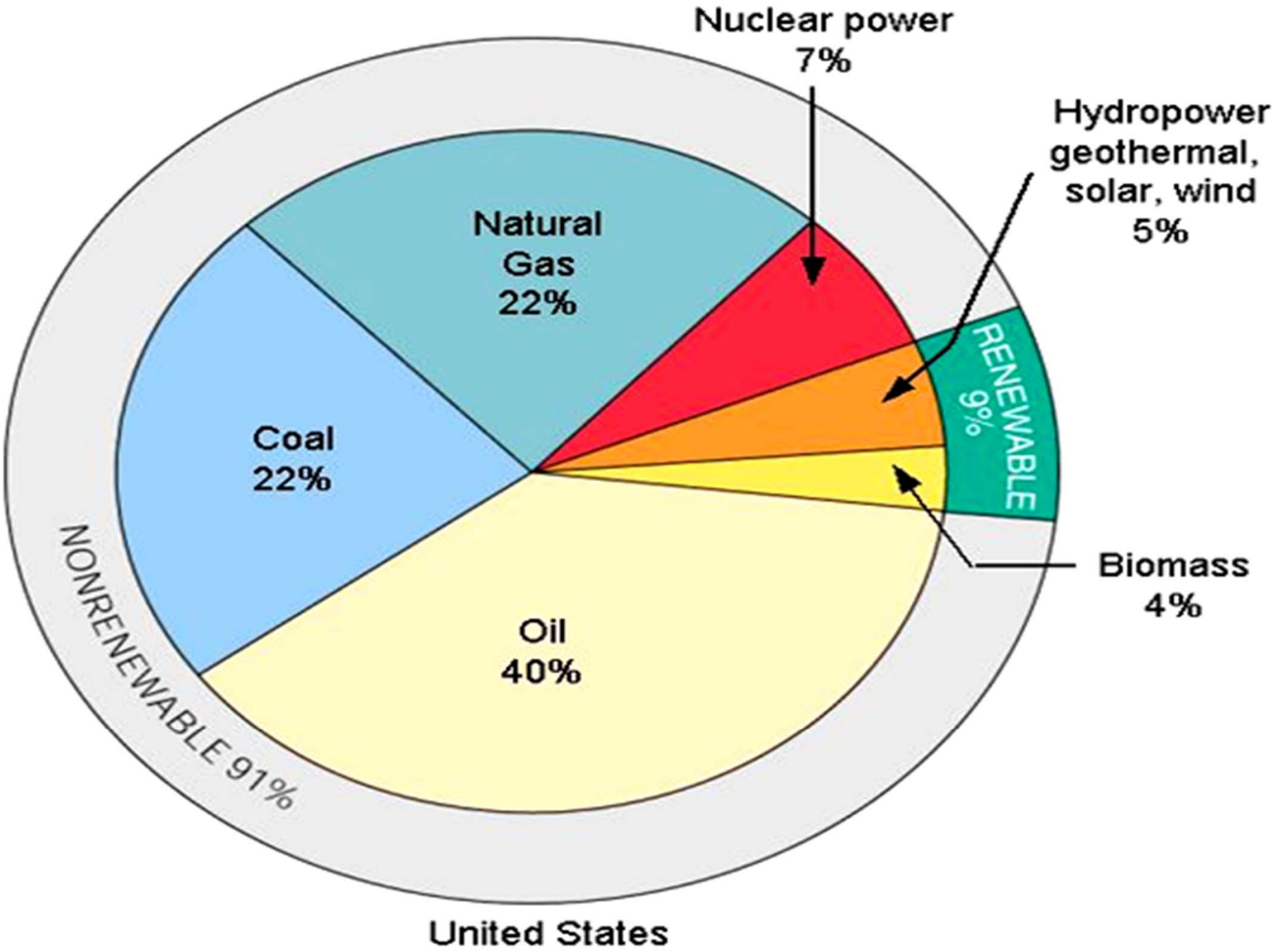
Renewable Energy Sources

Energy Resources

- Renewable (16%)
  - Solar
  - Wind
  - Falling, flowing water
  - Biomass
- Non-renewable (84%)
  - Oil
  - Natural gas
  - Coal
  - Nuclear power


Nuclear power
7%
Hydropower
geothermal,
solar, wind
5%
Natural
Gas
22%
Coal
22%
RENEWABLE
9%
Biomass
4%
Oil
40%
NONRENEWABLE 91%
United States

Renewable Energy Sources

- Lecture Question
  - What are the renewable energy sources? Make a list, as comprehensive as possible.
  - What are the environmental impacts of these energy sources?

  - Renewable Energy Sources
    - Radiant solar energy
      - Solar heating (passive and active), solar power plants, photovoltaic cells
    - Biomass energy
      - Direct: combustion of biomass
      - Indirect: chemical conversion to biofuel
    - Wind energy
    - Hydro energy
    - Geothermal energy
      - Power plants, direct use, heat pumps
    - Ocean energy
      - Tidal; salinity-driven

Hydro Energy

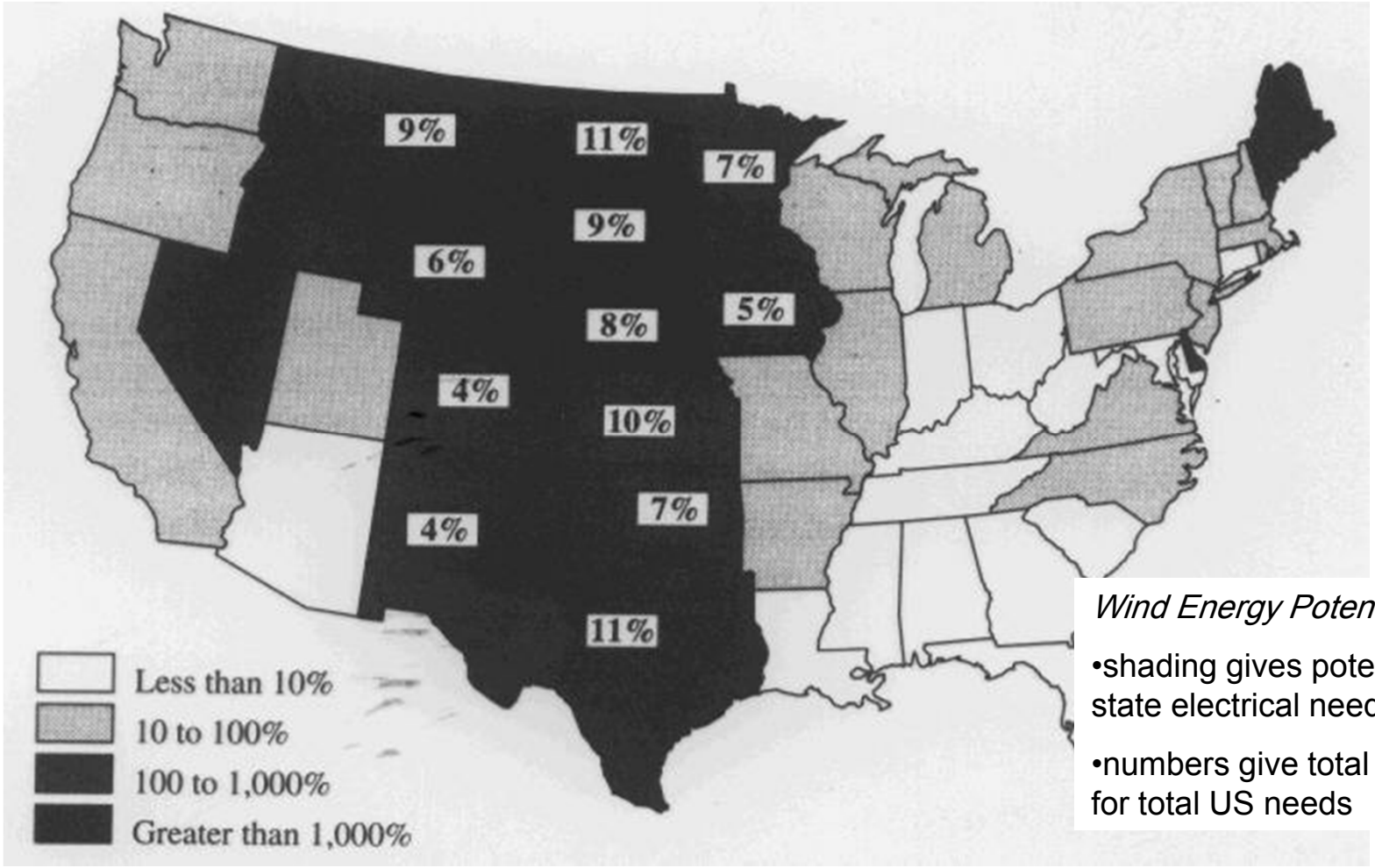
- Advantages
  - Cheap to operate
    - Long life and lower operating costs than all other power plants
  - Renewable
  - High yield
    - Lower energy cost than any other method
  - Pretty plentiful
    - Some countries depend almost entirely on it
  - Not intermittent (if reservoir is large enough)
  - Reservoirs have multiple uses
    - Flood control, drinking water, aquaculture, recreation
  - Less air pollution than fossil fuel combustion

Hydro Energy

- Disadvantages:
  - Human population displacement
  - More significant breeding ground for disease
  - Reduces availability of water downstream
  - Ecosystem impacts
    - Barriers to migrating fish
    - Loss of biodiversity both upstream and downstream
    - Coastal erosion
    - Reduces nutrient flow (dissolved and particulate)
  - Water pollution problems
    - Low dissolved oxygen (DO)
    - Increased H_2S toxicity; other DO-related problems
    - Siltation a big problem (also shortens dam life)
  - Air pollution
    - Actually may be a significant source of GHGs (CH_4, N_2O, CO_2)
  - Decommissioning is a big problem
- The Size Issue
  - Many (most) of the above problems are significantly worse for larger dams
  - However, small dams have shorter lifetimes, less capacity, and are more intermittent

Wind Energy

- How it works
  - Wind turbines directly generate electricity
  - Quite efficient (not a heat engine)



Wind Energy Potential

•shading gives potential for in-state electrical needs

•numbers give total potential for total US needs

Wind Energy

- Advantages
  - High net energy yield
  - Renewable and free
  - Very clean source of energy
    - No pollution (air or water) during operation
  - Long operating life
  - Low operating/maintenance costs
  - Can be quickly built; not too expensive
  - Now almost competitive with hydro and fossil fuels
  - Land can be used for other purposes
    - Can combine wind and agricultural farms

Wind Energy

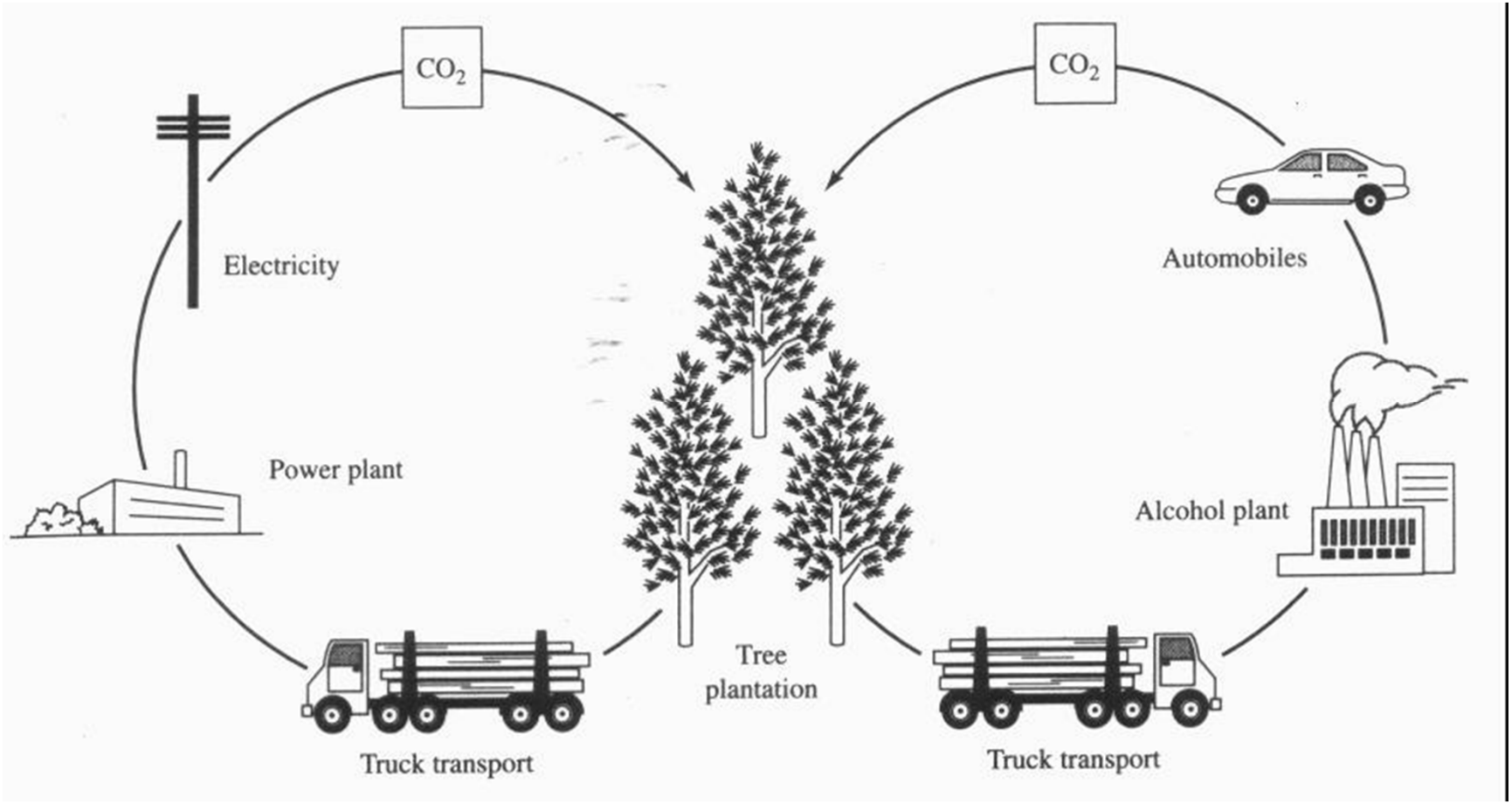
- Disadvantages
  - Energy storage issues
    - An intermittent source of energy; need backup (eg stored energy) for low-wind days
    - Or must be connected to the electrical grid
  - Only practical in areas that are windy enough
  - Visual pollution
  - Danger to birds
    - New (slow turning) designs largely eliminate this problem
  - Low energy density of wind
    - Must use large areas of land

Biomass Energy

- What is it?
  - Biomass energy is the use of living and *recently* dead biological material as an energy source
  - Ultimately dependent on the capture of solar energy and conversion to a chemical (carbohydrate) fuel
  - Theoretically it is a *carbon neutral* and renewable source of energy
- How it works?
  - Traditional: forest management, using wood as fuel
  - Use of biodegradable waste
    - Examples: manure, crop residue, sewage, municipal solid waste
  - Recent interest in agricultural production of ***energy crops***
    - Should be high yield and low maintenance
    - Examples: corn, sugarcane, switchgrass, hemp, willow, palm oil, rapeseed, and many others
    - Does not have to be a food crop
    - Recent interest in bioengineered (GM) plants as fuel sources
  - Production of a liquid or gaseous ***biofuel***
    - *Biogas* due to the breakdown of biomass in the absence of O_2
      - Includes capture of landfill methane
    - *Bioethanol* from fermentation, often from corn. Cellulosic bioethanol is usually from a grass (switchgrass)
    - *Biodiesel* from rapeseed and other sources

Biomass Energy

- Carbon neutral
  - CO_2 ultimately released in energy generation is *recently* captured and so ideally does not change total atmospheric levels
  - *Carbon leaks* can result in a net increase in CO_2 levels
  - Sequestration in soil can result in a net *decrease* in CO_2 levels



Biomass Energy

- Advantages
  - Versatile
  - Renewable
  - No net CO_2 emissions (ideally)
  - Emits less SO_2 and NO_x than fossil fuels
- Disadvantages
  - Low energy density/yield
    - In some cases (eg, corn-derived bioethanol) may yield no net energy
  - Land conversion
    - Biodiversity loss
    - Possible decrease in agricultural food productivity
  - Usual problems associated with intensive agriculture
    - Nutrient pollution
    - Soil depletion
    - Soil erosion
    - Other water pollution problems

Geothermal Energy

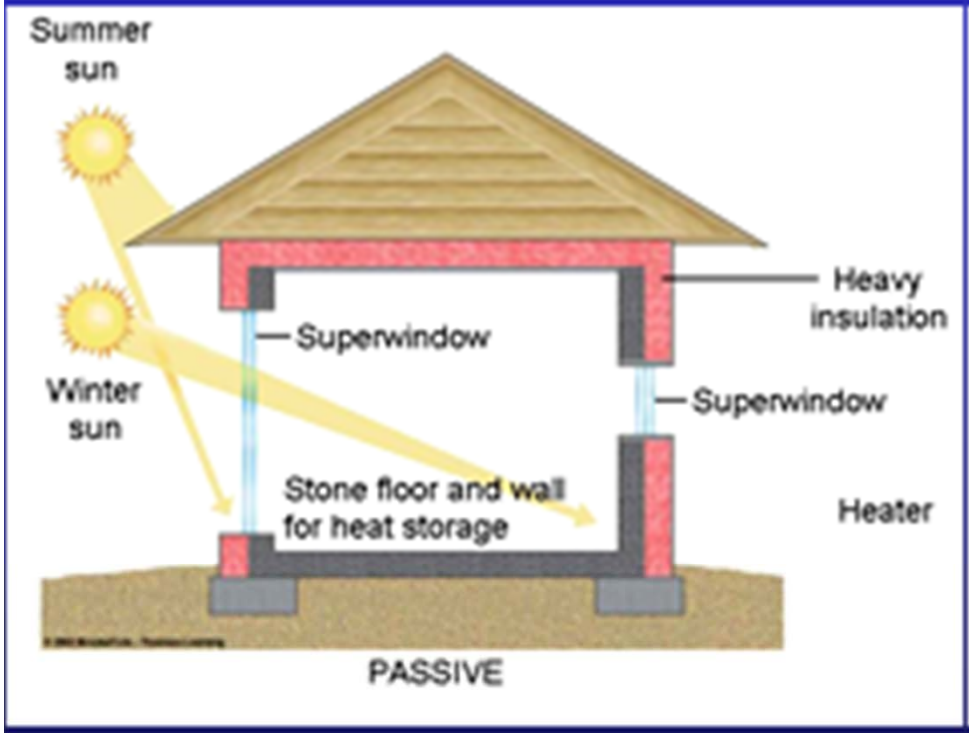
- How it works
  - Geothermal power plants
    - Use earth's heat to power steam turbines
  - Geothermal direct use
    - Use hot springs (etc) as heat source
  - Geothermal heat pumps
- Advantages
  - Renewable
  - Easy to exploit in some cases
  - CO_2 production less than with fossil fuels
  - High net energy yield
- Disadvantages
  - Not available everywhere
  - H_2S pollution
  - Produces some water pollution (somewhat similar to mining)

Radiant Solar Energy

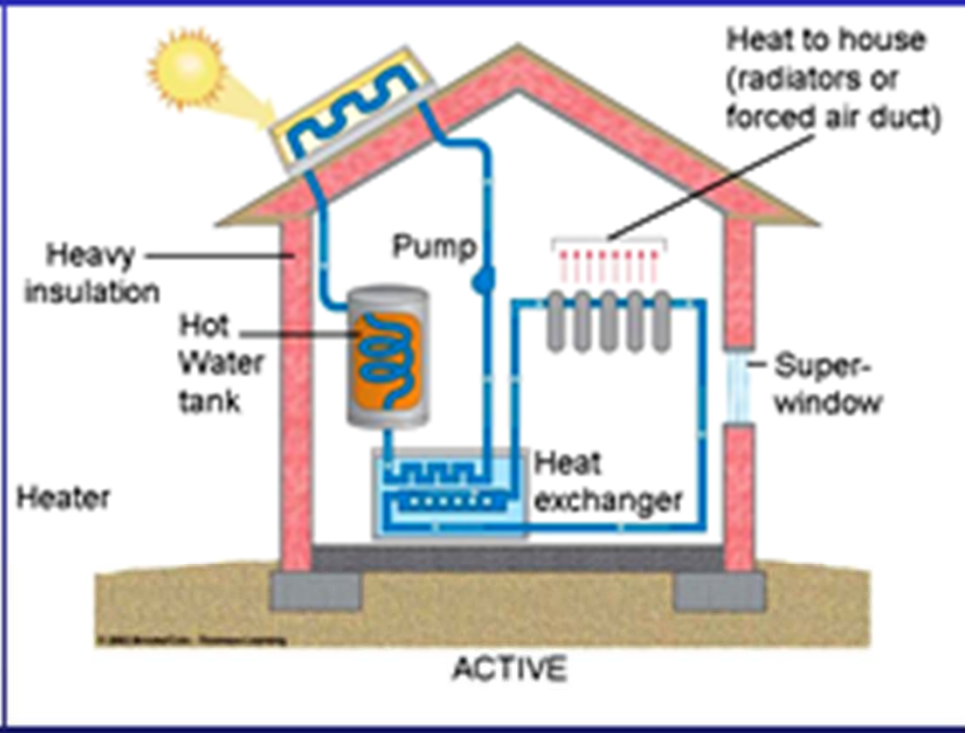
- How it works
  - Solar power plants
    - Steam produced to turn turbine
  - Solar heating
    - Active and passive systems
  - Photovoltaic cells
    - “Solar batteries” use special semiconductors
- Advantages
  - Renewable and free
  - High energy yield
  - A very clean source of energy
    - No air/water pollution during operation
  - Low operating costs
    - Will pay for themselves over time
- Disadvantages
  - Intermittent source
    - Energy storage issues
  - Low energy density
    - Requires pretty much land

Using Solar Energy to Provide Heat

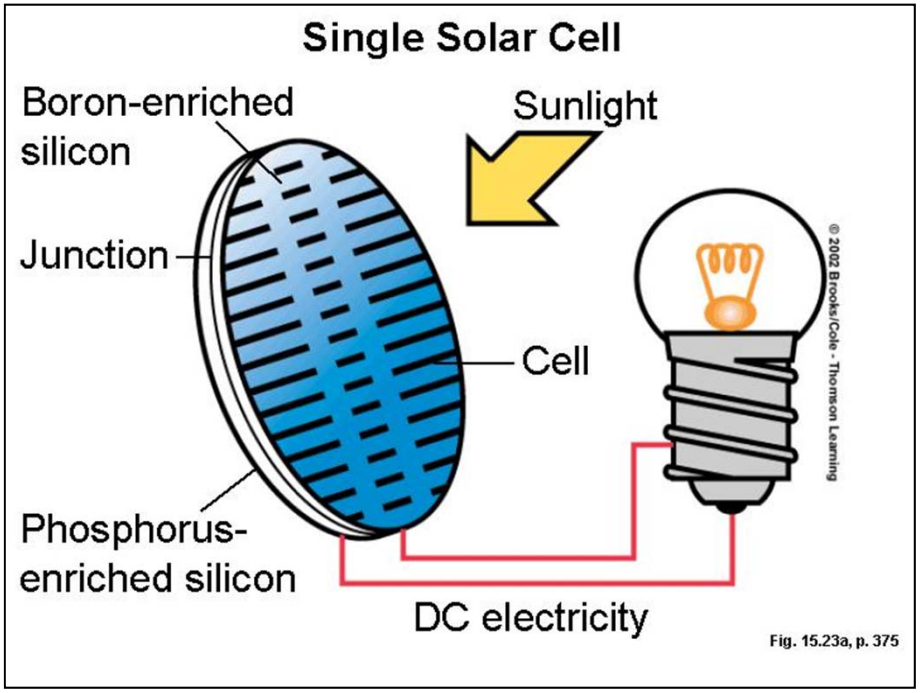
Passive solar heating



Active solar heating



Using Solar Energy to Provide High-Temperature Heat and Electricity



Trade-Offs

Solar Cells

Advantages	Disadvantages
Fairly high net energy	Need access to sun
Work on cloudy days	Low efficiency
Quick installation	Need electricity storage system or backup
Easily expanded or moved	
No CO_2 emissions	High land use (solar-cell power plants) could disrupt desert areas
Low environmental impact	
Last 20–40 years	
Low land use (if on roof or built into walls or windows)	High costs (but should be competitive in 5–15 years)
Reduces dependence on fossil fuels	DC current must be converted to AC

Renewable Solar Paths to Hydrogen