APES CHAPTER 13 NOTES (MRS. BAUCK):
ACHIEVING ENERGY SUSTAINABILITY

MODLUE 37: Conservation, Efficiency, and Renewable Energy

I. Conservation
   A. **conservation**—*decreasing energy use through various methods*
   B. conservation methods can be implemented by individuals, industries, local governments, countries, etc.
   C. **tiered rate system**—*electric companies charge a higher rate as customers use more electricity*

II. Efficiency
   A. **Energy Star Program** (from https://www.energystar.gov/about/)

> "ENERGY STAR is a U.S. Environmental Protection Agency (EPA) voluntary program that helps businesses and individuals save money and protect our climate through superior energy efficiency. The ENERGY STAR program was established by EPA in 1992… *the ENERGY STAR program has boosted the adoption of energy efficient products, practices, and services through valuable partnerships, objective measurement tools, and consumer education."*

   B. examples
      1) lighting: LED, fluorescent/CFL, skylight windows
      2) reduce or eliminate "vampire load"
      3) keep car in good running condition; carpool when possible
      4) install energy-efficient appliances
      5) walk, bike, etc.
      6) monitor and adjust thermostat
      7) implement sustainable building design
      8) install solar panels

III. Renewable Energy Types
   A. **potentially renewable**—*an energy source that can be regenerated indefinitely, as long as consumption does not outpace replenishment*
   B. **nondepletable**—*an energy source that can't be used up* (solar energy)

MODULE 38: Biomass and Water

I. Biomass
   A. contains **modern carbon** *that was recently in the atmosphere, as opposed to* **fossil carbon** *in fossil fuels*
   B. *strive for a* **carbon neutral** *state* (not changing atmospheric CO_2 concentrations)
   C. **net removal**—*process of removing more than is replaced by growth*
   D. production of biomass energy = bioconversion

II. Solid Biomass

A. **biomass energy** (**bioconversion**)

B. *plant and animal matter that can be used as an energy source*: paper, wood, plant waste, charcoal, manure, etc.

1) *firewood (fuelwood)*
   a) burning wood as is, in developing countries
   b) wood-burning stoves
   c) pellet stoves—burn pellets of wood (compressed wood waste)
   d) developing countries: over 1 billion people rely on fuelwood
   e) *consumptive* use, contributing to *deforestation*
   f) need more regulation of wood consumption and incentives for replanting
2) sludge
   a) anaerobic digestion by bacteria of organic matter produces *biogas (digester gas)* and sludge
   b) biogas is 2/3 *methane*; used as fuel
   c) the sludge is excellent as fertilizer
3) other waste products as fuel
   a) sugar refineries burn sugar cane
   b) wood working companies burn wood waste
4) *charcoal*—lightweight black carbon and ash residue from removing water and other volatile compounds from animal and vegetable matter

C. burning biomass produces CO_2, CO, NO_x, PM

III. Liquid Biomass: biofuels

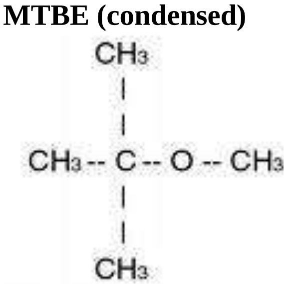
A. producing *alcohol* (**ethanol** = *ethyl alcohol* = CH_3CH_2OH) – *a* **biofuel**
   a) product of fermentation
   b) *gasohol*: usually *90% gasoline : 10% ethanol*
      or *97% gasoline : 3% methanol* (wood alcohol, CH_3OH)

from http://www.encyclopedia.com

> "Gasohol has higher octane, or antiknock, properties than gasoline and *burns more slowly, coolly, and completely*, resulting in reduced emissions of some pollutants, *but it also vaporizes more readily*, potentially aggravating ozone pollution in warm weather. *Ethanol-based gasohol is expensive and energy intensive to produce, and can damage rubber seals and diaphragms and certain finishes* if the ethanol is present in higher concentrations. Since 1998, however, many American automobiles have been equipped to enable them to run on *E85, a mixture of 85% ethanol and 15% gasoline*. *Methanol-based gasohol is also expensive to produce and is toxic and corrosive*, and its emissions produce cancer-causing formaldehyde."

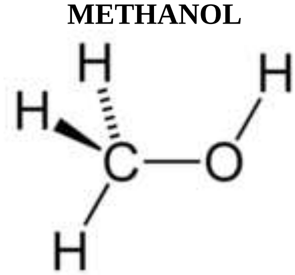
B. MTBE: methyl tert-butyl ether, used as a gasoline additive; may be phased out since it is a carcinogen

MTBE (condensed)



ETHANOL

METHANOL



IV. Biofuels

A. **biofuel**—*liquid fuel from processed or refined biomass*

B. *gasohol*

1) *E10 (90-% gasoline, 10% ethanol)*
   a) approved for cars but not for aircraft
   b) also E5 and E7 forms

2) *E85*
   a) *85% denatured fuel ethanol, 15% gasoline or other hydrocarbon*
   b) more info…

increasingly common in the U.S., mainly in the Midwest where corn is a major crop and is the primary source material for ethanol fuel production

3) **flex-fuel vehicles** *use gasoline or E85*

C. **Biodiesel—** a **biofuel** diesel substitute http://www.biodiesel.org
(not the same as raw vegetable oil)

1) official definition:

> "Biodiesel is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats which conform to ASTM D6751 specifications for use in diesel engines. *Biodiesel refers to the pure fuel before blending with diesel fuel.* Biodiesel blends are denoted as, "BXX" with "XX" representing the percentage of biodiesel contained in the blend… Biodiesel is the name of a clean burning alternative fuel, produced from domestic, renewable resources. *Biodiesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a biodiesel blend*. It can be used in compression-ignition (diesel) engines with little or no modifications. Biodiesel is simple to use, biodegradable, nontoxic, and essentially free of sulfur and aromatics."

2) *"neat biodiesel" = 100% natural oils*
3) *standard biodiesel* = B20 (a blend of 20% by volume biodiesel with 80% by volume petroleum diesel)
4) comparison of emissions vs. diesel fuel

> "Biodiesel is the only alternative fuel to have fully completed the health effects testing requirements of the Clean Air Act. The use of biodiesel in a conventional diesel engine results in substantial reduction of unburned hydrocarbons, carbon monoxide, and particulate matter compared to emissions from diesel fuel. In addition, the exhaust emissions of sulfur oxides and sulfates (major components of acid rain) from biodiesel are essentially eliminated compared to diesel… A 1998 biodiesel lifecycle study… concluded biodiesel reduces net CO_2 emissions by 78% compared to petroleum diesel."

V. Water

A. **hydropower** (**hydroelectricity**) *power from dams*

B. https://water.usgs.gov/edu/wuhy.html ~17% of the renewable energy in the U.S.

C. hydroelectric methods

1) **run-of-the-river systems** use dams

2) **water impoundment systems** use reservoirs

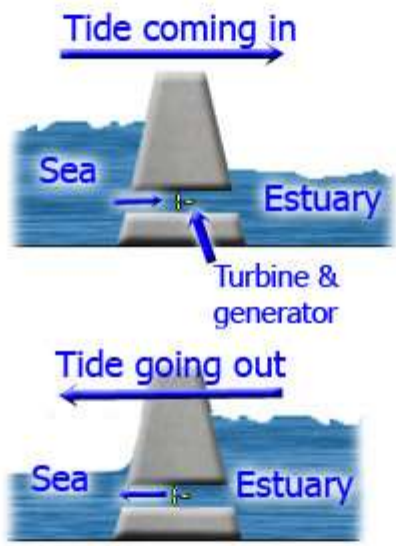
(**siltation**—*accumulation of sediments at the bottom of a reservoir*)

3) **tidal power**

From http://www.alternative-energy-news.info/technology/hydro/tidal-power/

"Tidal energy is produced through the use of tidal energy generators. These large underwater turbines are placed in areas with high tidal movements, and are designed to capture the kinetic motion of the ebbing and surging of ocean tides in order to produce electricity. Tidal power has great potential for future power and electricity generation because of the massive size of the oceans."

From http://www.darvill.clara.net/altenerg/tidal.htm



a) *pros*
- clean and renewable
- reliable and predictable
- produces no liquid or solid pollutants
- little aesthetic impact
- acts as coastal shelters
- no land waste

b) *cons*
- *tidal difference is too close (usually less than 2 ft)- must be above ~15 ft (4.6 m) differential*
- *only 30 places have the topography (land layout) to do this, and 20 locations are sited as possible places*

c) locations
- *Nova Scotia, Canada: Annapolis Tidal Generating Station* (BEC - Blue Energy Canada)
- *France:* La Rance estuary in Northern France
  - first tidal power station, built in 1966
  - 8-13.5 m tidal differential
- Other locations: China, Russia, South Korea, U.K.
- More proposed locations in South Korea, China, Russia, Philippines, India

D. **Ocean Thermal Energy Conversion (OTEC)**

(from http://www.nrel.gov)

1) *Closed-cycle systems*

"Closed-cycle systems *use the ocean's warm surface water to vaporize a working fluid*, which has a low-boiling point, such as ammonia. *The vapor expands and turns a turbine..*."

2) *Open-cycle systems*

"…Open-cycle systems actually *boil the seawater* by operating at low pressures. This produces steam that passes through a turbine/generator."

3) *Hybrid systems* – use both methods

E. pros and cons of dams

1) *pros*
   a) nonpolluting: no fuel burned
   b) renewable energy source (rainfall renews the water in the reservoir, so the fuel is almost always there)
   c) reducing greenhouse gas (GHG) emissions
   d) relatively low operations and maintenance costs
   e) technology is reliable and proven over time
2) *cons*
   a) high investment costs
   b) hydrology-dependent (on precipitation)
   c) possible inundation (flooding) of land and wildlife habitat
   d) possible loss or modification of fish habitat
   e) fish entrainment or passage/migration restriction, even when "ladders" are built in
   f) possible changes in reservoir and stream water quality
   g) possible displacement of local populations
   h) changing a cold-flowing river into a warm-water reservoir changes humidity, increases decomposition/disintegration
   i) changing water flow and sediment distribution

TOP 5 HIGHEST DAMS in the U.S. (Source: USSD Register of Dams)

DAM NAME	RIVER	STATE	OWNER	FEET	COMPLETED
Oroville	Feather	California	California DWR	770	1968
Hoover	Colorado	Nevada	Bureau of Reclamation*	730	1936
Dworshak	N. Fork Clearwater	Idaho	Corps of Engineers	717	1973
Glen Canyon	Colorado	Arizona	Bureau of Reclamation	710	1964
New Bullards Bar	North Yuba	California	Yuba County Water Agency	645	1969

TOP 5 LARGEST HYDRO PROJECTS IN THE UNITED STATES (Source: USSD Register of Dams)

DAM NAME	RIVER	LOCATION	MW
Grand Coulee	Columbia	Washington	6180
Chief Joseph	Columbia	Washington	2457
John Day	Columbia	Oregon	2160
Bath County P/S	Little Back Creek	Virginia	2100
Robert Moses - Niagara	Niagara	New York	1950

TOP 5 LARGEST HUMAN-MADE RESERVOIRS IN THE UNITED STATES
(Source: USSD Register of Dams)

DAM NAME	RESERVOIR	LOCATION	OWNER	ACRE-FEET	COMPLETED
Hoover	Lake Mead	Nevada	Bureau of Reclamation	28,255,000	1936
Glen Canyon	Lake Powell	Arizona	Bureau of Reclamation	27,000,000	1964
Oahe	Lake Oahe	South Dakota	Corps of Engineers	19,300,000	1966
Garrison	Lake Sakakawea	North Dakota	Corps of Engineers	18,500,000	1953
Fort Peck	Fort Peck Lake	Montana	Corps of Engineers	15,400,000	1957

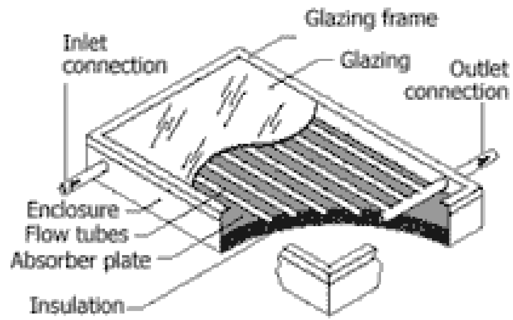
MODULE 39: Solar, Wind, Geothermal, and Hydrogen

I. Solar Energy
   A. *pros and cons*
      1) pros
         1) energy source is already present
         2) renewable
         3) will not disturb natural balance of energy
         4) products not radioactive
         5) will diminish our use of fossil fuels
         6) especially good for power generation in rural areas and developing countries
      2) cons
         a) expensive (but prices declining)
         b) requires a backup for nighttime or overcast conditions
         c) climate may not by sunny enough during winter for practical use in some parts of the world

B. solar heating of water

1) **passive solar design**—*uses natural convection currents and flat-plate collectors placed below the storage tank*
2) **active solar design**—a pump is used to move the liquid
3) **flat-plate collectors**—*solar collectors composed of a thin, wide box with a black bottom and imbedded water tubes*

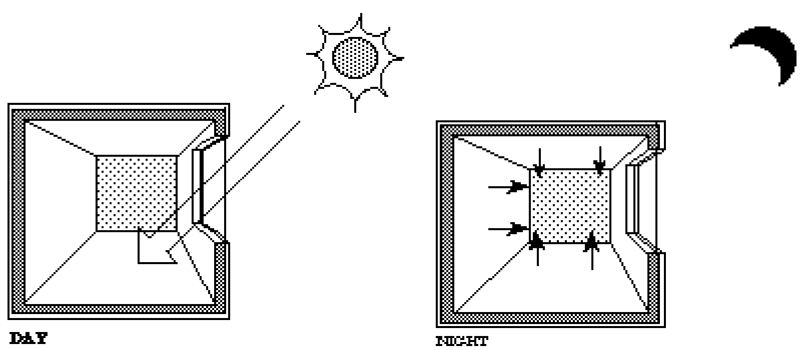
from www.flasolar.com :



C. solar space heating: types of solar heating/cooling

1) **passive solar heating**

From http://www.greenbuilder.com
"*Passive solar design refers to the use of the sun's energy for the heating and cooling of living spaces… the building itself or some element of it takes advantage of natural energy* characteristics in materials and air created by exposure to the sun. Passive systems are simple, have few moving parts, and require minimal maintenance and require no mechanical systems."



1) *uses natural convection currents*
2) *south-facing glass*
3) *thermal mass to absorb, store, & distribute heat*
4) **thermal mass** – *property of building material that allows it to retain or block heat*

2) **earth-sheltered housing**—*using the earth as insulation* to a passive solar energy building
   a) **earth berms**—*slopes of earth* built against the walls
   b) cover the walls with clay, etc.
   c) *in cold weather, insulated drapes can be used at night to trap the heat inside*
   d) *in warm weather, awnings are used to block sunlight*

3) landscaping
   a) use *deciduous trees* or vines to block sunlight in summer, not in winter when they are bare
   b) *evergreen hedge* on shady side protects from cold
   c) examples
      i. trombe wall (www.treehugger.com)

> "Trombe walls are particularly well-suited to sunny climates that have high diurnal (day-night) temperature swings, such as the mountain-west. *A Trombe wall is built on the winter sun side of a building with a glass external layer and a high heat capacity internal layer separated by a layer of air*. Light close to uv in the electromagnetic spectrum passes through the glass almost unhindered then is absorbed by the wall that then re-radiates in the far infrared spectrum which does not pass back through the glass easily, hence heating the inside of the building."

      ii. solar air panels (www.solarheating.org)
         - glazed – space heating/recirculation
         - unglazed – heating ambient air
            - perforated (transpired collector)
            - unperforated (back pass)

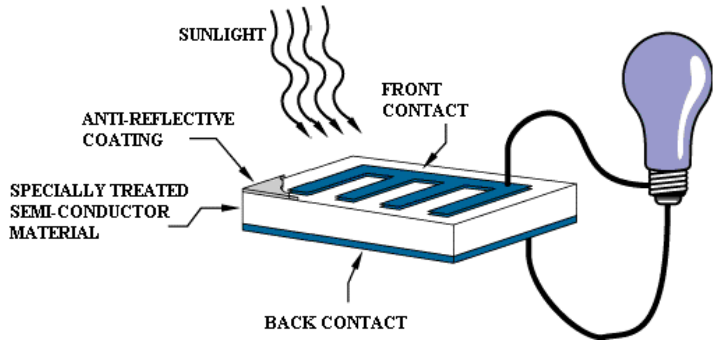
4) **active solar heating**
   a) solar water heaters
      i. *liquid* (water or antifreeze) heated in a "hydronic" collector
      ii. *air* heated in an "air collector"

(from http://energy.gov/energysaver/active-solar-heating)

> "*Active solar heating systems use solar energy to heat a fluid -- either liquid or air -- and then transfer the solar heat directly to the interior space or to a storage system for later use*. If the solar system cannot provide adequate space heating, an auxiliary or *back-up system* provides the additional heat. Liquid systems are more often used when storage is included, and are well suited for radiant heating systems, boilers with hot water radiators, and even absorption heat pumps and coolers. Both liquid and air systems can supplement forced air systems."

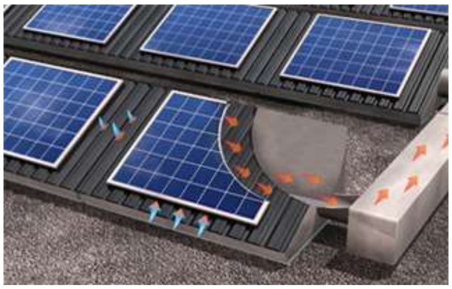
   b) solar production of electricity
      i. **photovoltaic (PV) cell**—a wafer-thin *solar cell*, usually less than 2 x 2" with two layers, *converting sunlight directly into electricity*
      ii. types (from http://www.affordable-solar.com/learning-center/solar-basics/pv-technologies/)
         - single-crystal silicon
         - polycrystalline silicon
         - thin film
      iii. other characteristics
         - first used in the 1950s on satellites
         - cost has dropped 90+% since the 1970s
         - *made of silicon, Si* **(**called c-Si, crystalline silicon)
         - *thin-film collector* technology *(SnS and CuS or Cu_2S)*
         - *electrical current caused by dislodged electrons in two thin layers*: one with electropositive elements and one with electronegative elements

         (from http://science.nasa.gov)



iv. *hybrid technology – PV/T photovoltaic/thermal*

Hybrid solar photovoltaic/thermal (PV/T) technology combines PV with a solar thermal component to generate up to four times the energy from the same surface area.



v. *Hybrid Solar Lighting (HSL)*

(from http://www.ornl.gov)

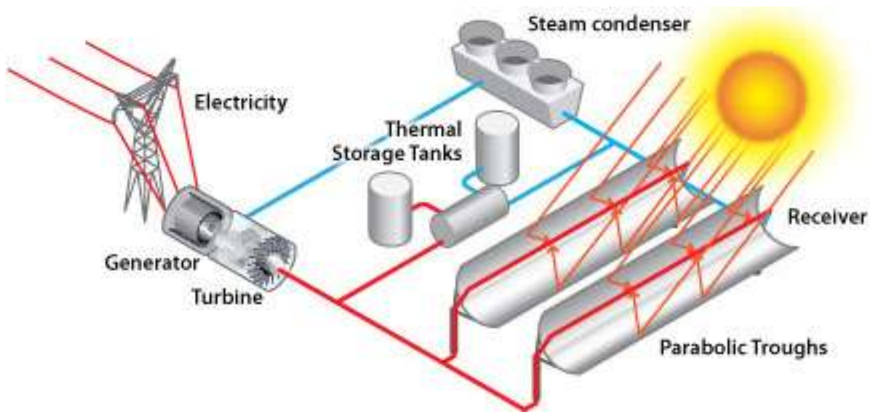
"*Hybrid lighting is a combination of natural and artificial illumination to be used indoors for all lighting needs…* Hybrid light fixtures will allow use of all available natural light and supplement it with the amount of artificial light required to bring the total level of illumination to the rated value… By combining natural light and improved artificial sources available today—centralized, high-efficiency light sources—energy costs for lighting could be reduced by one-third."

"A hybrid lighting fixture in which sunlight is routed through an optical fiber to two of the four 40-watt tubes. The fixture's sensors constantly monitor the room light level."

D. CST—concentrating solar thermal energy generation use mirrors and tracking systems
   1) **solar-trough collectors**—*parabolic, trough-shaped solar collectors* (from www.energy.wsu.edu)

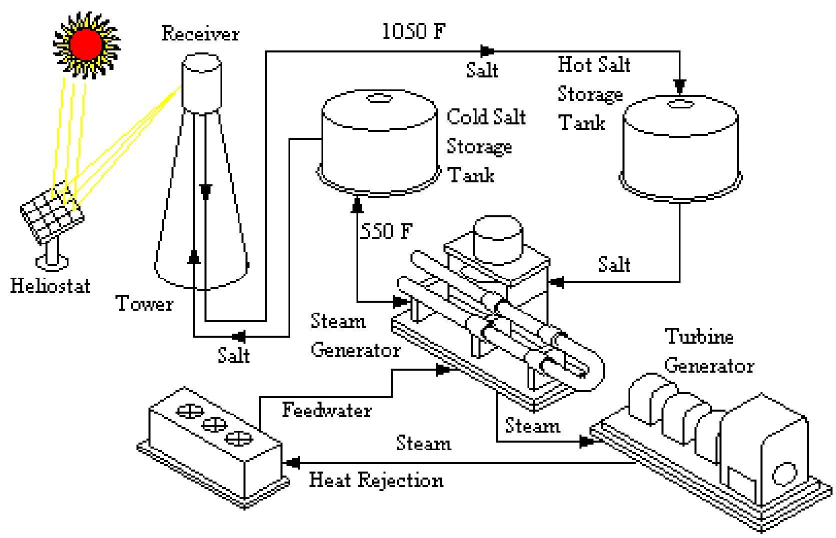
"*Parabolic-trough solar collectors use mirrored surfaces curved in a parabolic shape that linearly extend into a trough shape.* The collector focuses sunlight on a tube running the length of the trough. A heat transfer fluid is pumped around a loop through this tube, picking up heat. The fluid then goes to a heat exchanger where it either directly heats potable water or heats a thermal storage tank. *As with all concentrating solar collectors, parabolic-trough collectors use tracking systems that keep them facing the sun throughout the day, maximizing solar heat gain*."

From C&S Enterprises: A linear concentrator power plant using parabolic trough collectors



2) experimental technology, 1995-1999
   a) **Solar One**, 1982-1986
      i. pilot solar-thermal project in the Mojave Desert near Barstow, CA
      ii. converted into Solar Two (see below)
   b) *The Power Tower Project* – **Solar Two** (California), 1996-1999
      i. 1,926 *sun-tracking heliostats (mirrors)*
      ii. *molten salt thermal storage system*
      iii. 300 ft tower with central receiver
      iv. conventional steam driven turbogenerator
      v. produced about 10 MWe, enough to serve 10,000 homes
      vi. cost about $40 million
      vii. converted into a telescope measuring gamma (γ) rays

From http://www-stud.fht-esslingen.de/projects/alt_energy/sol_thermal/powertower.html



3) **Gemasolar** (formerly Solar Tres), in Spain

From http://www.torresolenergy.com/TORRESOL/gemasolar-plant/en

"Gemasolar is the first commercial-scale plant in the world to apply central tower receiver and molten salt heat storage technology.

Characteristics of Gemasolar:

Rated electrical power: 19.9 MW

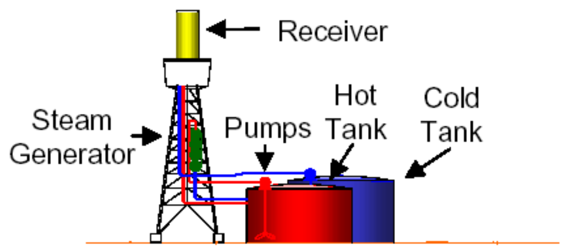
Net electrical production expected: 110 GWh/year

Solar field: 2,650 heliostats on 185 hectares

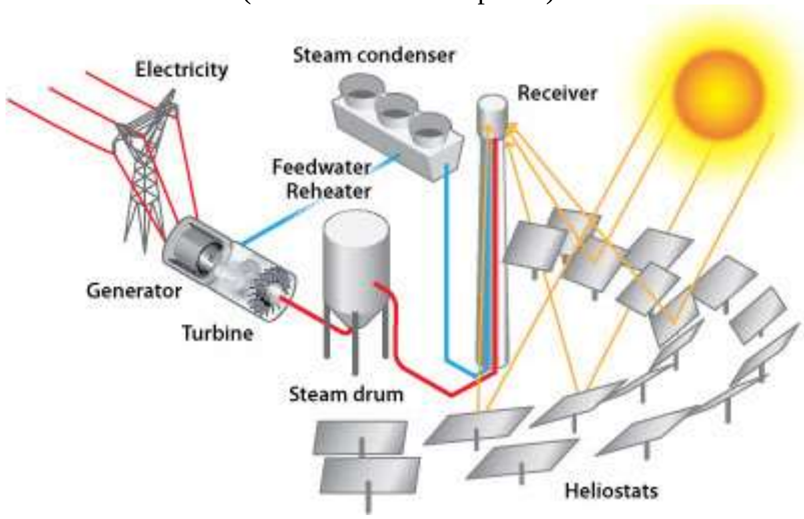
Heat storage system: the molten salt storage tank permits independent electrical generation for up to 15 hours without any solar feed

The solar heat will be directed at a receiver at the top of the tower. *Molten salt* is then pumped through the tower receiver which heats the liquid to around 600ºC. A portion of the fluid is then pumped to a heat transfer unit to create super-heated steam. The balance is pumped into a hot tank where it is stored for use in times when the sun is not shining…

… The notable increase in the plant's power efficiency guarantees electrical production for 6,500 hours a year, 1.5 to 3 times more than other renewable energies. The plant will thus supply clean, safe power to 25,000 homes and reduce atmospheric CO_2 emissions by more than 30,000 tons a year."



A Power-Tower Power Plant (Source: C&S Enterprises)

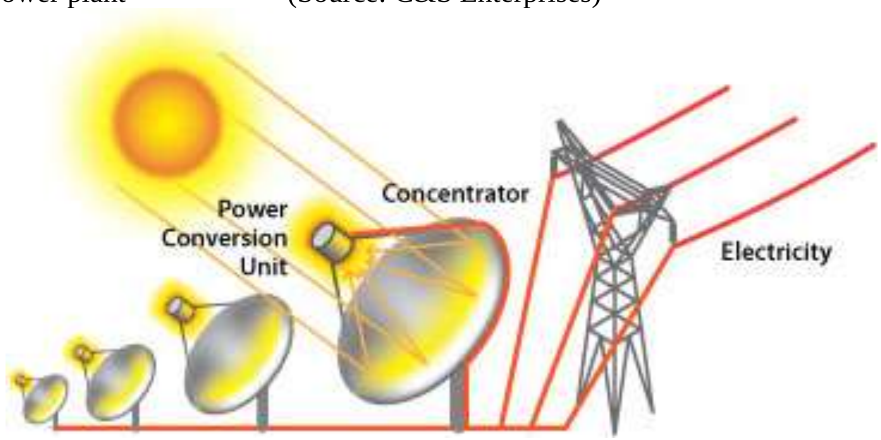


4) Dish Engine

From http://www.sandia.gov

> *"The solar dish generates electricity by focusing the sun's rays* onto a receiver, which *transmits the heat energy to an engine. The engine is a sealed system filled with hydrogen, and as the gas heats and cools, its pressure rises and falls. The change in pressure drives the pistons inside the engine, producing mechanical power. The mechanical power in turn drives a generator and makes electricity."*

A dish-engine power plant (Source: C&S Enterprises)



E. Costs of solar energy

from http://education.seattlepi.com/solar-power-vs-fossil-fuels-3937.html

> "Because solar power is generated in a completely different way from fossil fuel-based power, it's a little complicated to compare the price. Fossil-fuel plants are not as expensive per megawatt as solar power systems, but you'll need to pay for the fuel as long as you use the plant. Solar power costs more up front, but the fuel is free, and the maintenance costs are much lower than for fossil fuel plants. *Putting the factors together, the basic costs of solar power generation are about two to three times the cost of fossil fuel plants. When you add in distribution costs and specific local variables, there are some places where solar energy is already as cheap as fossil-fuel energy -- and solar costs are likely to fall more than fossil-fuel costs*."

"According to a (2015) report from Lawrence Berkeley National Laboratory (LBNL), solar energy prices are at an all-time low, with the average price of solar energy in the United States having dropped down to 5¢/kWh, representing a 70% decline in power purchase agreement (PPA) prices since 2009."

II. Wind Energy

A. **wind energy** uses the K.E. of moving air

B. stats from http://www.awea.org

  A. types of wind power
    1) *utility-scale wind* (> 100 kW turbines) for power to the grid
    2) *distributed "small" wind* (< 100 kW tubines) for direct local use
    3) *offshore wind* (turbines placed in bodies of water)

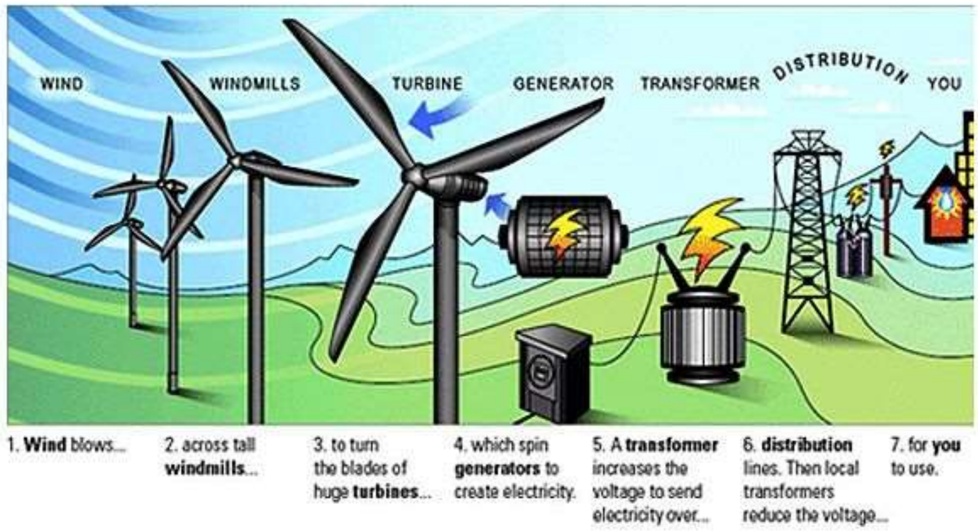
  B. **wind turbine**—"windmill" made of a *propeller (rotor) and shaft (tower)*, hooked up to a generator
    1) sizes
      - residential or small business turbines: rotor < 8 m tall, tower < 40 m tall
      - utility turbines: rotor 50-90 m tall, tower 50-90 m tall
    2) materials
      - tubular tower: steel
      - rotor: fiberglass-reinforced polyester or wood-epoxy
    3) power range: 250 W to 5 MW per turbine

"Example: A 10-kW wind turbine can generate about 10,000 kWh annually at a site with wind speeds averaging 12 miles per hour, or about enough to power a typical household. A 5-MW turbine can produce more than 15 million kWh in a year—enough to power more than 1, 400 households. The average U.S. household consumes about 10,000 kWh of electricity each year."

  C. **wind farm**—*area of thousands of wind turbines*

  D. cons—*intermittent source of power; damaging to scenery, bird collisions*

"When wind blows past a turbine, the blades capture the energy and rotate. This rotation triggers an internal shaft to spin, which is connected to a gearbox increasing the speed of rotation, which is connect to a generator that ultimately produces electricity. Most commonly, wind turbines consist of a steel tubular tower, up to 325 feet, which supports both a 'hub' securing wind turbine blades and the 'nacelle' which houses the turbine's shaft, gearbox, generator and controls. A wind turbine is equipped with wind assessment equipment and will automatically rotate into the face of the wind, and angle or 'pitch' its blades to optimize energy capture… Wind turbines often stand together in a windy area that has been through a robust development process in an interconnected group called a wind project or wind farm, which functions like a wind power plant. These turbines are connected so the electricity can travel from the wind farm to the power grid. Once wind energy is on the main power grid, electric utilities or power operators will deliver the electricity where it is needed. Smaller transmission lines called distribution lines will collect the electricity generated at the wind project site and transport it to larger 'network' transmission lines where the electricity can travel across long distances to the locations where it is needed, when finally the smaller 'distribution lines' deliver electricity directly to towns and homes."



III. **Geothermal Energy** *(geo-therm = "Earth heat")*

A. background info.
   1) *using naturally heated water for steam turbines to produce electricity*
   2) water is heated by *magma*
      a) high temp. >150 °C
      b) medium temp. 100-150 °C
      c) low temp. < 100 °C
   3) used in over 30 countries
   4) U.S. – about 2% of our energy

B. pros
   1) no radioactive waste products
   2) can aid agriculture and aquaculture in cold climates
   3) helpful to areas without access to fossil fuels
   4) some scientists believe we have barely tapped into this power supply

C. cons
   1) *water issues*
      a) water from watershed/waterways being depleted
      b) damming / diverting water flow
      c) water taken from reservoir
      d) subsidence
      e) salt water intrusion
      f) lowered water table
   2) *land issues*
      a) loss of vegetation
      b) soil erosion / landslides
      c) ownership issues
   3) *waste (brine and condensate) disposal issues*
      --biological and chemical implications
   4) *reinjection issues*
      a) cooling of water

b) possible seismic activity

5) *air emissions*

a) fogging of the area

b) slight heating of the area

c) biological and chemical effects

6) *noise pollution*

a) hearing loss

b) nuisance/ disturbance

D. geothermal direct-heat usage: space heating, bathing, aquaculture, greenhouses, heat pumps, industrial, etc.

from GEO – Geothermal Education Office http://geothermal.marin.org/

- *"Aquifer* - a porous or fractured body of rock carrying cold or hot water.
- *Basin or Sedimentary basin* - a bowl-shaped depression in the earth filled with sedimentary rocks (rocks usually formed in water such as sandstone, limestone, etc.).
- *Fault* - a break in the earth's crust which extends a considerable distance (horizontally and vertically) along which relative (sliding) movement occurs.
- *Fumarole* - a flow of steam from the ground. Fumaroles can be weak or strong, noisy and superheated (temperature above boiling).
- *Hot spot* - a relatively small area of a plate heated by a rising plume of magma from deep within the mantle which produces local volcanic activity over a long time period.
- *Plate* - a rigid part of the earth's crust that moves relative to other plates. The map shows eight major plates and several minor ones.
- *Plate boundary* - where two plates meet.
- *Rift* - a part of the crust that has been pulled apart, usually bordered by faults. A rift zone is a rift with bordering faults. When rifting occurs, magma can move near the surface, forming volcanoes and geothermal systems. Rift zones may become plate boundaries.

U.S. Geothermal Energy Overview:

"The west coast boundary between the North American and Pacific plates is 'sliding' along the San Andreas fault… from the Gulf of California up to northern California and subducting from the Cascade volcanoes north through the Aleutians. There are also volcanic hot spots under Yellowstone and Hawaii and intra-plate extension with hot springs in the Great Basin…

California generates the most geothermal electricity… (much less than its capacity, but still the world's largest developed field and one of the most successful renewable energy projects in history)… There are also (geothermal) power plants in Nevada, Utah, Oregon, and Hawaii, with plans in other states. Due to environmental advantages and low capital and operating costs, direct use of geothermal energy has skyrocketed …

In the western United States, hundreds of buildings are heated individually and through district heating projects. Large greenhouse and aquaculture facilities in Arizona, Idaho, New Mexico, and Utah use low-temperature geothermal waters, and onions and garlic are dried geothermally in Nevada."

E. **ground source heat pumps**—*use thermal mass of the ground to heat buildings*

https://www.energy.gov/energysaver/heat-and-cool/heat-pump-systems/geothermal-heat-pumps

> "Geothermal heat pumps (GHPs), sometimes referred to as GeoExchange, earth-coupled, ground-source, or water-source heat pumps, have been in use since the late 1940s. They use the constant temperature of the earth as the exchange medium instead of the outside air temperature… As with any heat pump, geothermal and water-source heat pumps are able to heat, cool, and, if so equipped, supply the house with hot water. Some models of geothermal systems are available with two-speed compressors and variable fans for more comfort and energy savings. Relative to air-source heat pumps, they are quieter, last longer, need little maintenance, and do not depend on the temperature of the outside air."

IV. **Hydrogen Fuel Cells – H_2**

A. general info: http://www.hydrogencarsnow.com/

B. **fuel cell**—*an electrical-chemical device that converts fuel into electricity*

C. pros

1) *H_2 burns pretty cleanly, releasing water vapor*

$$2\,H_2 + O_2 \rightarrow 2H_2O + \text{energy}$$

2) no CO_2 produced
3) cars have been developed to run on H_2
4) we can set up vast solar arrays in the desert areas to obtain power to be used for electrolysis
5) underground pipelines for transport are already in place

D. cons

1) *there is very little H_2 gas on Earth*
2) *production of H_2 gas is expensive*
3) **electrolysis**—*electric current used to split water molecules into hydrogen gas and oxygen gas*

$$2H_2O + \text{energy} \rightarrow 2\,H_2 + O_2$$

E. **fuel cell vehicles (FCVs)** https://www.fueleconomy.gov/feg/fuelcell.shtml

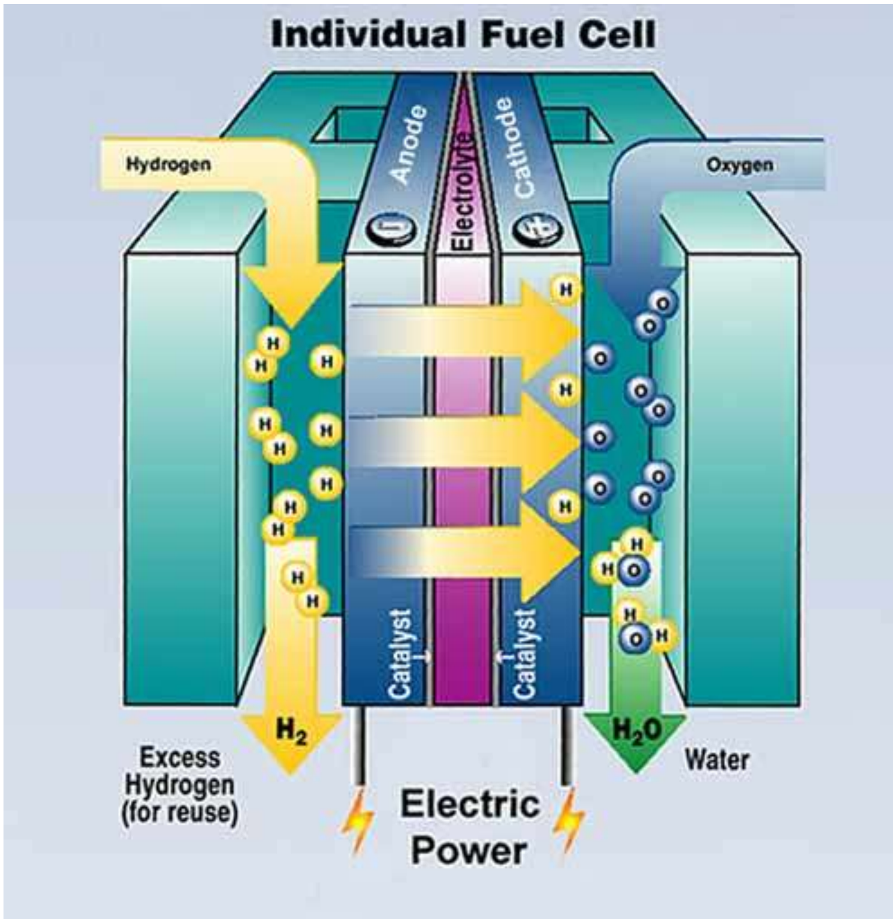
1) what they are…

from http://www.howstuffworks.com/fuel-cell.htm/printable

> "A fuel cell is an *electrochemical energy conversion device*. *A fuel cell converts the chemicals hydrogen and oxygen into water, and in the process it produces electricity*... With a fuel cell, chemicals constantly flow into the cell so it never goes dead -- as long as there is a flow of chemicals into the cell, the electricity flows out of the cell... This reaction in a single fuel cell produces only about 0.7 volts. To get this voltage up to a reasonable level, many separate fuel cells must be combined to form a *fuel-cell stack*."

2) example: *proton exchange membrane fuel cell (PEMFC)*
3) reactions:
   a) *Anode side:* $2H_2 \rightarrow 4H^+ + 4e^-$
   b) *Cathode side:* $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
   c) *Net reaction:* $\mathbf{2H_2 + O_2 \rightarrow 2H_2O}$

from http://www.geni.org



MODULE 40: Planning Our Energy Future

I. Energy Use in our Future
   A. there is no perfect fuel for all situations
   B. sustainable energy strategy = efficiency, conservation, sensible use of nonrenewable resources, increased use of appropriate renewable energy sources
   C. ** TABLE 40.1 ***
      1) advantages, disadvantages, emissions, cost per kWh, EROEI
      2) energy options—geothermal, hydroelectric, H_2 fuel cell, liquid biofuels, PV cells, solar water heating, solid biomass, tidal, wind

II. Renewable Energy Strategy Challenges
   A. specific challenges
      1) existing mindset as fossil fuels being the go-to fuel
      2) making the cost of new technology competitive
      3) governmental and/or private funding for renewable tech R&D
      4) long-distance transmission through the grid
      5) energy cost and storage

6) political climate can influence how renewable energy is viewed – can be negative

B. Improving the electrical grid
   1) upgrades needed for long-distance transmission
   2) some areas produce more power than needed; some areas don't produce enough.. some energy is lost through long-distance transmission
   3) reduce blackouts and brownouts
   4) upgrades needed to power plants and network
   5) **Smart Grid**

https://www.smartgrid.gov/the_smart_grid/smart_grid.html

"*Our current electric grid was built in the 1890s and improved upon as technology advanced through each decade*. Today, it consists of more than 9,200 electric generating units with more than 1 million megawatts of generating capacity connected to more than 300,000 miles of transmission lines. Although the electric grid is considered an engineering marvel, we are stretching its patchwork nature to its capacity. To move forward, *we need a new kind of electric grid, one that is built from the bottom up to handle the groundswell of digital and computerized equipment and technology dependent on it*—and one that can automate and manage the increasing complexity and needs of electricity in the 21st Century.

What makes a grid 'smart'?

In short, the digital technology that allows for two-way communication between the utility and its customers, and the sensing along the transmission lines is what makes the grid smart. Like the Internet, the Smart Grid will consist of controls, computers, automation, and new technologies and equipment working together, but in this case, these technologies will work with the electrical grid to respond digitally to our quickly changing electric demand."