropower
  - Suited only to large dams
- New technology
  - Utilize low flow systems



Hydropower

- Three Gorges Dam on Yangze River, China
  - Huge electricity generation
  - Displaced ~1.5 million
  - Large environmental shift in area

Table 12.2 Advantages and Disadvantages of Dams

Reasons to Build Dams	*Problems with Dams*
Electrical power	Ecological disruption downstream
Mechanical power	• Sediment stopped in dam
Irrigation	• Water source diverted
Navigation	• Fish migration halted at dam
Flood control	Ecological disruption in reservoir
Commercial fishing	• Habitat flooded
Recreation	• Sediment buildup
• Fishing	• Pollution if toxic materials are submerged
• Swimming	Displacement of people
• Boating	Loss of cultural resources
	Catastrophic failure
	Disease
	Seismicity
	Evaporation from reservoir

Other Indirect Solar Energy

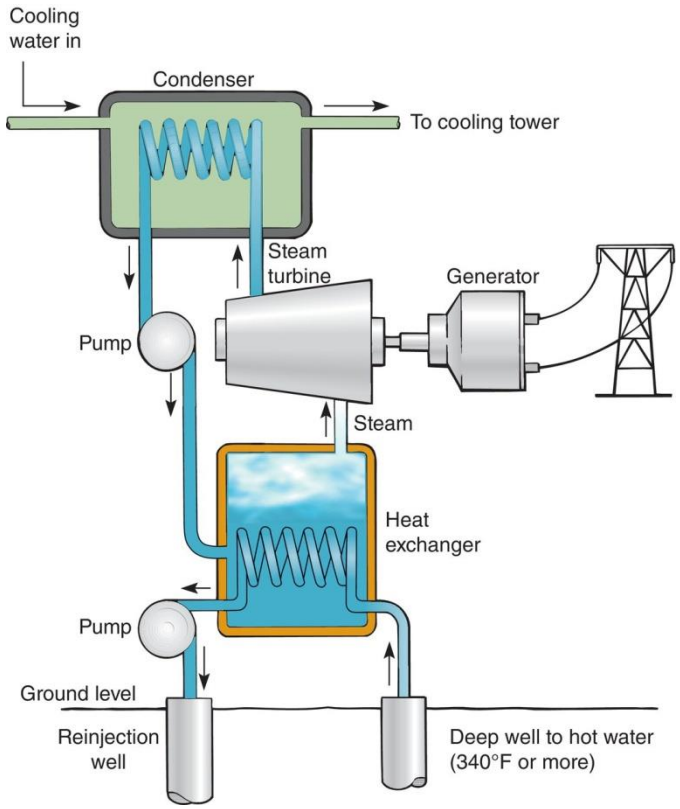
- Ocean waves
  - Produced by winds
  - Has potential to turn a turbine- and create electricity
- Ocean Thermal Energy Conversion (OTEC)
  - Ocean Temperature Gradients
  - Use difference in temperature of surface and deep water to create electricity

Other Renewable Energy Sources

- Geothermal energy
  - Energy from the Earth's interior for either space heating or generation of electricity
  - Becoming an option in homes
- Tidal Energy
  - Form of renewable energy that relies of the ebb and flow of the tides to generate electricity
  - Location dependent

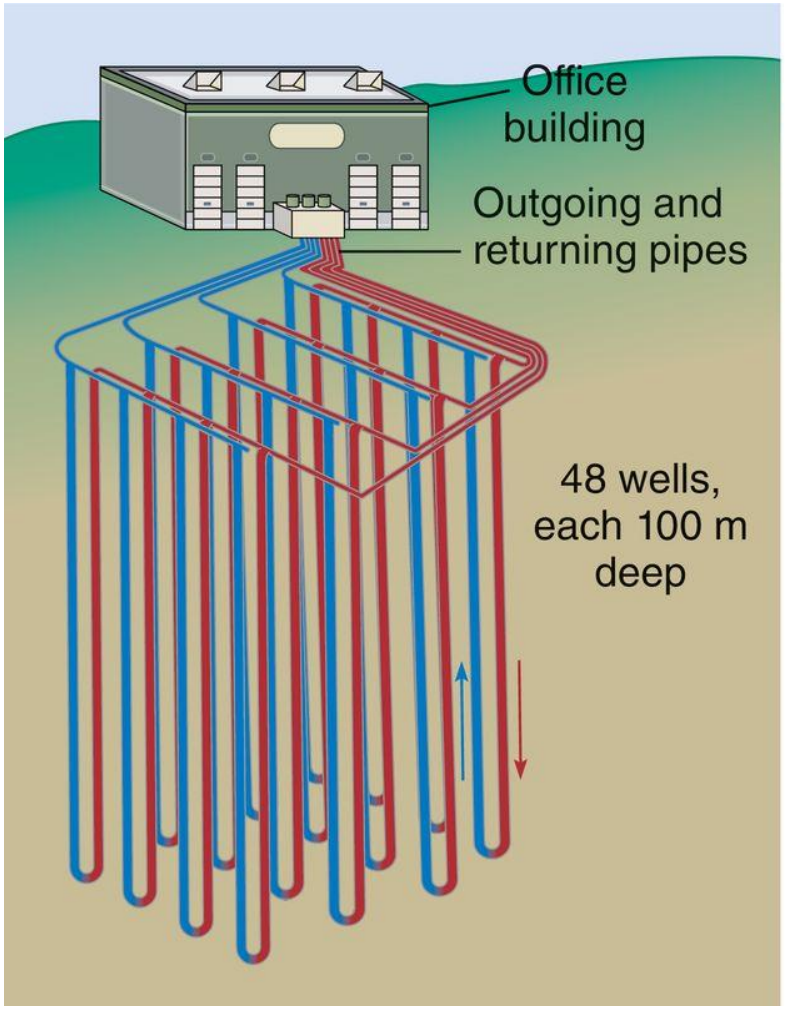
Geothermal Energy

- Enormous energy source
  - 1% of heat in upper 10km of earth crust is equal to 500X the earth's fossil fuel sources
- From Hydrothermal Reservoirs
  - Created by volcanoes
  - Reservoirs used directly for heat or to generate electricity



Geothermal Energy

- From hot, dry rock
- Geothermal heat pumps
  - Use difference in temperature between surface and subsurface
  - Great for heating buildings
  - Expensive installation



Tidal Energy

- Typical difference between high and low tide is 1-2 ft
  - Narrow bays may have greater variation
- Potential energy difference between low and high tide can be captured with
  - A dam across a bay
  - A turbine similar to a wind turbine

Nuclear Power

- Nuclear energy
  - Energy released by nuclear fission or fusion
- Nuclear fission
  - Splitting of an atomic nucleus into two smaller fragments, accompanied by the release of a large amount of energy
- Nuclear fusion
  - Joining of two lightweight atomic nuclei into a single, heavier nucleus, accompanied by the release of a large amount of energy

Atoms and Radioactivity

- Nucleus
  - Comprised of protons (+) and neutrons (neutral)
- Electrons (–) orbit around nucleus
- Neutral atoms
  - Same # of protons and electrons

Atoms and Radioactivity

- Atomic mass
  - Sum of the protons and neutrons in an atom
- Atomic number
  - Number of protons per atom
  - Each element has its own atomic number
- Isotope
  - Atom where the number of neutrons is greater than the number of protons

Radioactive Isotope

- Unstable isotope
- Radioactive Decay
  - Emission of energetic particles or rays from unstable atomic nuclei
- Example
  - Uranium (U-235) decays over time to lead (Pb-207)
- Each isotope decays based on its own half-life

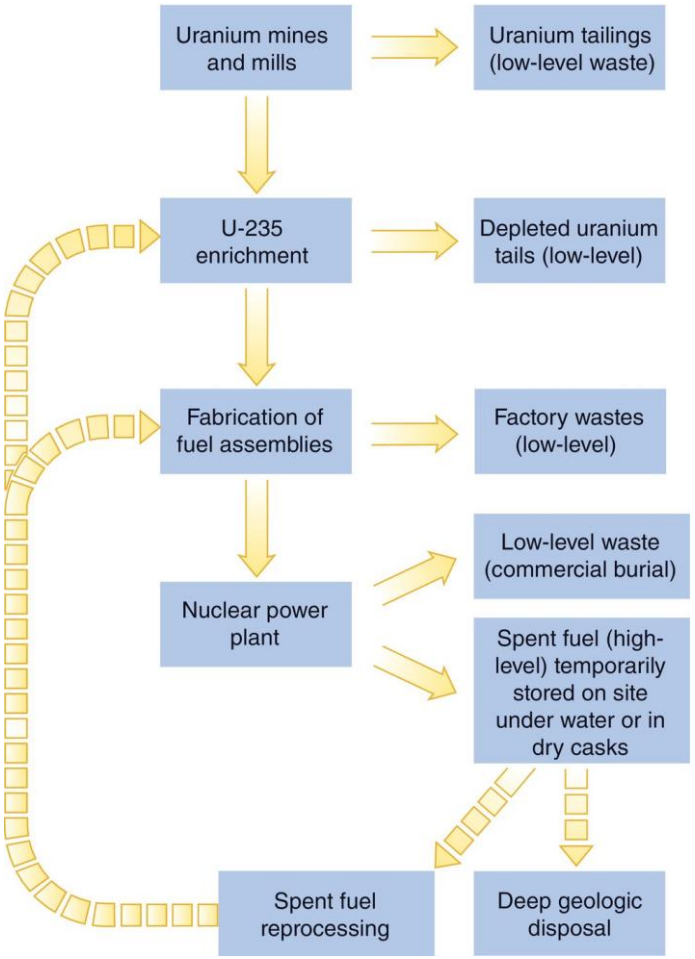
Radioactive Isotope Half-lives

Table 12.3 Some Common Radioactive Isotopes Associated with the Fission of Uranium

Radioisotope	*Half-Life (years)*
Iodine-131	0.02 (8.1 days)
Xenon-133	0.04 (15.3) days
Cerium-144	0.8
Ruthenium-106	1.0
Krypton-85	10.4
Tritium	12.3
Strontium-90	28
Cesium-137	30
Radium-226	1,600
Plutonium-240	6,600
Plutonium-239	24,400
Neptunium-237	2,130,000

Nuclear Fission

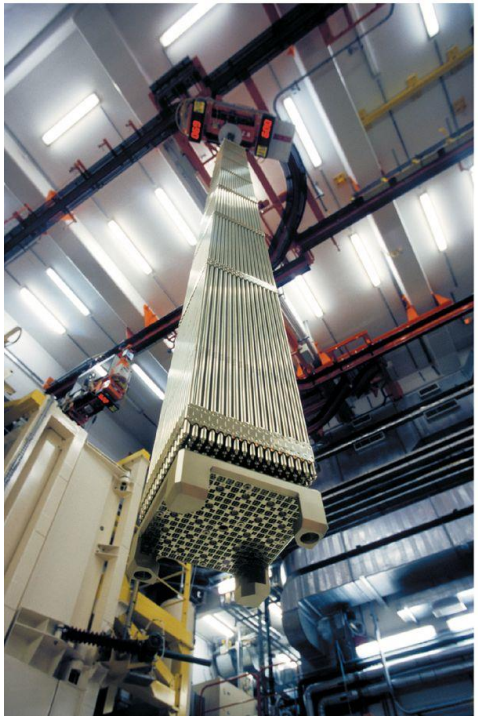
- Nuclear Fuel Cycle
  - Processes involved in producing the fuel used in nuclear reactors from mining to disposing of radioactive (nuclear) wastes



Nuclear Reactors

- Device that initiates and maintains a controlled nuclear fission chain reaction to produce energy

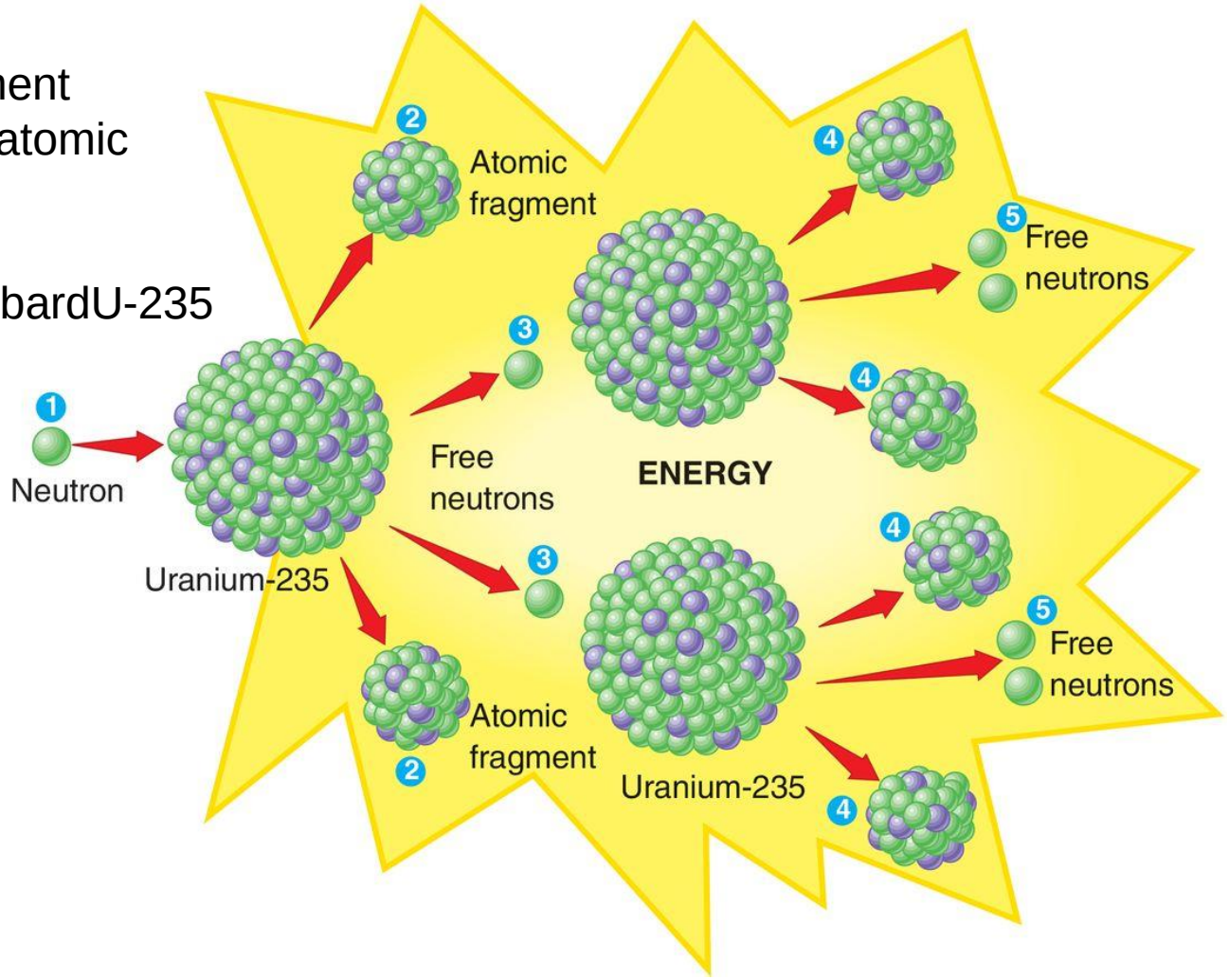
RIA Novosti/Science Source



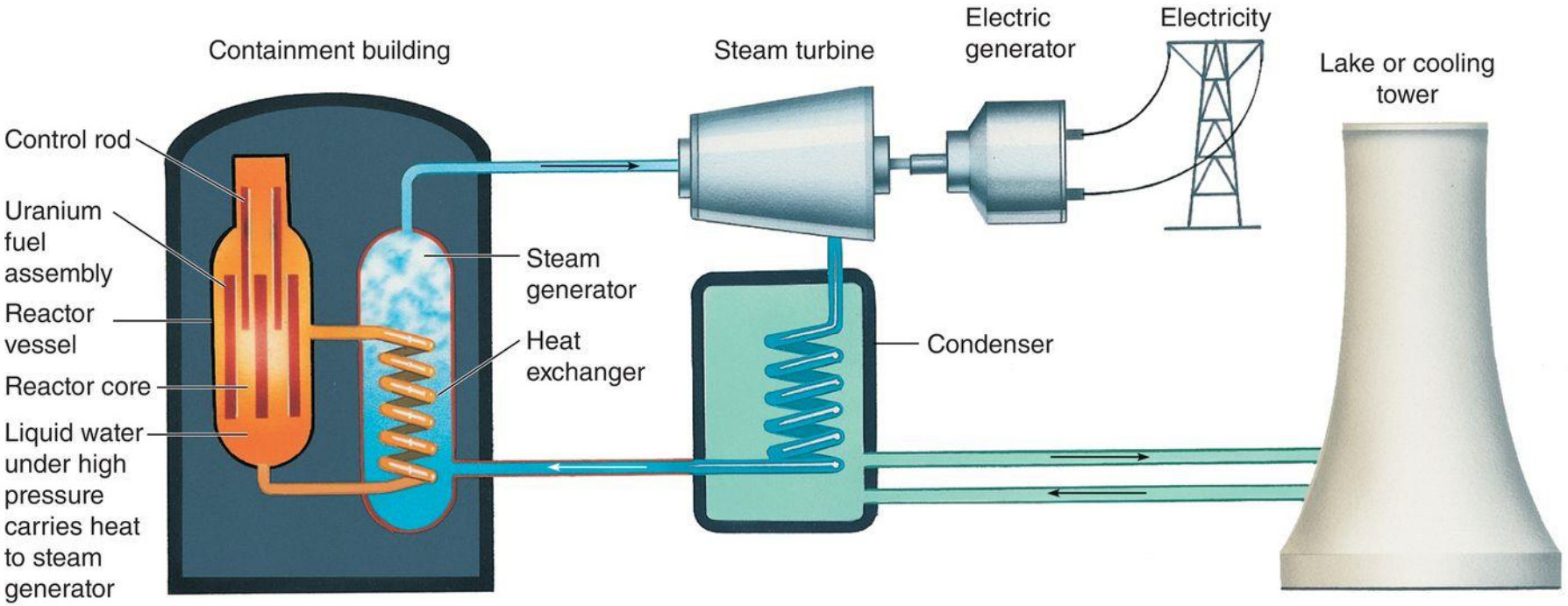
Patrick Landmann/Science Source

Nuclear Fission

1. Neutron bombardment
2. Nucleus splits into atomic fragment
3. And free neutrons
4. Free neutrons bombardU-235 nuclei
5. More free neutrons released



How Electricity is Produced



Breeder Nuclear Fission and MOX

- Breeder Nuclear Fission
  - A type of nuclear fission in which non-fissionable U-238 is converted into fissionable Pu-239 (plutonium)
  - Promising for energy, but safety concerns
- Mixed Oxide Fuel
  - Combination of uranium and plutonium oxides, can reprocess spent fuel from other reactors
  - Common in Europe

Pros and Cons of Nuclear Energy

- Pros
  - Less of an immediate environmental impact compared to fossil fuels
  - Carbon-free source of electricity
  - May be able to generate H-fuel
- Cons
  - Generates radioactive waste for long term storage
  - Many steps require fossil fuels (mining and disposal)
  - Expensive

Pros and Cons of Nuclear Energy

Table 12.4 Comparison of Environmental Impacts of 1000-MW Coal and Nuclear Power Plants*

Impact	*Coal*	*Nuclear (Conventional Fission)*
Land use	17,000 acres	1900 acres
Daily fuel requirement	9000 tons/day	3 kg/day
Availability of fuel, based on present economics	A few hundred years	100 years, maybe longer (much longer with breeder fission)
Air pollution	Moderate to severe, depending on pollution controls	Low**
Climate change risk (carbon dioxide emissions)	Severe	Relatively small**
Radioactive emissions, routine	1 curie	28,000 curies
Water pollution	Often severe at mines	Potentially severe at nuclear waste disposal sites
Risk from catastrophic accidents	Short-term local risk	Long-term risk over large areas
Link to nuclear weapons	No	Yes
Annual occupational deaths	0.5 to 5	0.1 to 1
Certainty about risks	Well known	Highly uncertain

*Impacts include extraction, processing, transportation, and conversion. Assumes coal is strip-mined. (A 1000-MW utility, as a 60% load factor, produces enough electricity for a city of 1 million people.)
**While nuclear electricity generation does not generate air pollution and carbon dioxide directly, many of the steps (mining, construction, and waste disposal, for example) require fossil fuels.

Safety Issues in Nuclear Power Plants

- Meltdown
  - At high temperatures, the metal encasing the uranium fuel can melt, releasing radiation
- Probability of meltdown is low
- Public perception is that nuclear power is not safe
- Sites of major accidents:
  - Three Mile Island, PA
  - Chernobyl, Ukraine
  - Fukushima Daiichi, Japan

Three-Mile Island

- 1979 - most serious reactor accident in US
- 50% meltdown of reactor core
  - Containment building kept radiation from escaping
  - No substantial environmental damage
  - No human casualties
- 12 years and 1 billion dollars to repair
- Elevated public fear of nuclear energy
  - Led to cancellation of many new plants in US

Chernobyl

- 1986 - worst accident in history
- 1 or 2 explosions destroyed the nuclear reactor
  - Large amounts of radiation escaped into atmosphere
- Spread across large portions of Europe
- Caused by range of violations, flawed design, inferior construction, and operator errors

Chernobyl

- Radiation spread was unpredictable and uneven
- 4,000 deaths attributed to plant explosion
  - Mostly due to cancer

Fukushima Daiichi

- March 11, 2011 - caused by magnitude 9.0 earthquake and ensuing tsunami
  - Disrupted power systems that pump cooling water to reactor cores and spent fuel rods
- Increased radiation in local water and food supplies
  - May limit seafood catches for decades

Fukushima Daiichi

ABACA / Newscom

Nuclear Energy and Nuclear Weapons

- 31 countries use nuclear energy to create electricity
- These countries have access to materials needed to produce enriched plutonium or uranium for nuclear weapons
- Safe storage and handling of these weapons is a concern
- NIMBY – “not in my backyard”

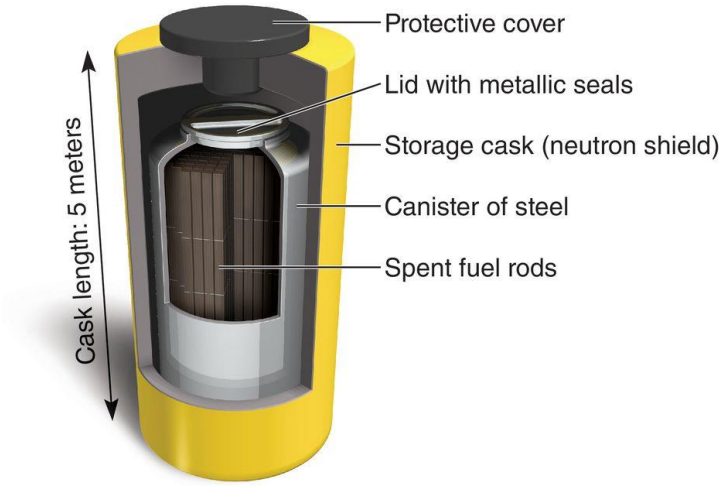
Radioactive Waste

- Low-level radioactive waste
  - Radioactive solids, liquids or gases that give off small amounts of ionizing radiation
  - Produced by power plants, research labs, hospitals and industry
  - States responsible for all waste they generate
- High-level radioactive waste
  - Radioactive solids liquids or gases that give off large amounts of ionizing radiation
  - Primarily spent fuel rods and assemblies

Radioactive Waste

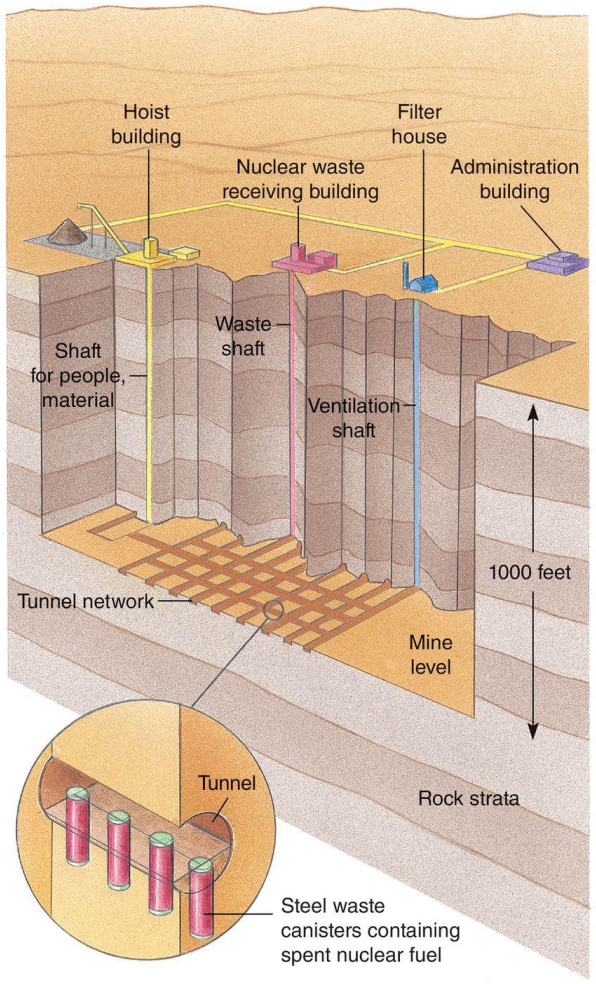
- Temporary storage solutions
  - In nuclear plant facility (require high security)
    - Under water storage
    - Above ground concrete and steel casks
- Need approved permanent options soon.

Dry cask storage



Case-In-Point Yucca Mountain

- 70,000 tons of high-level radioactive waste
- Tectonic issues have been identified
- U.S. federal courts demanded site meet EPA safety standards for 1 million years
- Not active



Decommissioning Nuclear Power Plants

- Licensed to operate for 40 years
  - Several have received 20-year extensions
- Power plants cannot be abandoned when they are shut down
- Three solutions
  - Storage
  - Entombment
  - Decommissioning (dismantling)- best option
- 110 power plants were retired as of 2010
  - 23 in U.S. and the rest are aging quickly

Attitudes Towards Nuclear Power

- Generally a major case of mistrust on the part of the public towards pro-nuclear power scientists and politicians
- NIMBY- Not In My Backyard
  - Citizens to not want a nuclear facility or waste disposal site near their home
- Dad- Decide, Announce, Defend
  - Pronuclear advocates
  - Based on the science, not fears

Future of Nuclear Power

- Plan to build safer plants
  - Technologically advanced designs
  - New fission reactors
- Fusion
  - Energy of the future?
  - Still in research phase