



Chapter 13

Achieving Energy Sustainability

Tidal Power

Energy from the Moon

in areas with large differences between
high and low tides.



Chapter 13 Opener
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What is renewable energy?

- ▣ Renewable energy can be rapidly regenerated, and some can never be depleted, no matter how much of them we use.

Nonrenewable



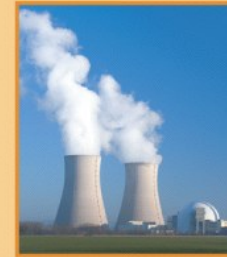
Natural gas



Oil

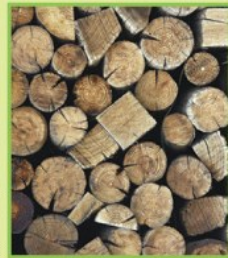


Coal



Nuclear

Potentially renewable



Wood



Biofuel

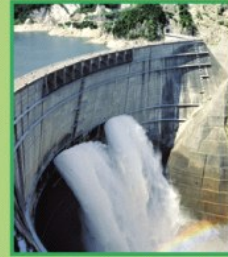
Nondepletable



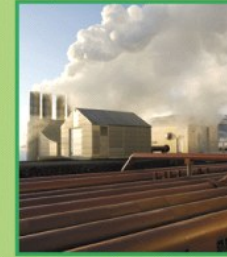
Wind



Solar



Hydroelectric



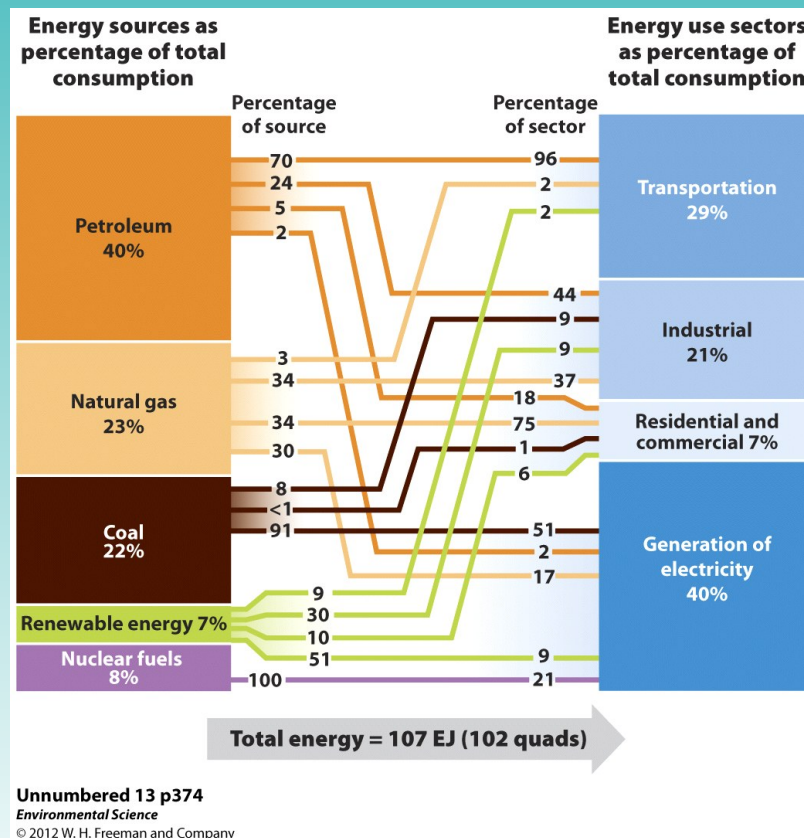
Geothermal

Figure 13.1

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Major Sources and Uses of Energy



Energy Use

Global

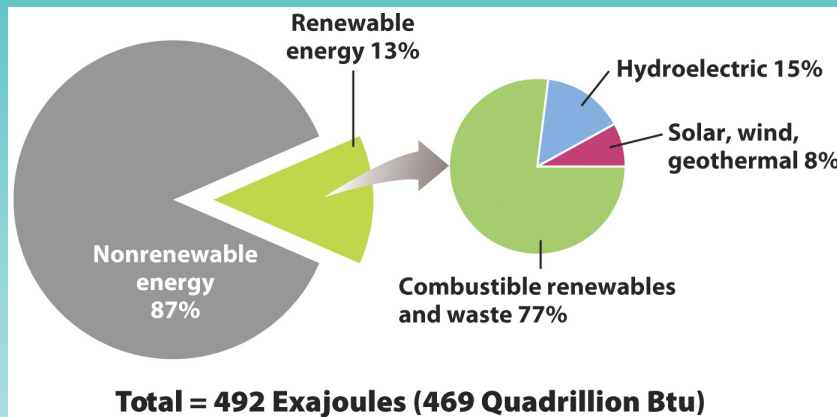


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United States

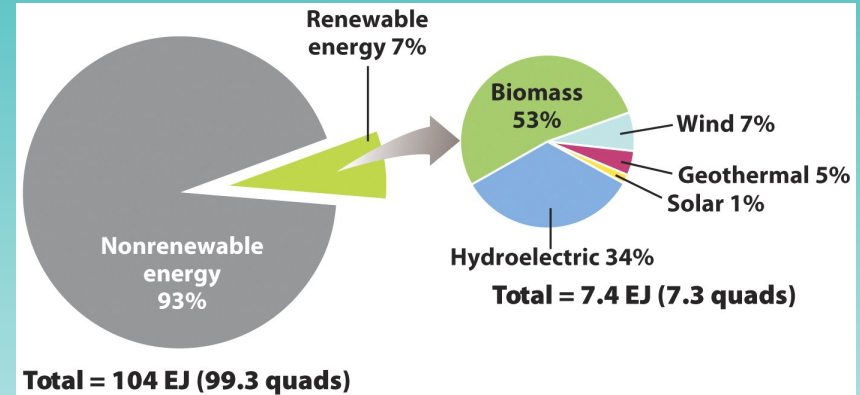


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Notice that in the US, over 80% of our renewables comes from Biomass and Hydroelectric...others are minor sources.

How can we use less energy?

- ▣ **Energy conservation**- finding ways to use less energy. For example, lowering your thermostat during the winter or driving fewer miles.
- ▣ **As Individual Consumers** – tiered rate system... lower rates at first, rate increases as usage increases.
- ▣ **Gov't programs** – higher taxes on fossil fuels, tax credits to replace old appliances, invest in smart grid tech.
- ▣ **Gov't mandates** – increase energy efficiency (ex: mpg), require some % of “green energy”.

Home

- **Weatherize (insulate, seal gaps).**
- **Turn thermostat down in winter, up in summer.**
- **Reduce use of hot water (do laundry in cold water/take shorter showers).**
- **Replace incandescent bulbs with compact fluorescents or LEDs.**



Transportation

- **Walk or ride a bike.**
- **Take public transportation.**
- **Carpool.**
- **Consolidate trips.**

Electrical and electronic devices

- **Buy Energy Star devices and appliances.**
- **Unplug when possible or use a power strip.**
- **Use a laptop rather than a desktop computer.**



Figure 13.4

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Benefits of Conservation and Efficiency

- ▣ Many energy companies have an extra backup source of energy available to meet the peak demand, the greatest quantity of energy used at any one time.
- ▣ Reducing Peak Demand to counter the need to build excess capacity.
- ▣ As to the 2nd Law...if efficiency of coal or nuclear is 30%, then if we can save 100 kWh of use, we save 300 kWh of energy resource, such as coal.

Sustainable Design

- Improving the efficiency of the buildings we live and work in.

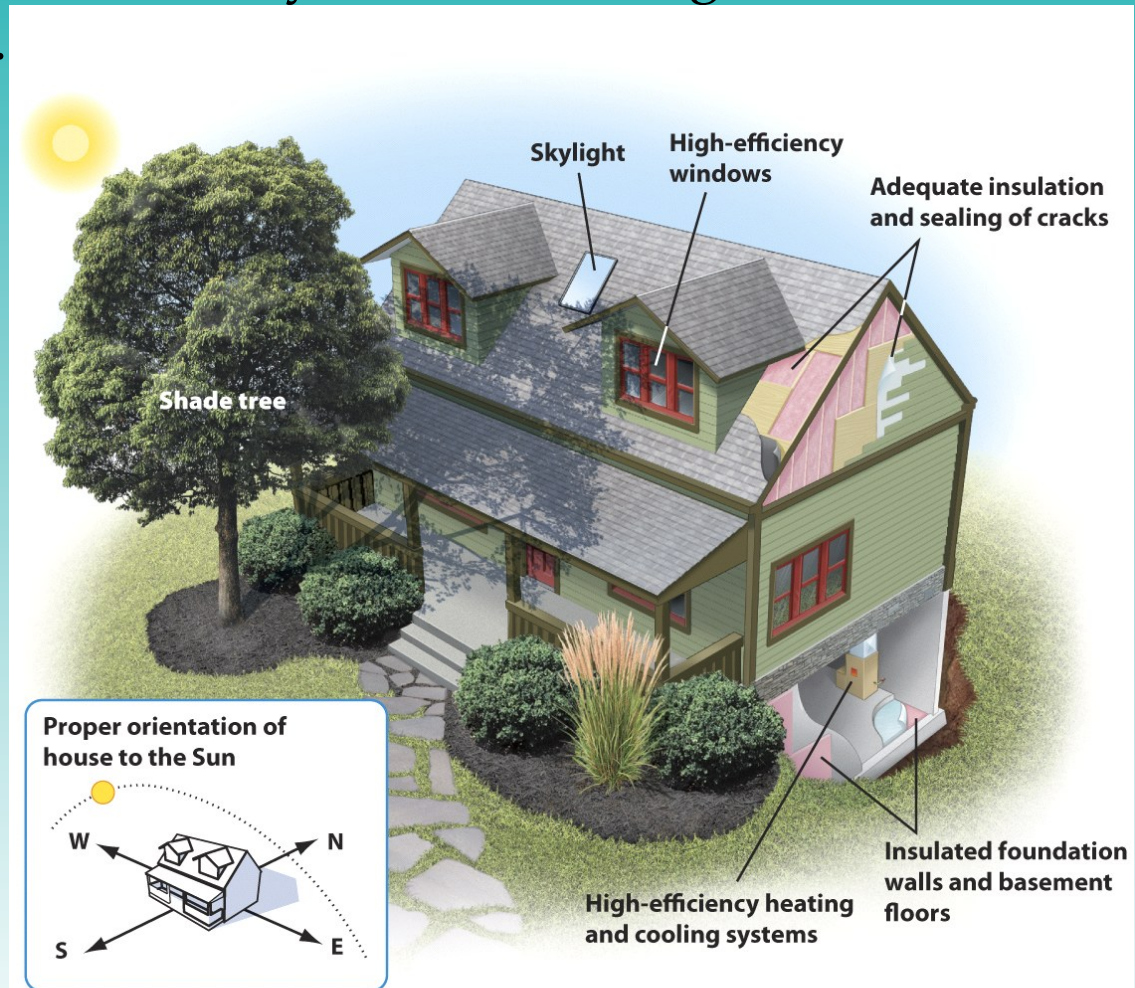


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Passive Solar Energy

- **Design elements:**
- South-facing windows
- Roof overhang
- Stone/concrete floors and walls
- Double-paned and Argon windows.
- Efficient venting and circulation systems.

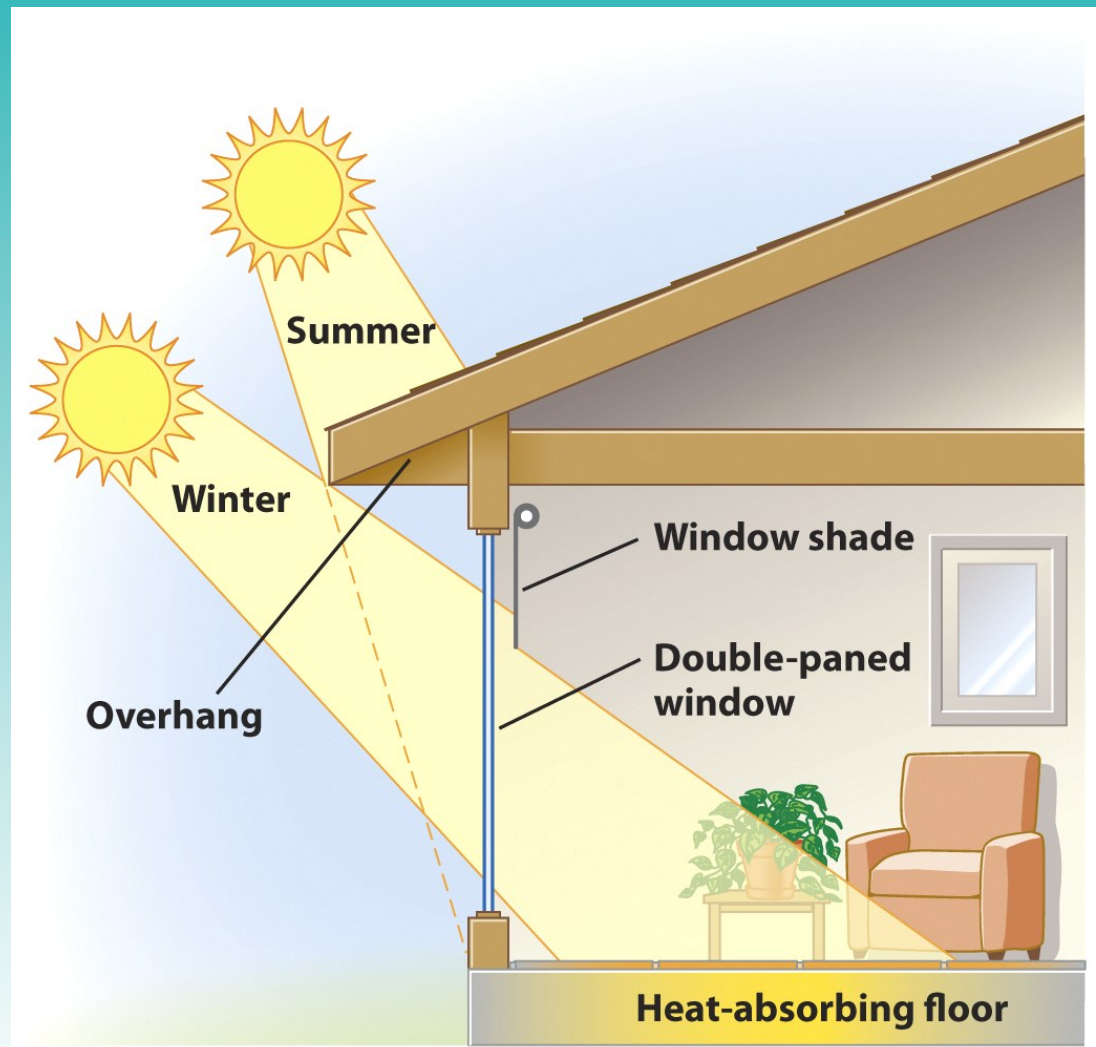


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Sustainable Design: California Academy of Sciences

Elements:
Natural light,
Ventilation,
Solar PV Panels,
Green Roof,
Water capture



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Fossil fuels, Renewable Energy, (including Biomass) are energy derived from the Sun

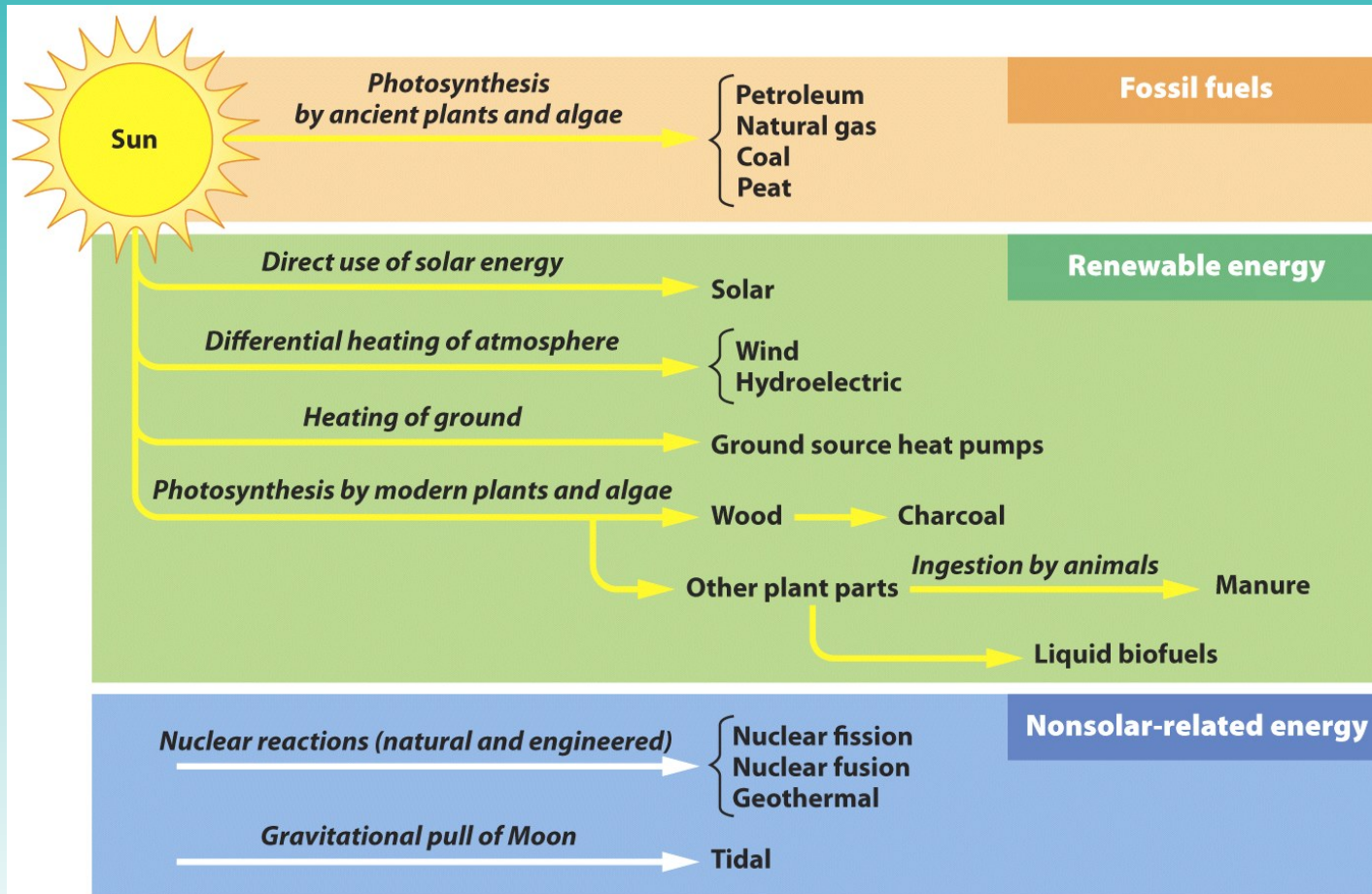


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Modern Carbon vs. Fossil Carbon

- ▣ Many people are confused how burning biomass such as wood is better than burning coal.
- ▣ The carbon found in biomass was in the atmosphere as carbon dioxide, taken in by the tree, and by burning it we put it back into the atmosphere
- ▣ Burning coal is carbon that has been buried for millions of years and was out of circulation until we began to use it. This results in a rapid increase in the concentration of carbon dioxide in the atmosphere.

Biomass

- ▣ Wood, Charcoal and Manure- used to heat homes throughout the world.
- ▣ Ethanol and Biodiesel (biofuels)- used as substitutes for gasoline and diesel fuel.



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The “Dark Side” of Biomass...particulates and smog due to use of wood-burning stoves. (Montreal, 2009)



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The kinetic energy of water can generate electricity – 2nd most common form of renewable energy.



China's 3 Gorges Dam

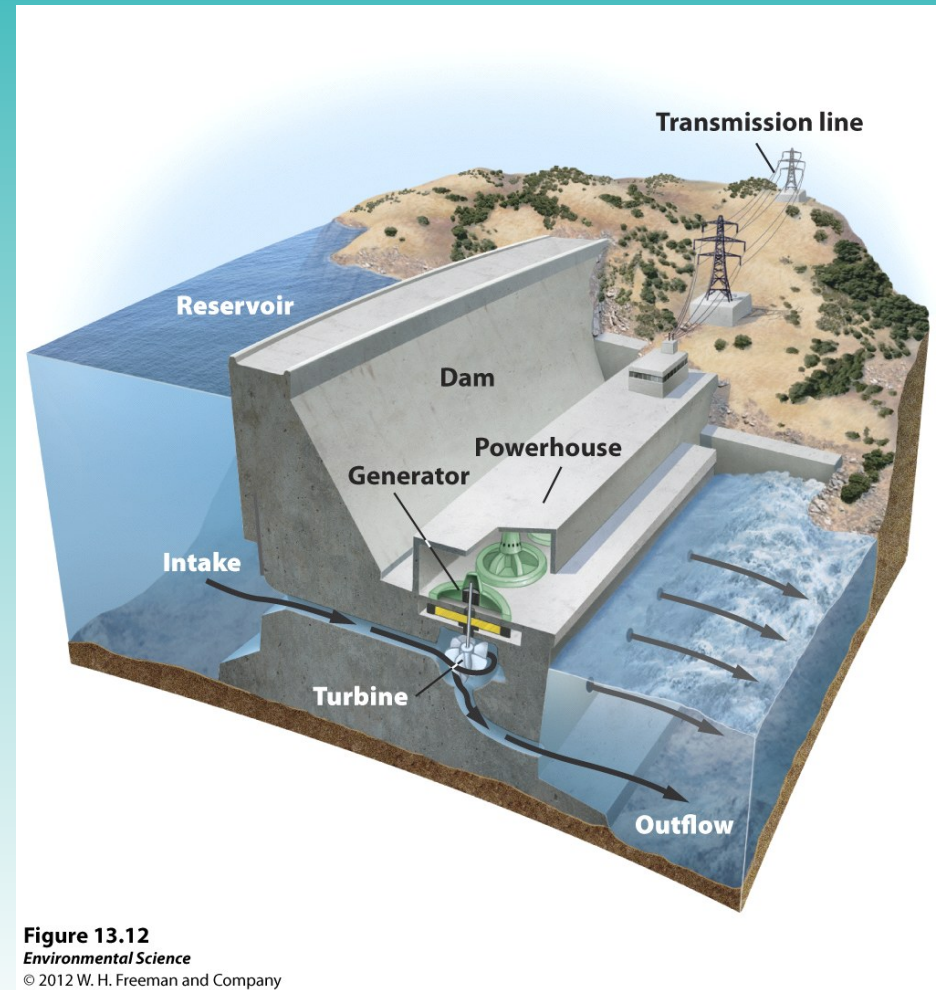


3 Gorges Dam Footprint



Types of hydroelectric power systems

- **Run-of-the-river systems-** water is held behind a dam and runs through a channel before returning to the river.
- **Water impoundment-** water is stored behind a dam and the gates of the dam are opened and closed controlling the flow of water.
- **Tidal systems-** the movement of water is driven by the gravitational pull of the Moon.



Dam Removal Restoring a River



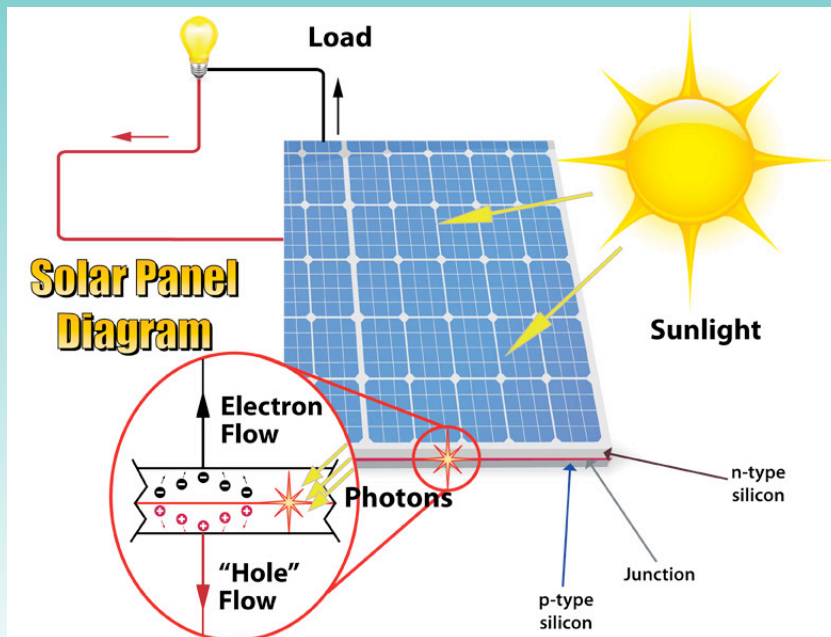
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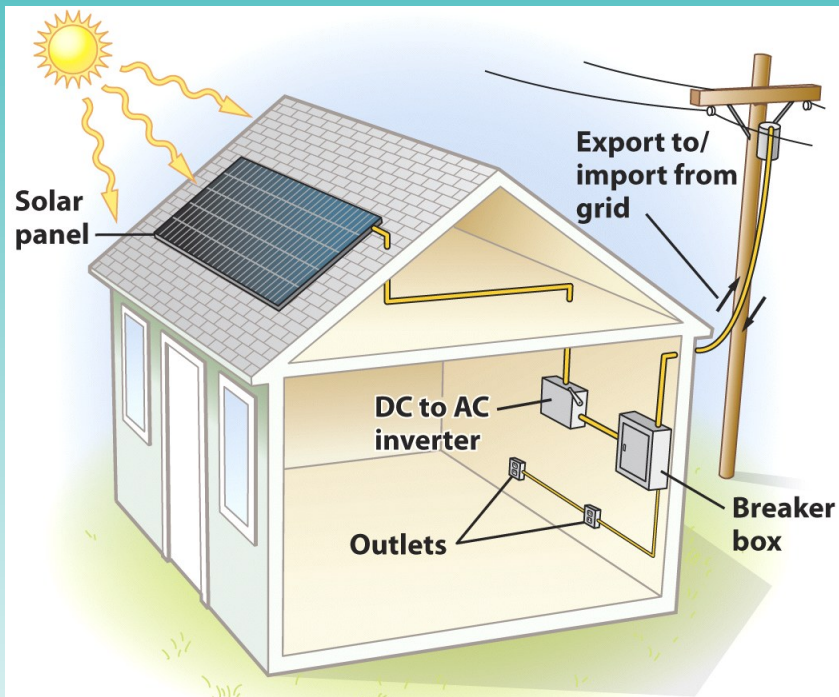
The Sun's energy can be captured directly

- Active solar energy- capturing the energy of sunlight with the use of a pump or photovoltaic cell and generating electricity.



Active Solar Power

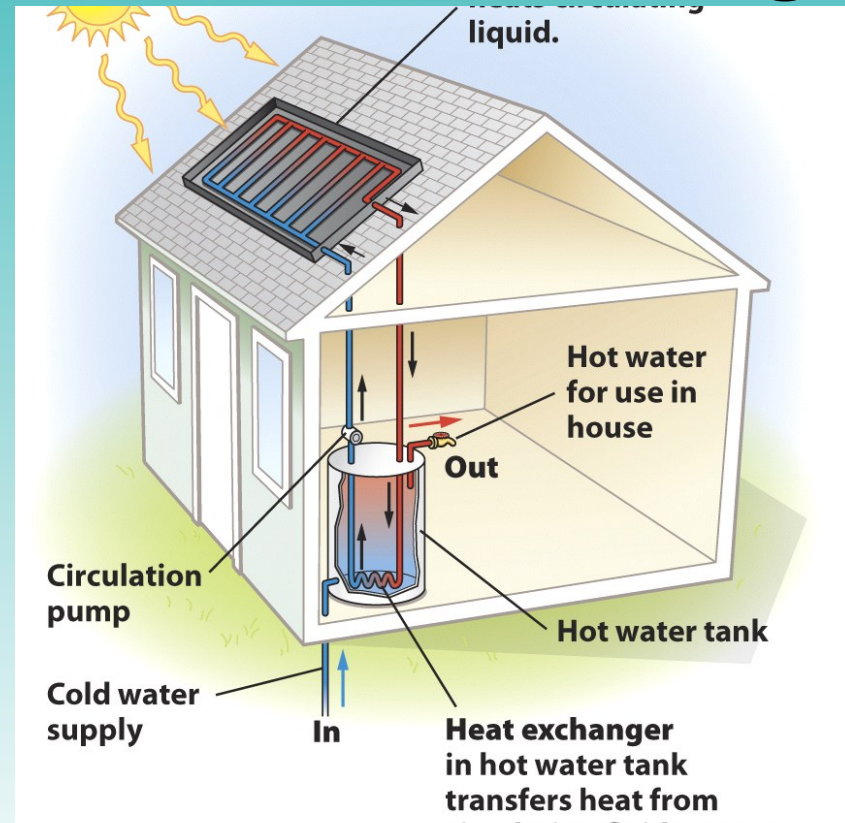
Photovoltaic PV



Schematic of photovoltaic (PV) system

Figure 13.18a
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Solar Water Heating





California home with PV panels on roof

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Geographic Variation in Solar Radiation and Solar Power Potential

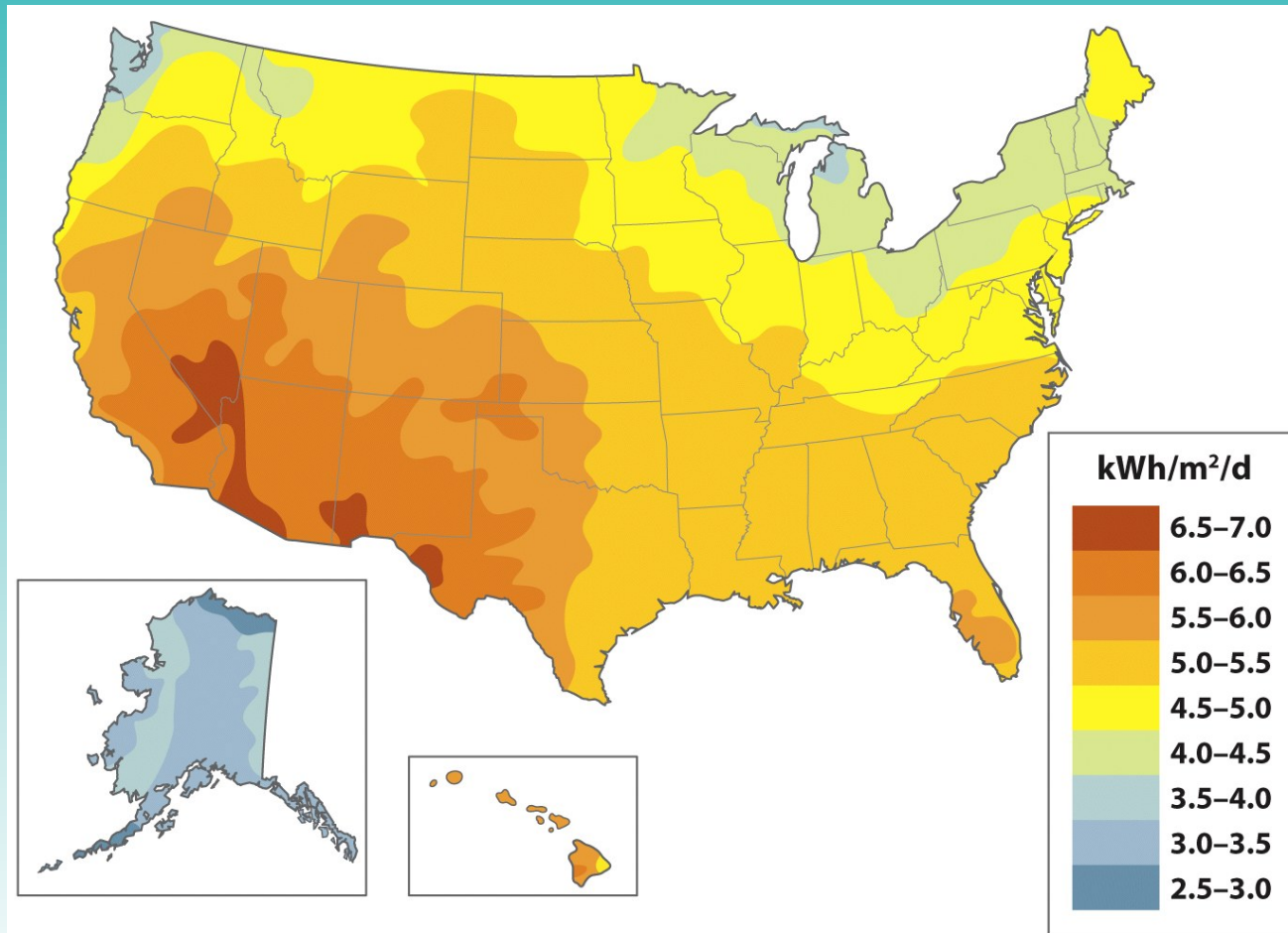


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Concentrating Solar Thermal (CST) Power Plant

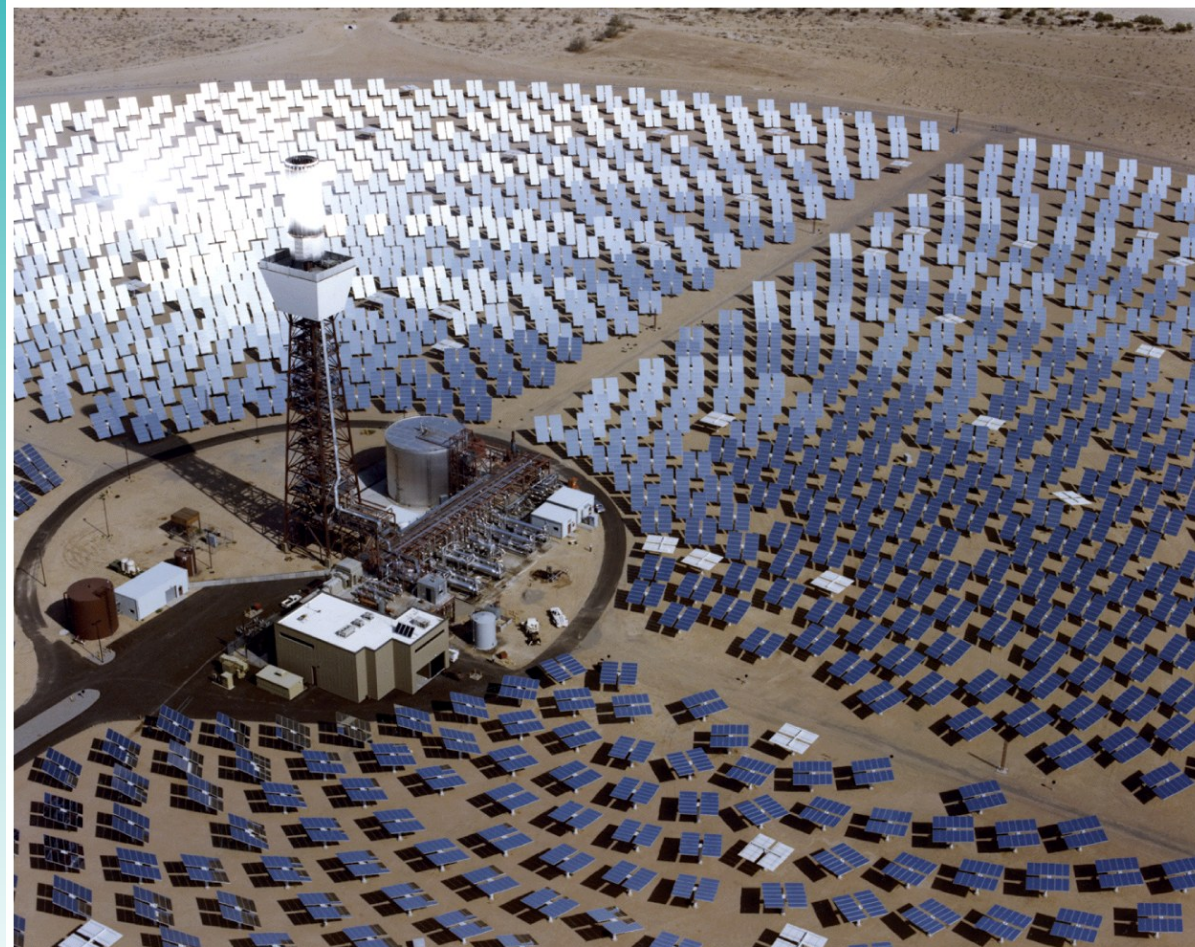


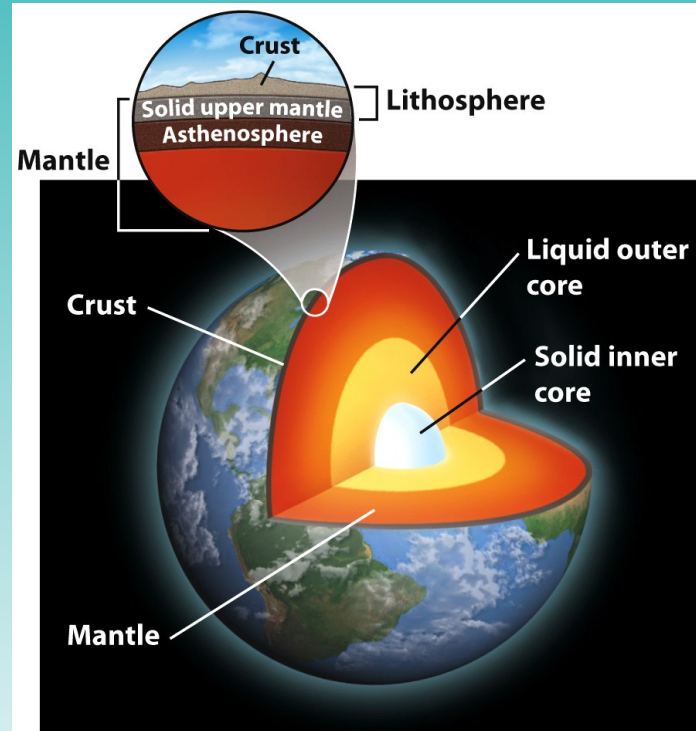
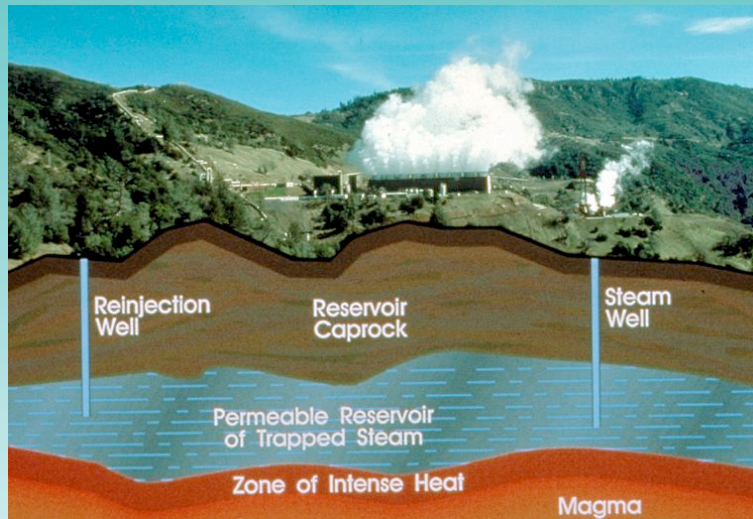
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Solar Cookers – to reduce use of firewood and other biomass fuels.



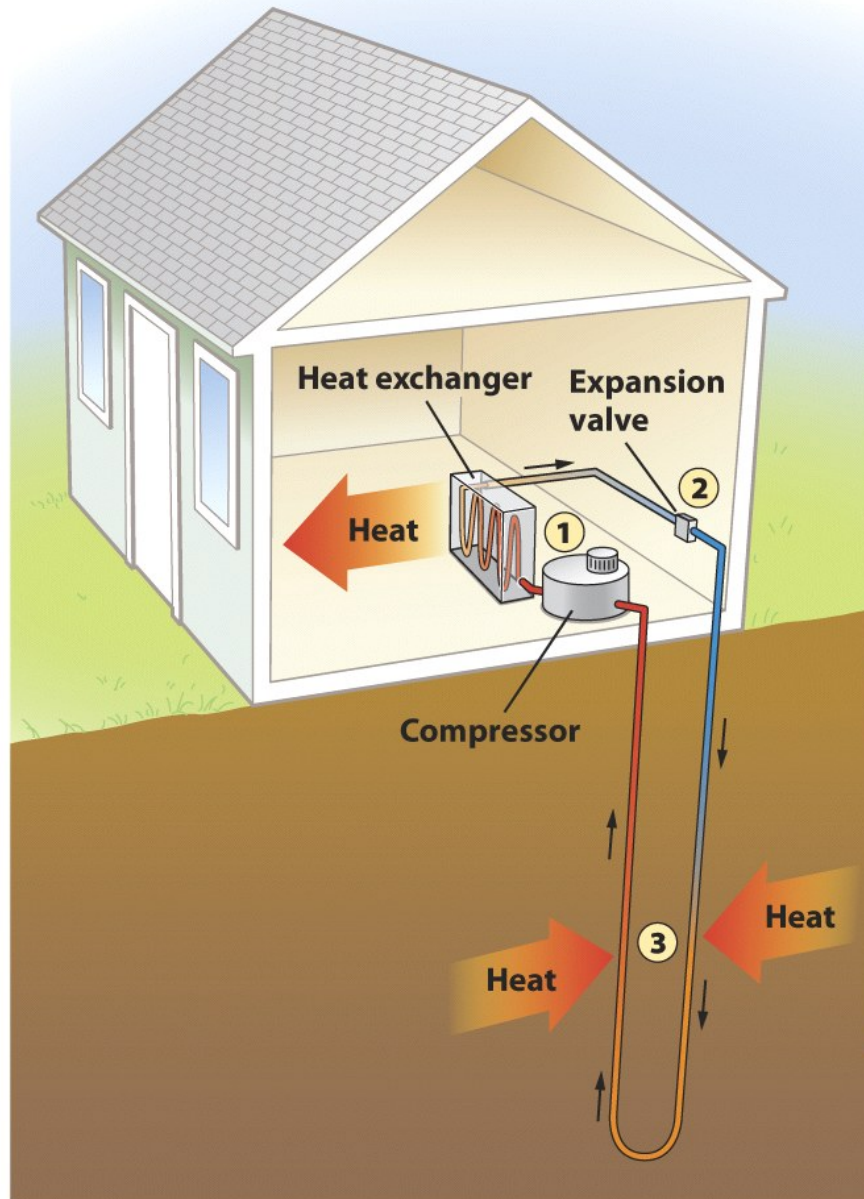
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Geothermal Heat Geyser, Hot Rock



Earth's vertical zonation

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1 At the compressor, the circulating fluid is compressed to form a hot gas. Heat is given off into the house from the heat exchanger as the gas cools to form a liquid.

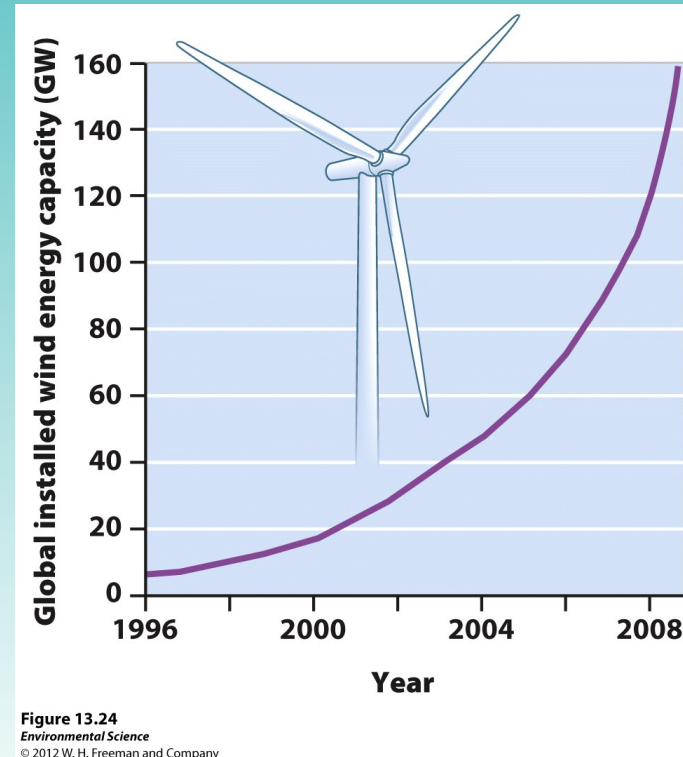
2 As the fluid expands and cools, it becomes a gas that is much cooler than the ground through which it will move.

3 The warmer ground heats the cool fluid, which cycles through buried tubing. Thus heat from the ground is essentially "pumped" into the building.

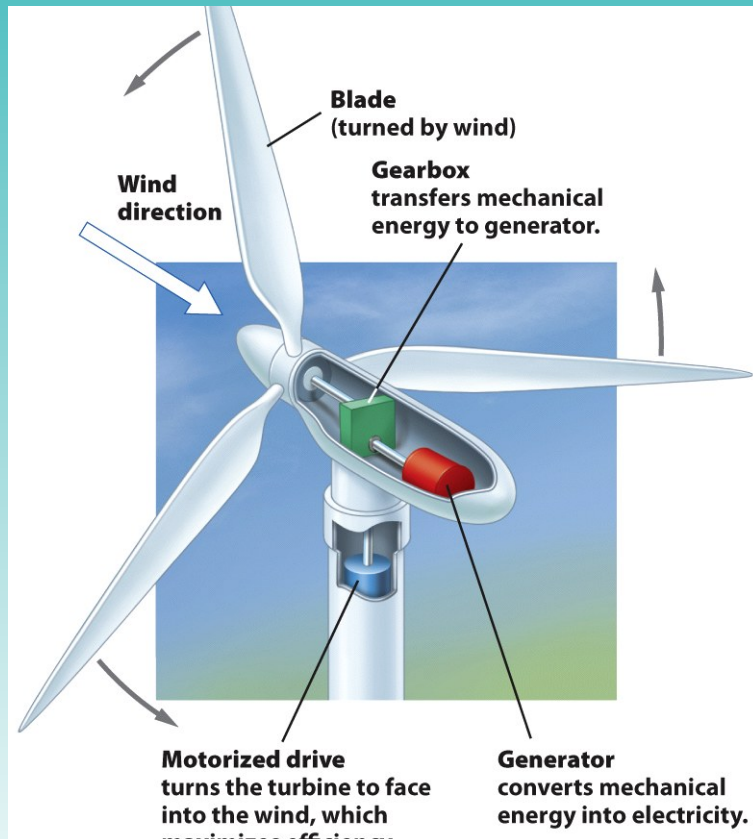
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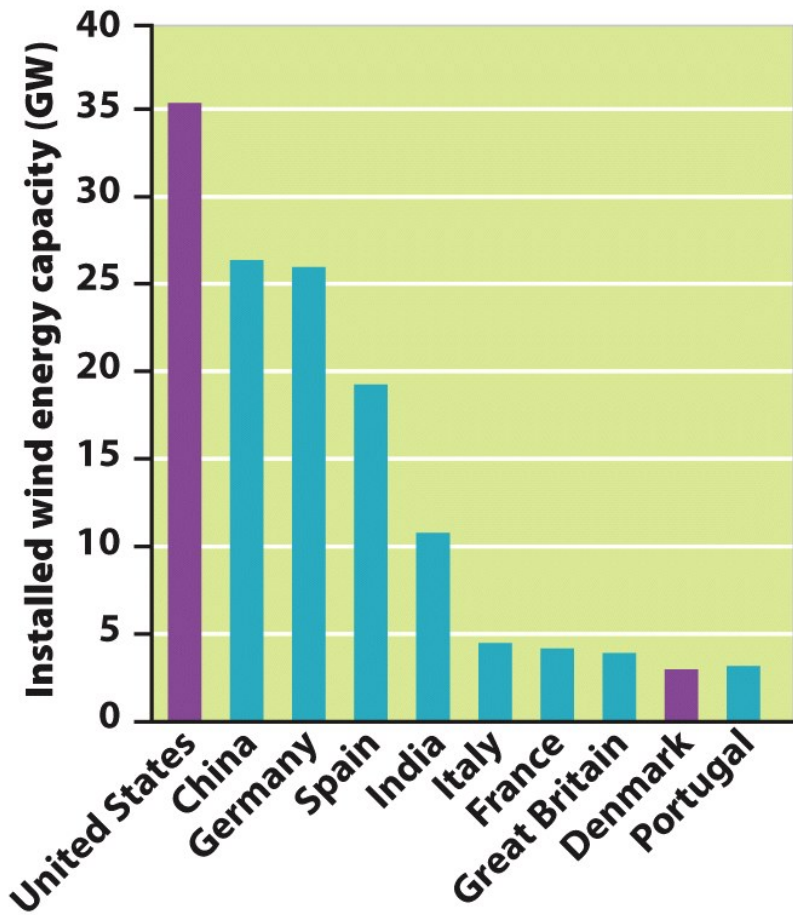
Wind energy is the most rapidly growing source of electricity

- ▣ Wind energy- using a wind turbine to convert kinetic energy into electrical energy.

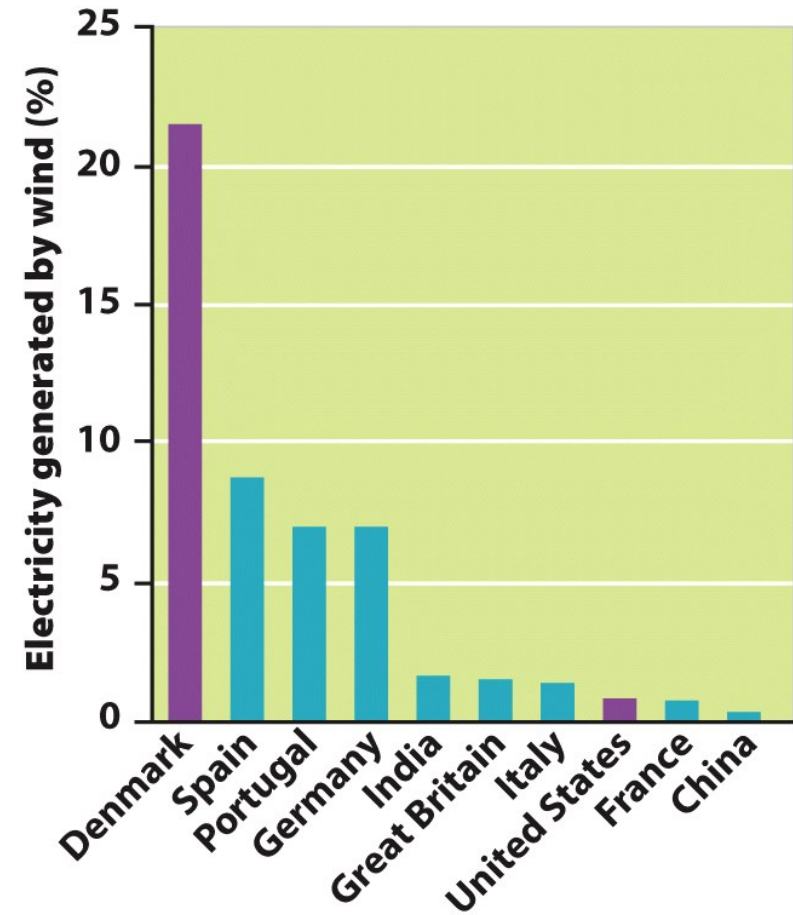


Wind Turbines





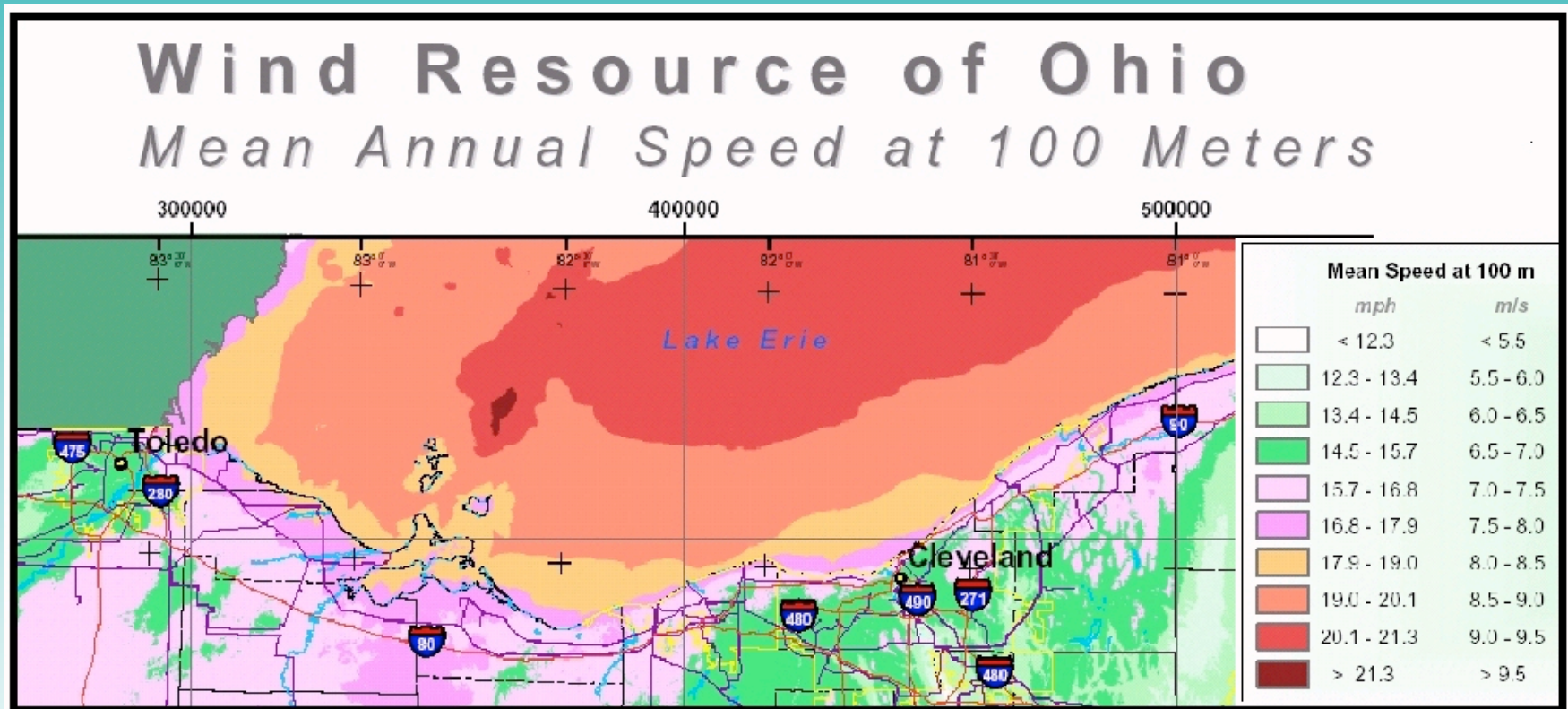
(a) Wind capacity



(b) Percentage from wind

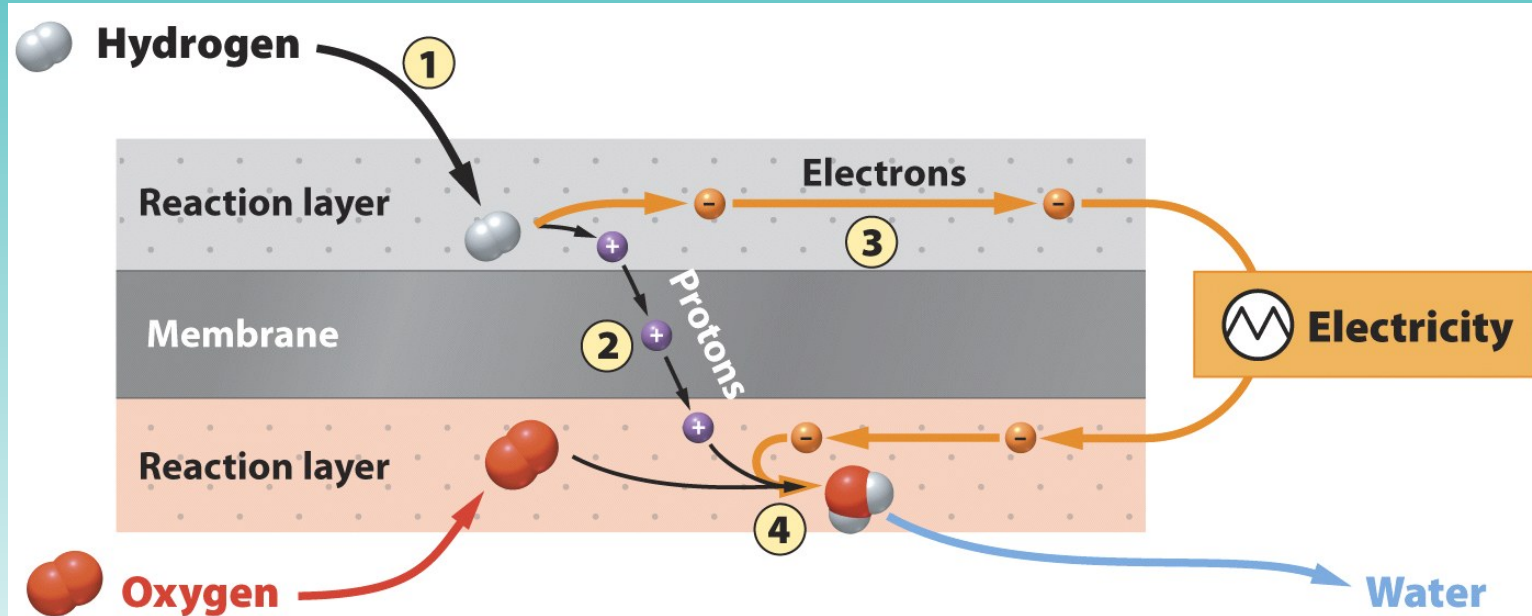
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Wind Farms on Lake Erie?



Hydrogen fuel cells have many potential applications

- ▣ Fuel cell- a device that operates like a common battery where electricity is generated by a reaction between two chemicals.

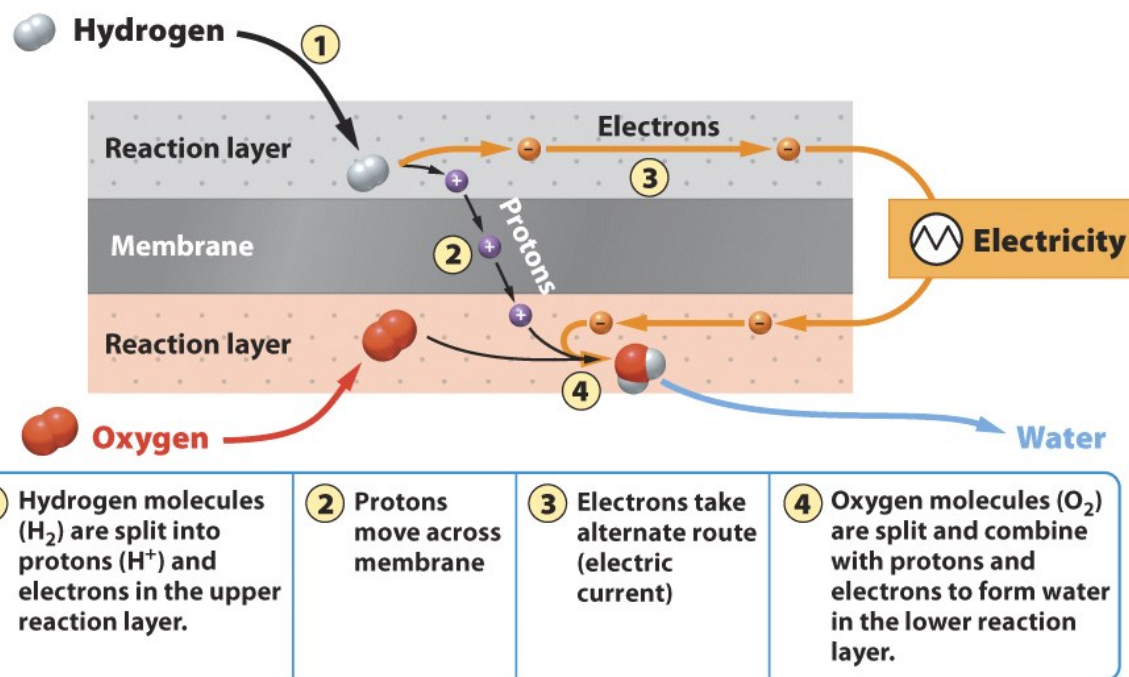


One common fuel cell design

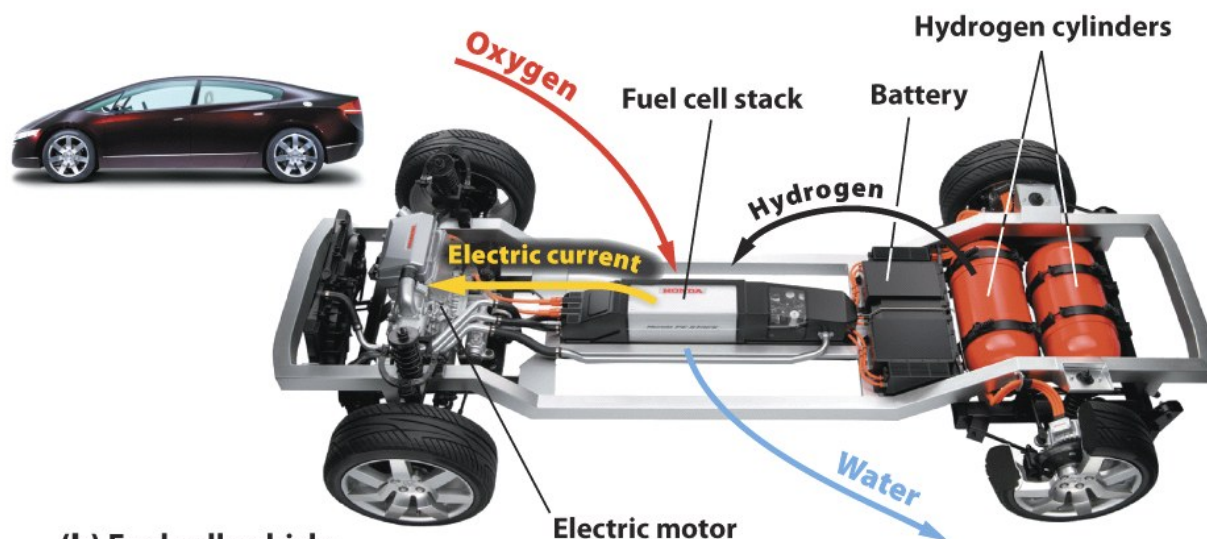
Figure 13.25a part 1

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(a) One common fuel cell design



(b) Fuel cell vehicle

Figure 13.25
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TABLE 13.1 Comparison of renewable energy resources

Energy resource	Advantages	Disadvantages	Emissions (pollutants and greenhouse gases)	Electricity cost (\$/kWh)	Energy return on energy investment
Liquid biofuels	Potentially renewable Can reduce our dependence on fossil fuels Reduces trade deficit Possibly more environmentally friendly than fossil fuels	Loss of agricultural land Higher food costs Lower gas mileage Possible net increase in greenhouse gas emissions	CO ₂ and methane		1.3 (from corn) 8 (from sugarcane)
Solid biomass	Potentially renewable Eliminates waste from environment Available to everyone Minimal technology required	Deforestation Erosion Indoor and outdoor air pollution Possible net increase in greenhouse gas emissions	Carbon monoxide Particulate matter Nitrogen oxides Possible toxic metals from MSW Danger of indoor air pollution		
Photovoltaic solar cells	Nondepletable resource After initial investment, no cost to harvest energy	Manufacturing materials requires high input of metals and water No plan in place to recycle solar panels Geographically limited High initial costs Storage batteries required for off-grid systems	None during operation Some pollution generated during manufacturing of panels	0.2	8
Solar water heating systems	Nondepletable resource After initial investment, no cost to harvest energy	Manufacturing materials requires high input of metals and water No plan in place to recycle solar panels Geographically limited High initial costs	None during operation Some pollution generated during manufacturing of panels		
Hydroelectricity	Nondepletable resource Low cost to run Flood control Recreation	Limited amount can be installed in any given area High construction costs Threats to river ecosystems Loss of habitat, agricultural land, and cultural heritage; displacement of people Siltation	Methane from decaying flooded vegetation	0.05–0.11	12
Tidal energy	Nondepletable resource After initial investment, no cost to harvest energy	Potential disruptive effect on some marine organisms Geographically limited	None during operation		15
Geothermal energy	Nondepletable resource After initial investment, no cost to harvest energy Can be installed anywhere (ground source heat pump)	Emits hazardous gases and steam Geographically limited	None during operation	0.05–0.30	8
Wind energy	Nondepletable resource After initial investment, no cost to harvest energy Low up-front cost	Turbine noise Deaths of birds and bats Geographically limited to windy areas near transmission lines Aesthetically displeasing to some Storage batteries required for off-grid systems	None during operation	0.04–0.06	18
Hydrogen fuel cell	Efficient Zero pollution	Producing hydrogen is an energy-intensive process Lack of distribution network Hydrogen storage challenges	None during operation		8

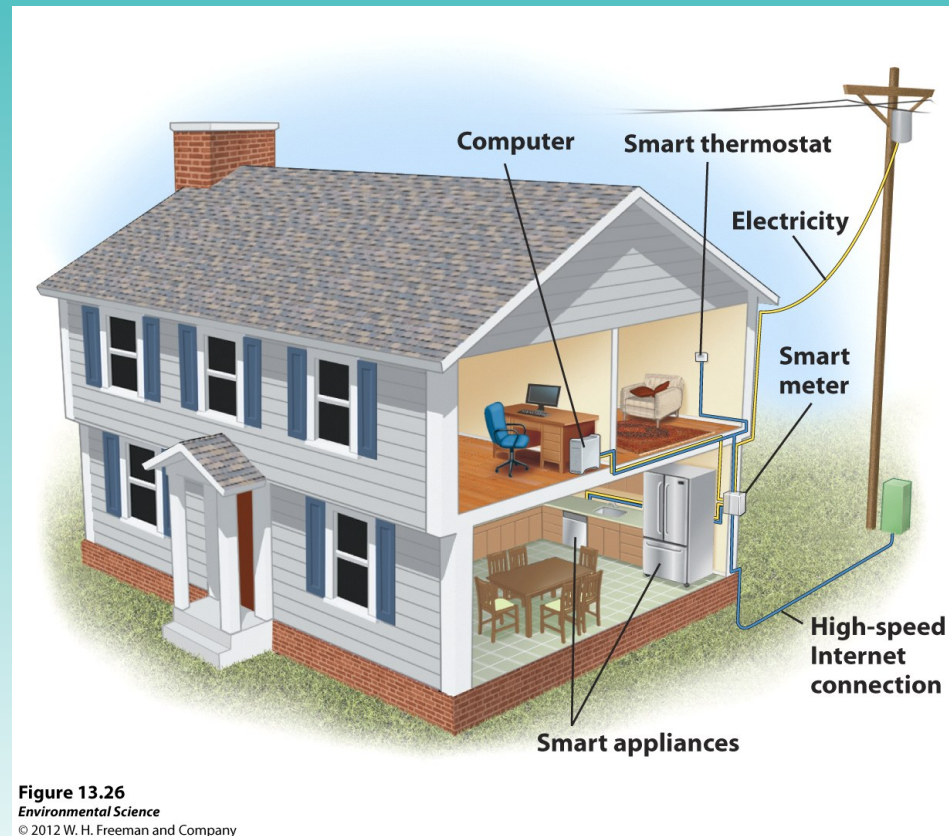
Sources: I. Kubiszewski and C. J. Cleveland, Energy return on investment (EROI) for wind energy, in *Encyclopedia of Earth*, ed. C. J. Cleveland, 2008; C. Hall, Why EROI matters (Part 1 of 6), *The Oil Drum*, April 1, 2008, <http://www.theoil Drum.com/node/3786>.

Table 13.1

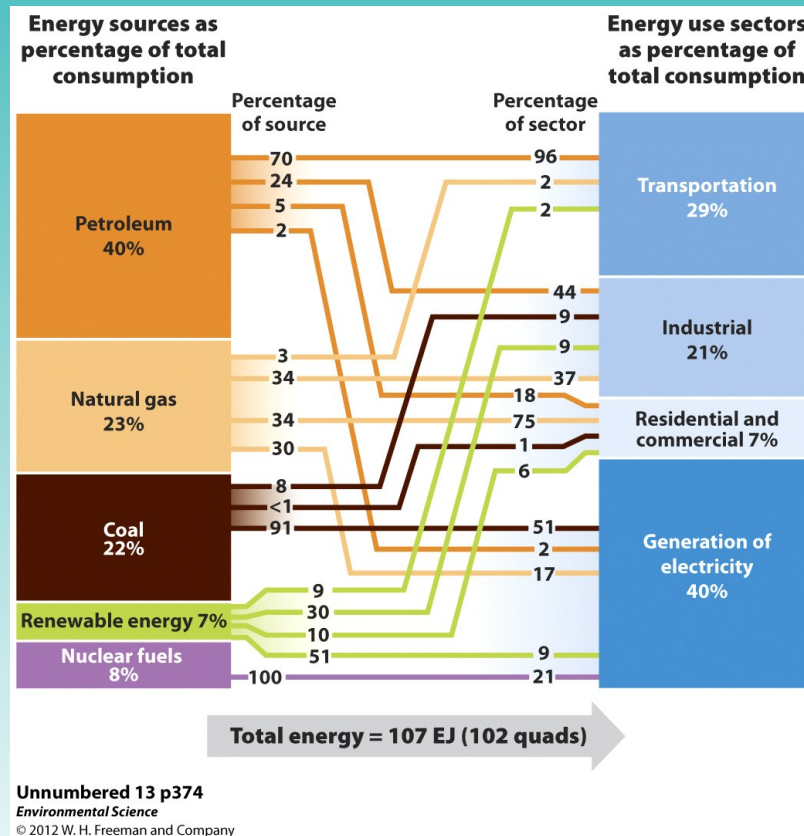
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Planning for the Future



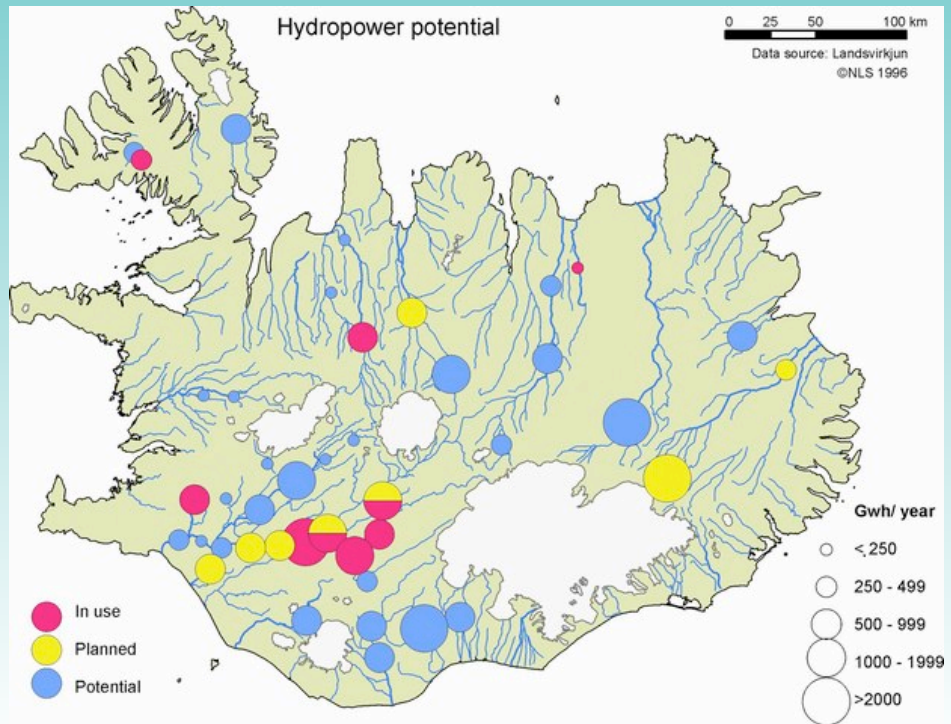
Energy Reconsidered



Iceland



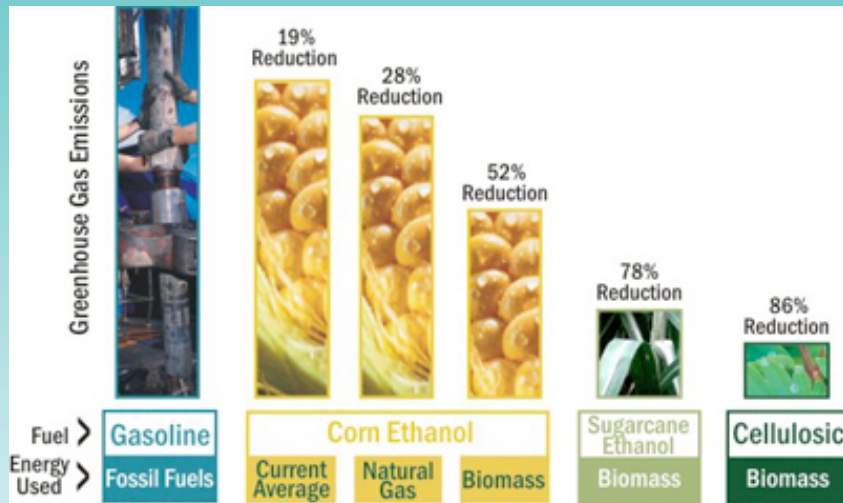
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Use Corn for Biofuel?

Ethanol from Corn

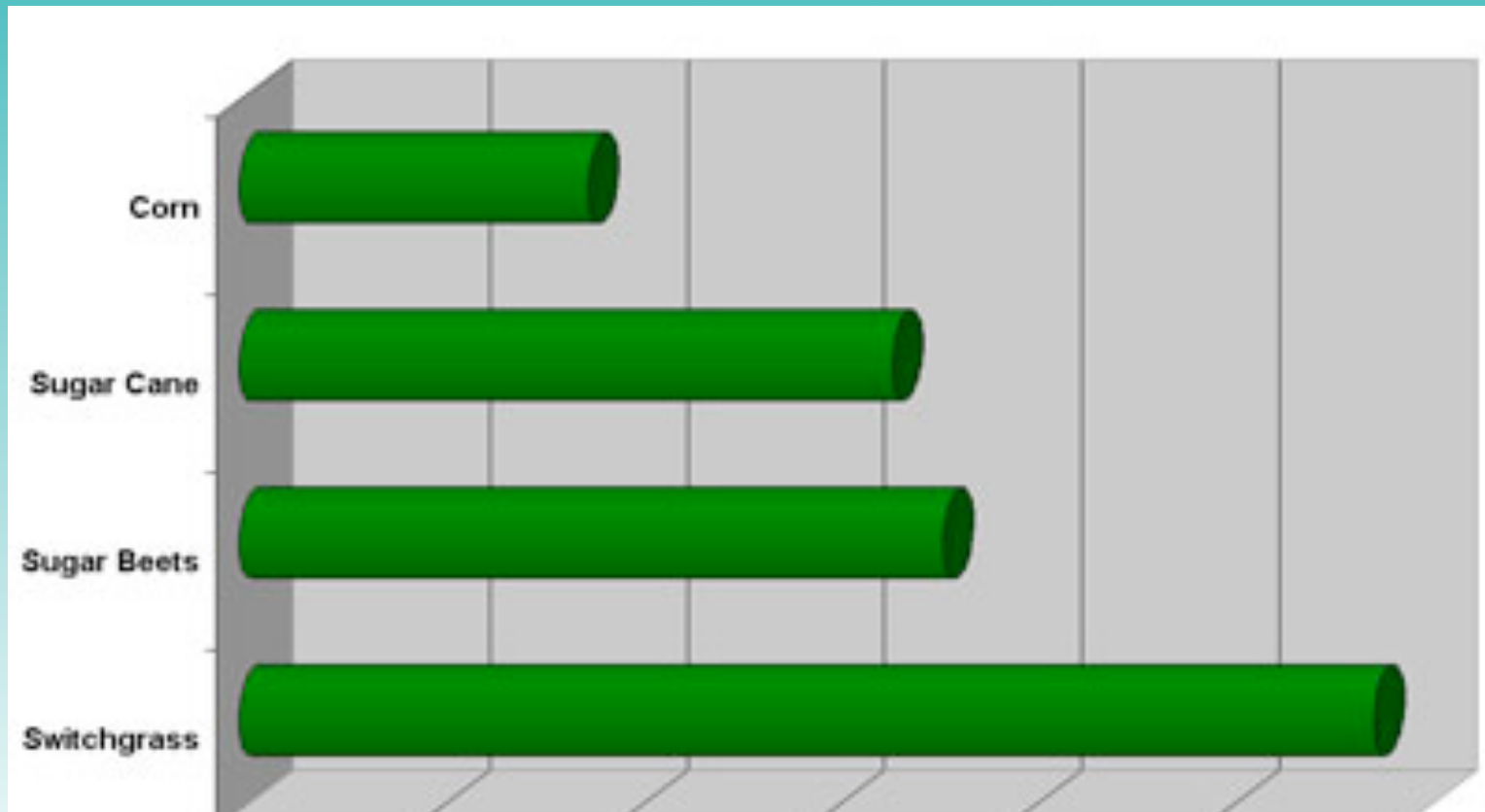
Ethanol from other sources...

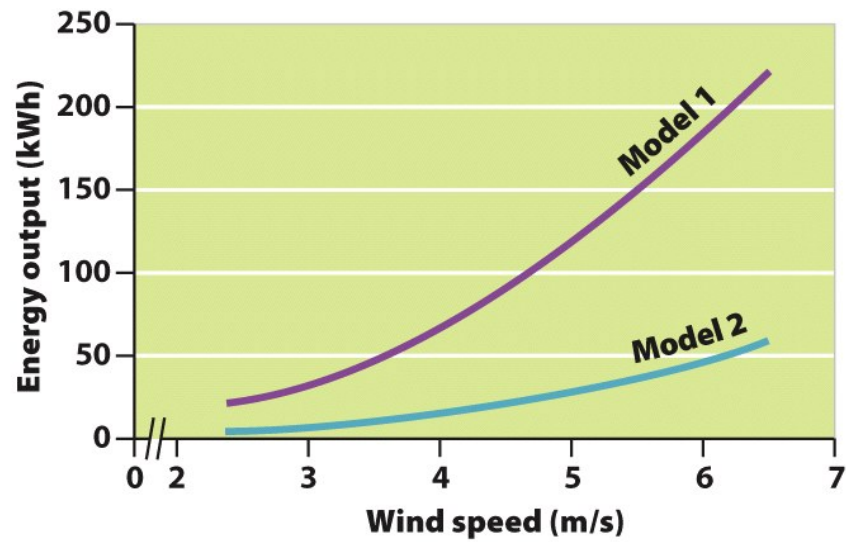


Source: Wang et al, *Environmental Research Letters*, Vol. 2, 024001, May 22, 2007

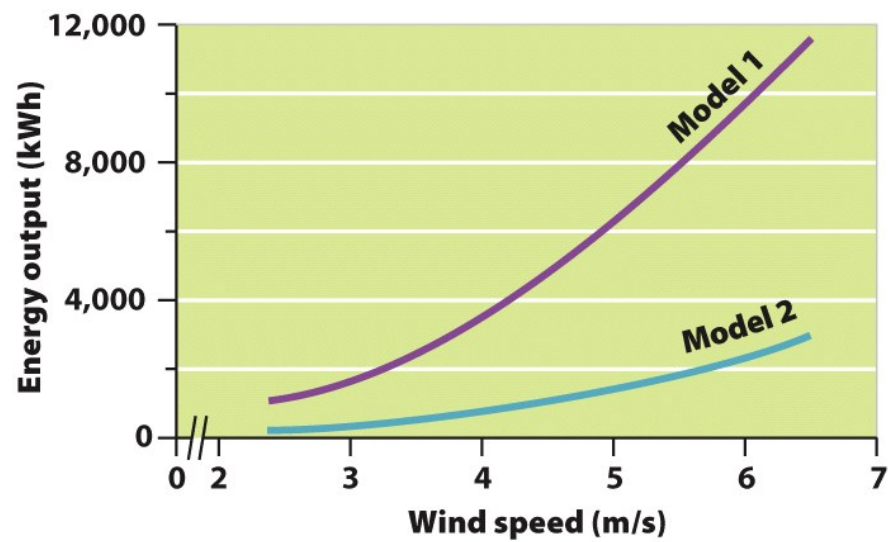


Comparison...





(a) Weekly energy output



(b) Annual energy output

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Energy Reconsidered

