Solar Energy

. . . why solar?

Why Solar Energy

- There is lots of solar energy available, and it's renewable.
- There are limited amounts of fossil fuels.
- Global warming due to fossil fuel use.

Jargon Slide

- Insolation = INcedent SOLar radiATION.
- 40W light bulb x 1hour = 40 Wh
- 40W light bulb x 1hour x 1day = 960 Wh
- 40W light bulb x 1hour x 1day 1kWh.

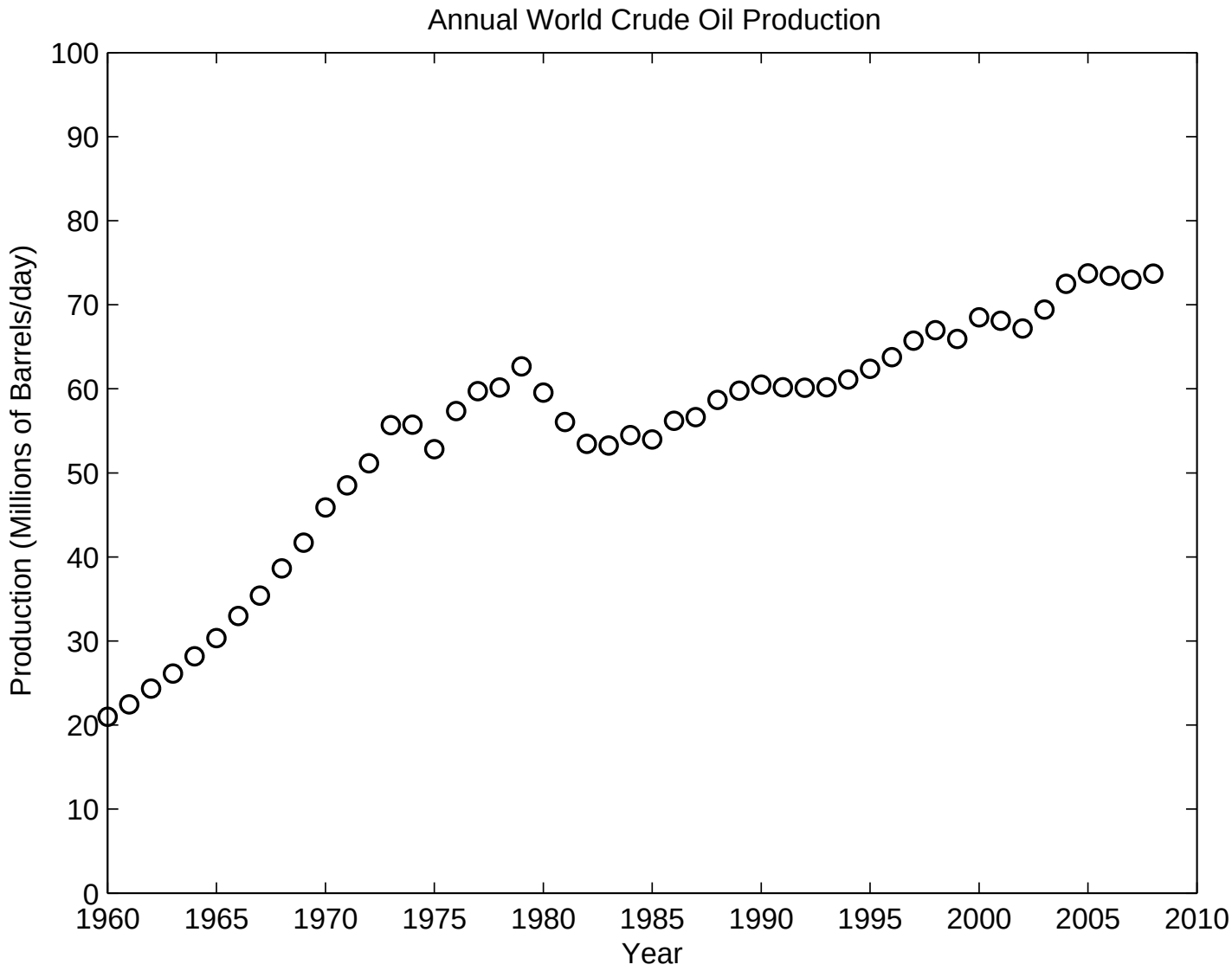
Why Solar: Lots of Solar Energy

There is about 10^{17}W of insolation arriving at the earth's surface.

- For 10 billion people this is 10^{7}W = 10MW per person.
- If 1% of that could be collected at 10% efficiency this would give 10kW per person.
- 10kW per person per day = 240kWh ~the total energy consumption of the average American per day.

Why Solar: Fossil Fuels

A finite resource, we may have already hit peak oil.



Why Solar: Global Warming

The Intergovernmental Panel on Climate Change (IPCC) 4th assesment report states:

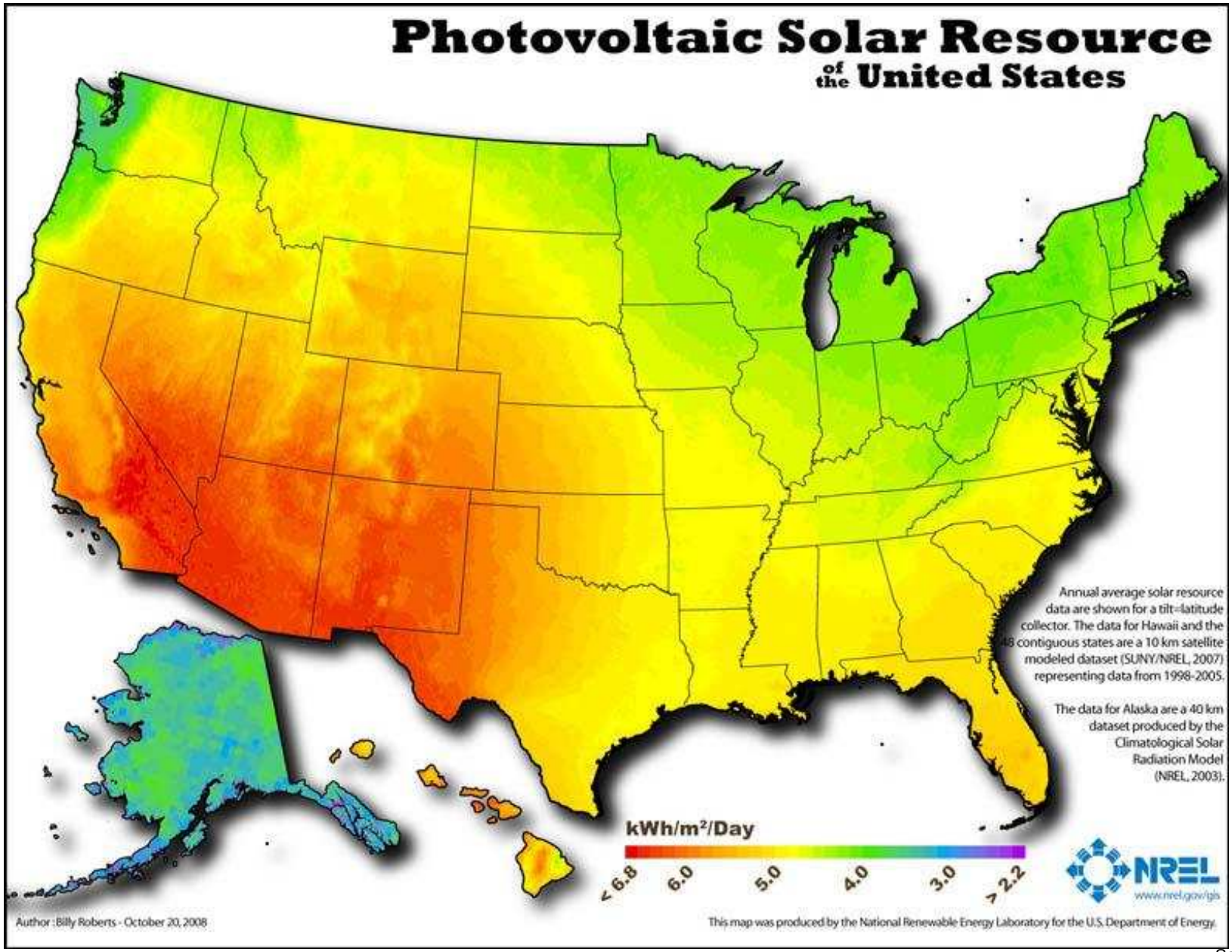
- “Warming of the climate system is unequivocal.”
- “Most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations.”

Solar: Where and How Much

Since solar clearly seems to be a bright idea

- Q: What is our resource availability here in the United States?
- A: The average amount of insolation depends on one's location.

How Much/Where?



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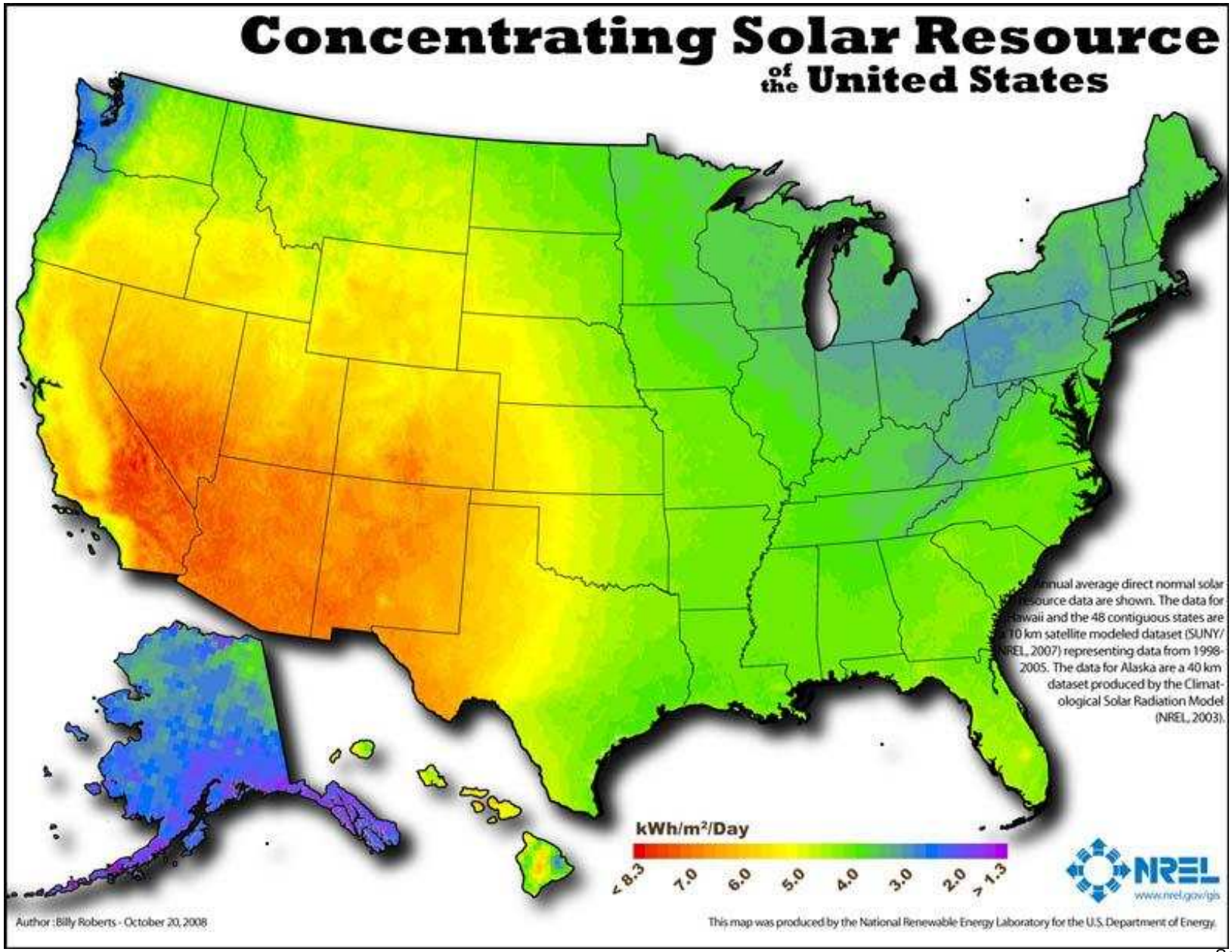


How to Use Solar Energy

There are two general scales that we'll consider.

- Home/Residential Scale.
- Utility/Industrial Scale.

Solar at Home

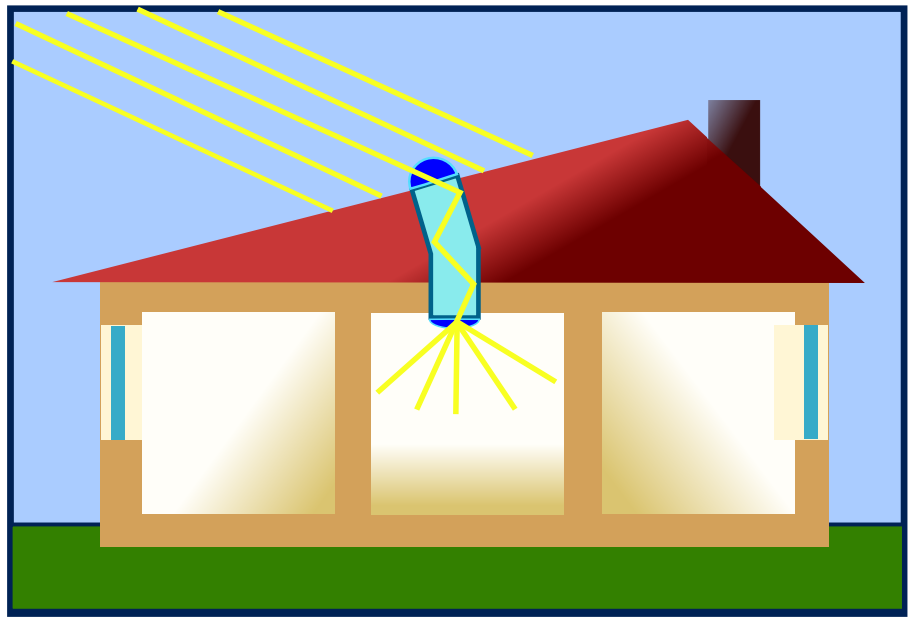
There are three general categories for solar energy use at home

- Light.
- Heat.
- Electricity.

Solar at Home: Light

Use of Solar Lighting may be accomplished by:

- Opening blinds/windows.
- Skylights.
- Light-tubes.



Originally from `http://en.wikipedia.org/wiki/File:Sonnenrohr.svg`

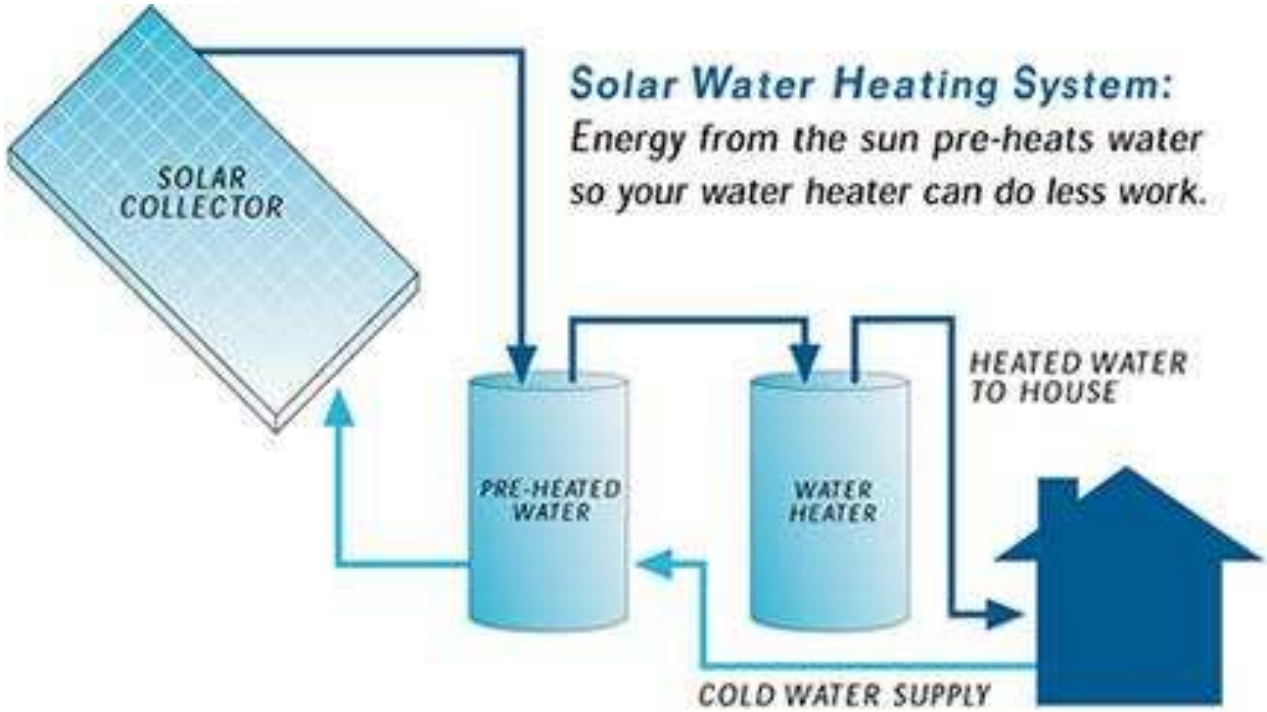
Solar at Home:Heat

Solar energy may be used for heating in place of, or along with another household heat source. Uses for solar heat include:

- Solar Hot water.
- Clothes drying.
- Solar ovens.
- Sanitation (pasteurization).
- Desalination.

Solar at Home: Heat

Solar Water heater absorbs solar energy to heat water



Originally from `http://www.solarnoworegon.org/101.html`

Solar at Home: Heat

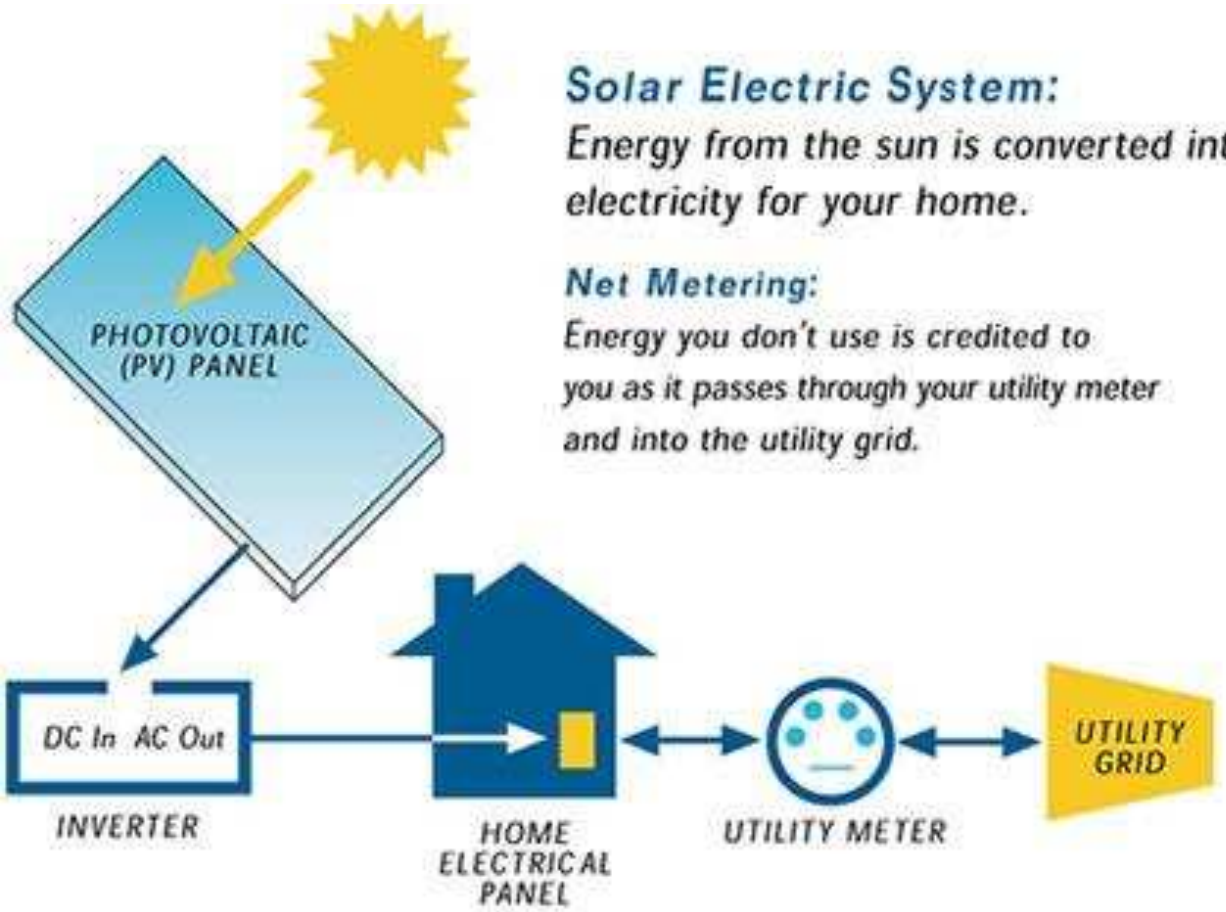
The sun is a tried and true method for drying clothes.

Originally from

`http://www.websters-online-dictionary.org/images/wiki/wikipedia/commons/t`

Solar at Home: Electricity

Photovoltaic (PV) Panels can provide electricity at home



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Solar at Home: Electricity

Solar photovoltaic(PV) cells.

- Modules can be over 15 % percent efficient.

Originally from `http://www.nrel.gov/learning/re_photovoltaics.html`

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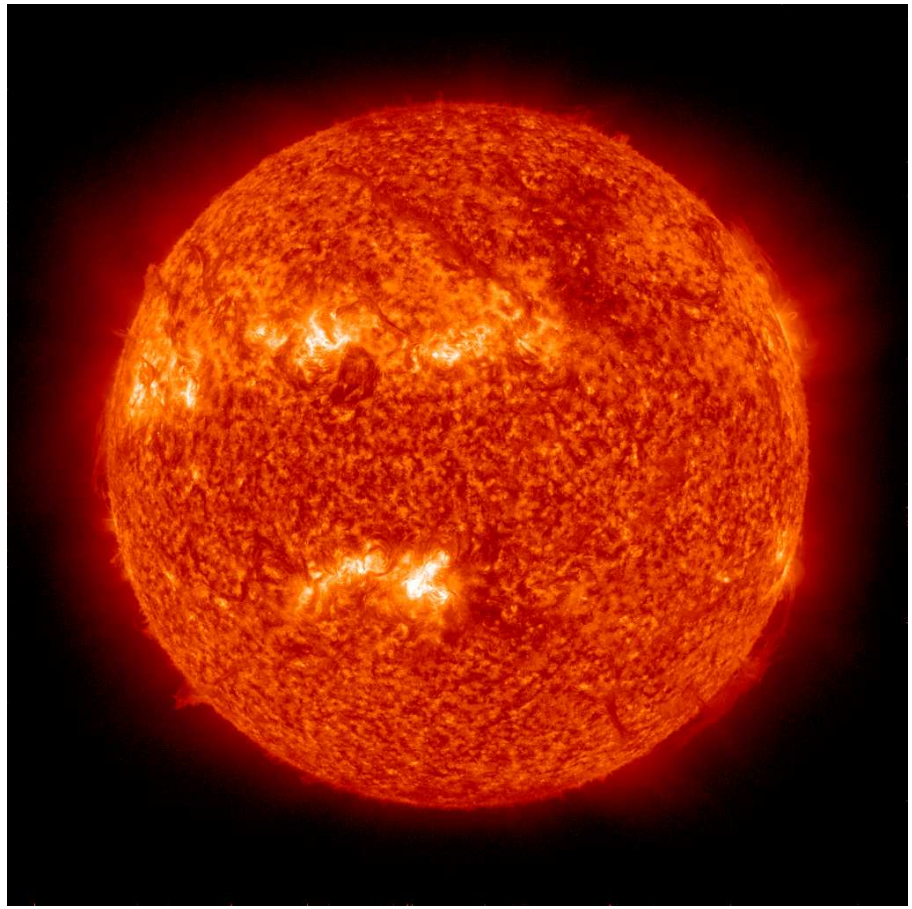
Utility Scale

Solar energy may also be used on a larger scale at Solar Electric Power Plants.



Originally from `http://umbra.nascom.nasa.gov/images/latest_aia_304.gif`

Solar Energy to Electricity:Utility Scale

Solar utility electricity generation can be broken into 2 areas:

Originally from
`http://earthobservatory.nasa.gov/Features/RenewableEnergy/`

- Concentrated Solar Thermal.

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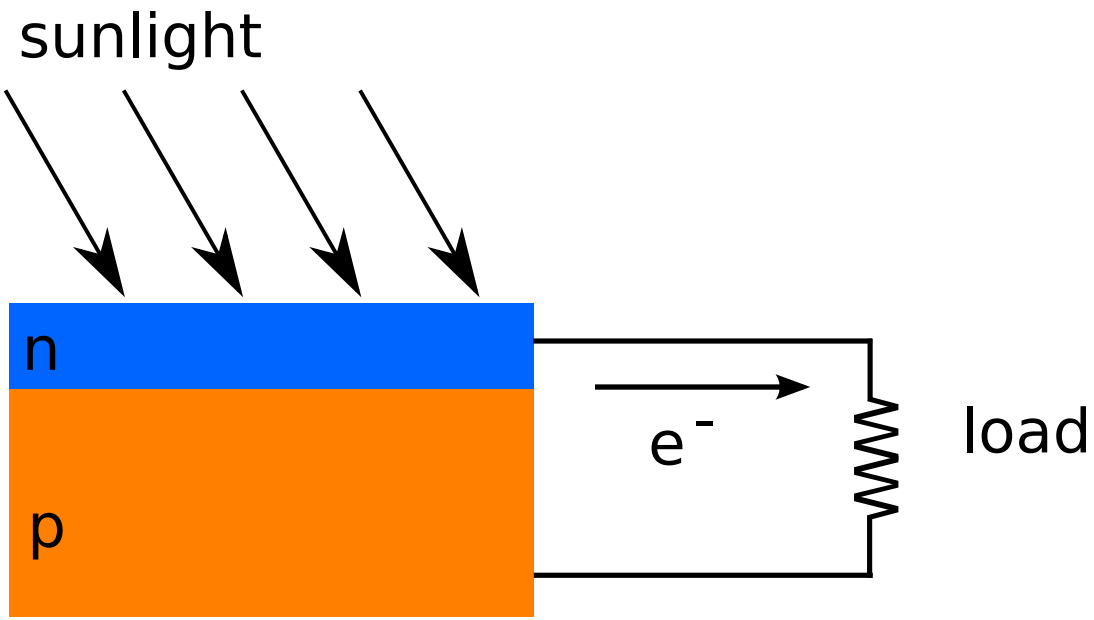
How PV's work

Like large area photodiodes. A diode is a solid state junction of n-type and p-type semiconductors.



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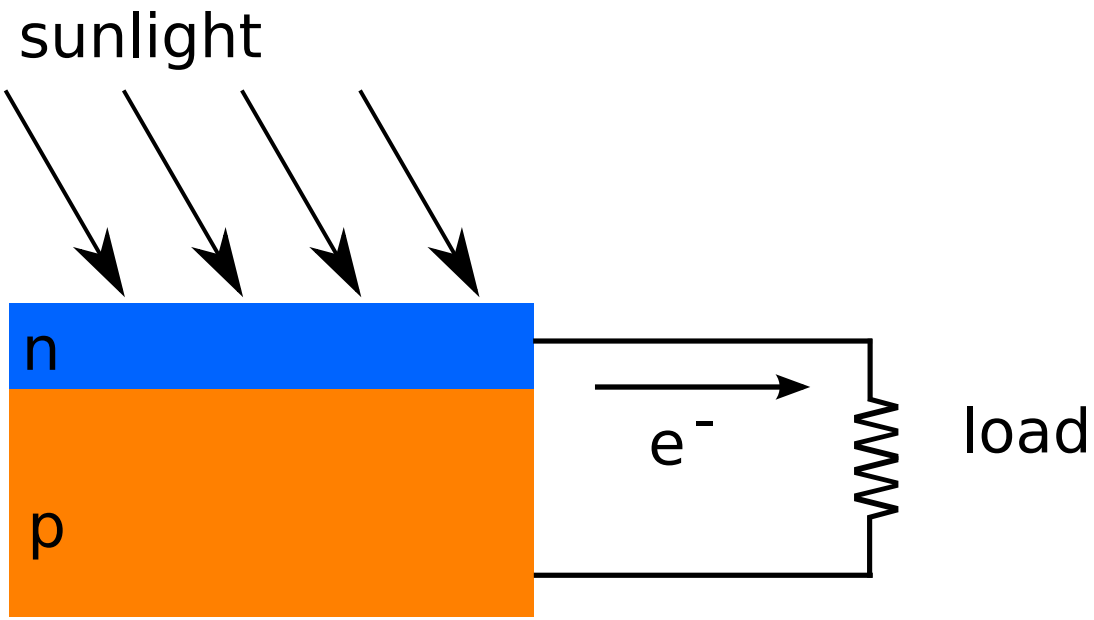

- Photons striking the surface of the cell dislodge electrons.

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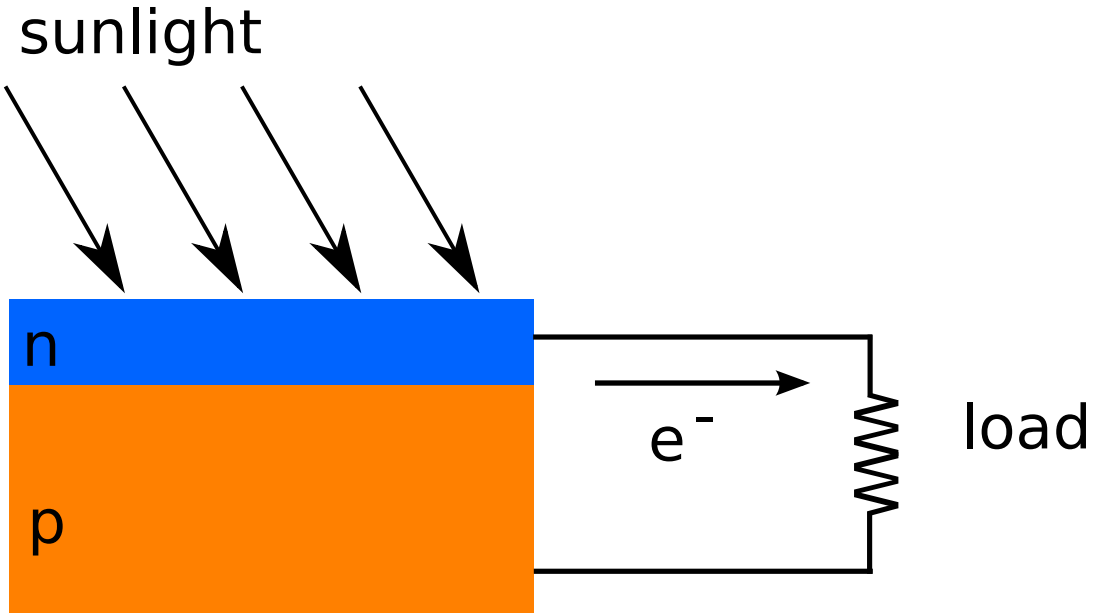

- An electric field built into the diode causes electrons to accumulate on one side.

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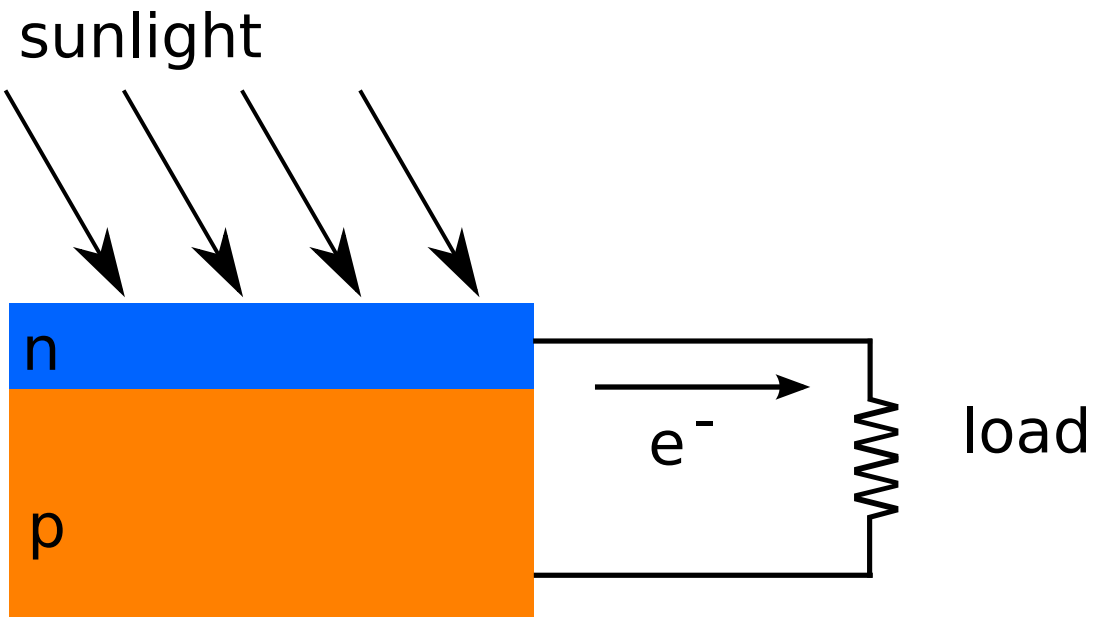
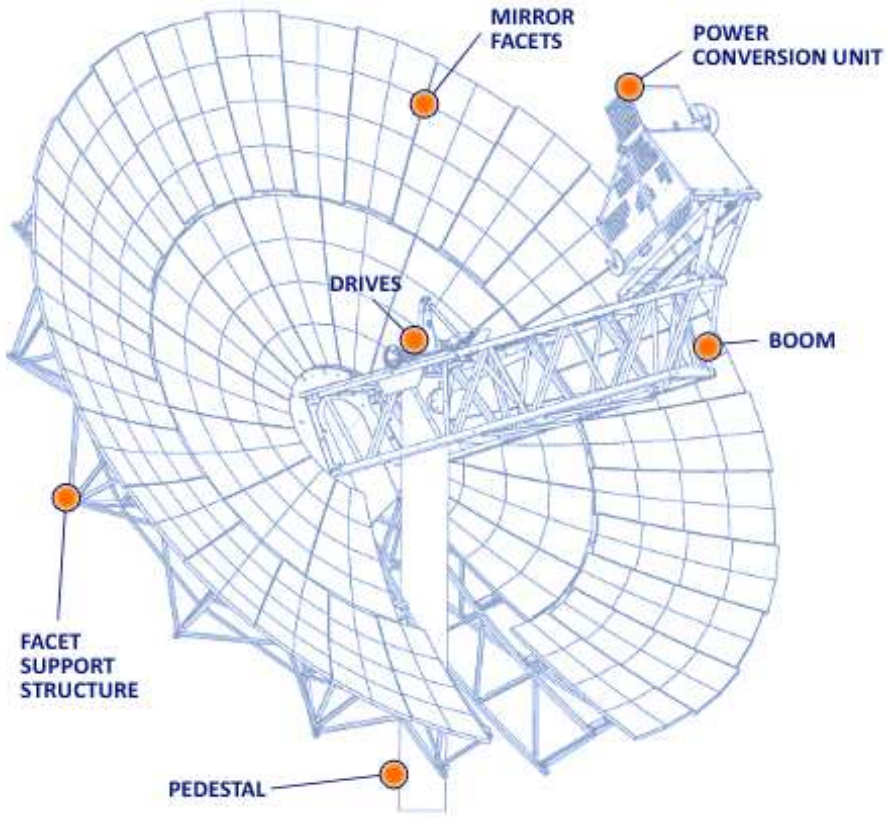


- Connecting a load to the two parts of a diode causes a current to flow through it.

Concentrated solar thermal power

For solar thermal power the sunlight is concentrated. Concentration allows higher operating temperatures. Higher operating temperatures mean that more work can be extracted.

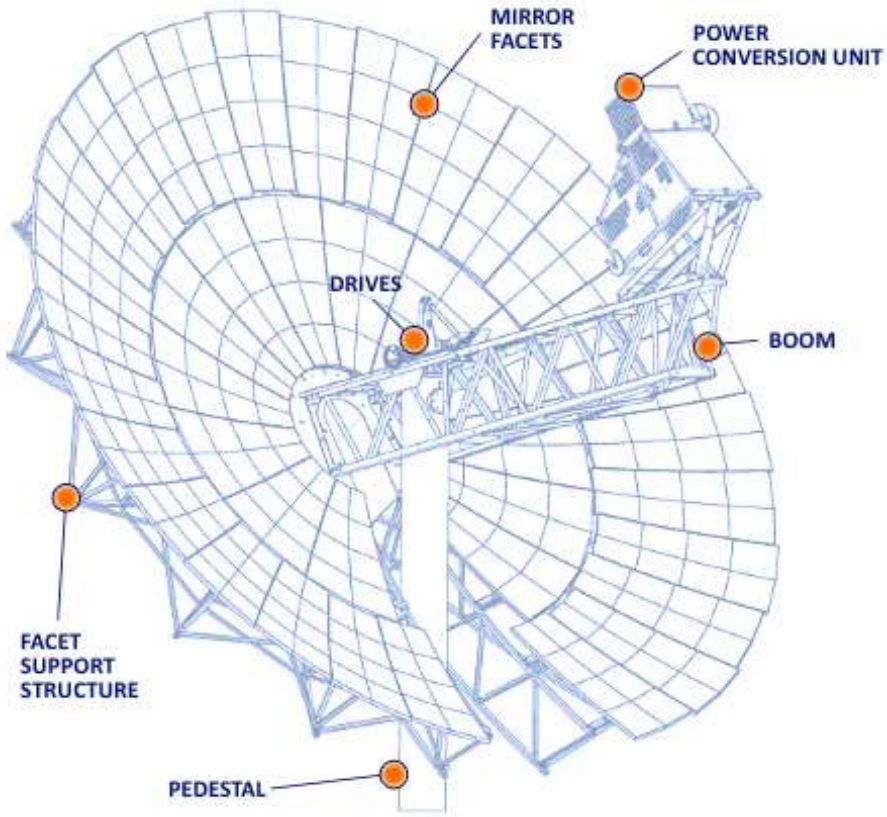
Concentrated solar thermal power



Originally from `http://www.stirlingenergy.com/how-it-works.htm`

- Concentrate solar energy to heat a ‘working fluid’.

Concentrated solar thermal power



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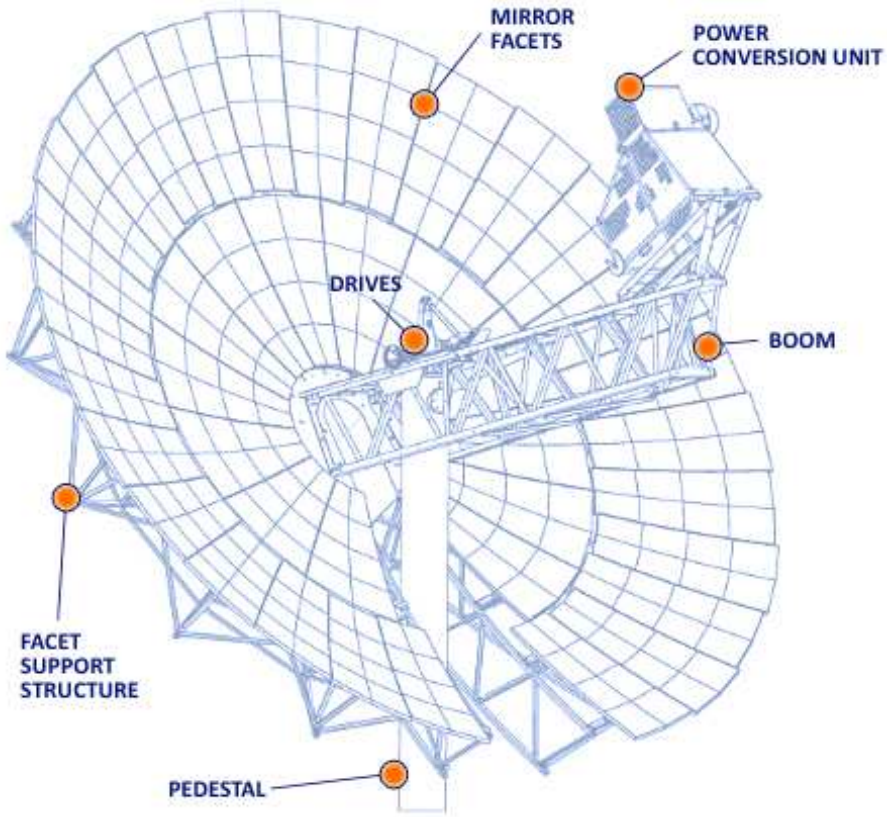
- Temperatures may be as high as 1200K for gas cycle engines.

Concentrated solar thermal power



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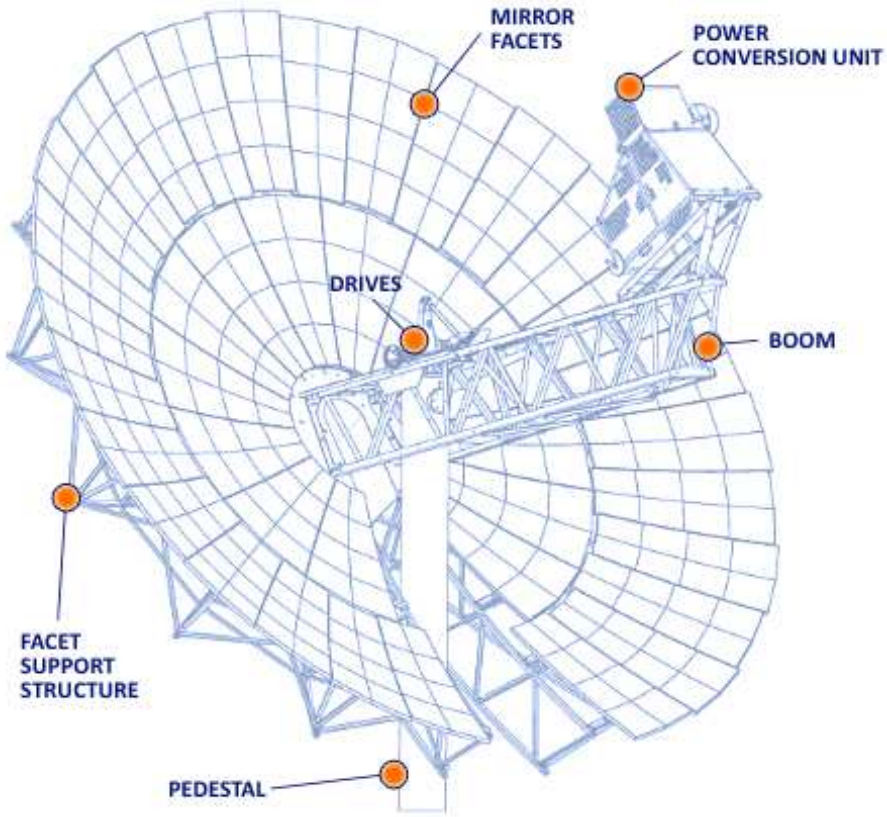
- Plants typically use the Rankine cycle (steam turbines), although some use Stirling Engines.

Concentrated solar thermal power



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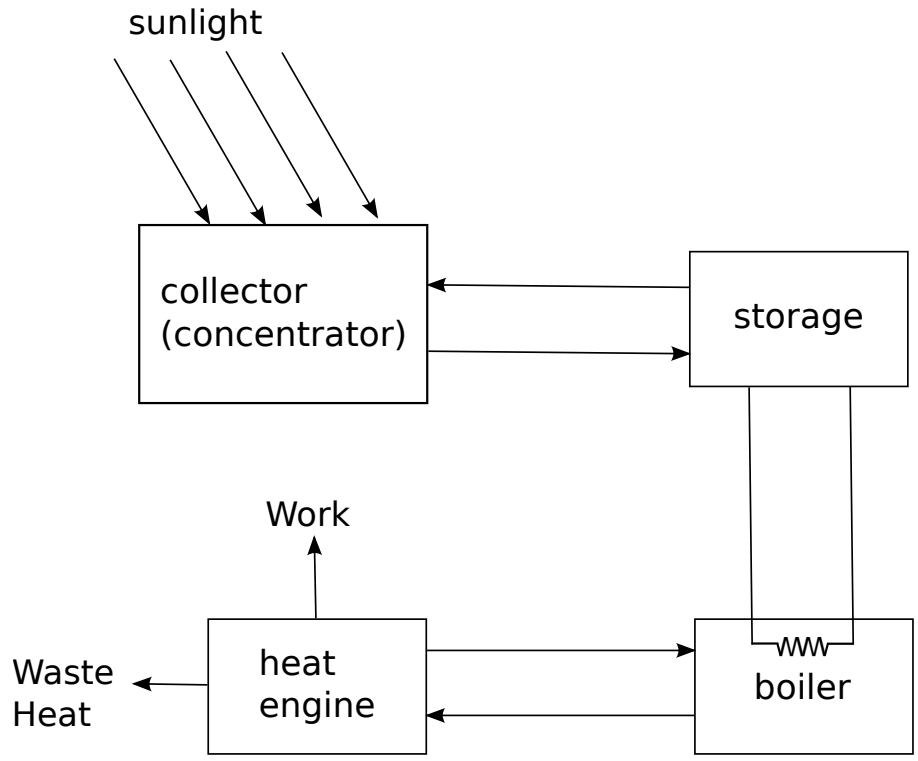
solar thermal power

Typical layout of a solar thermal power plant.

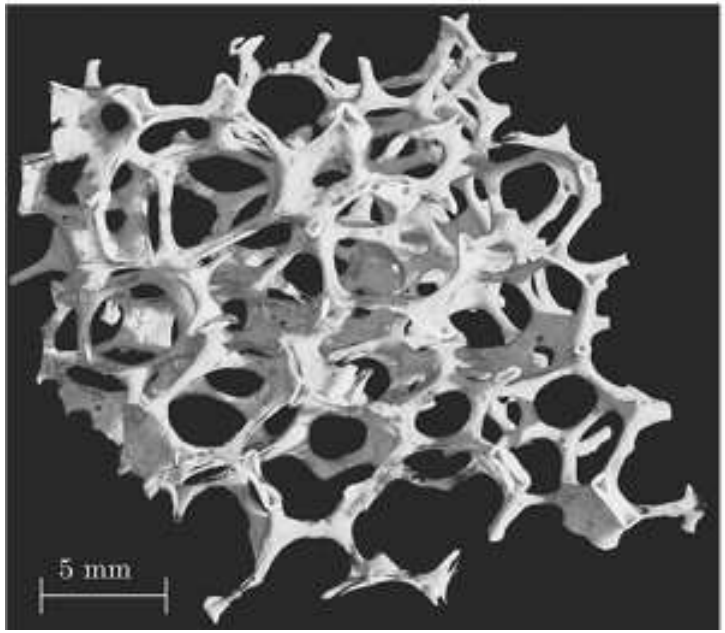
- A collector heats a fluid using concentrated sunlight.
- The hot fluid may go to some thermal storage system.
- The hot fluid heats the working fluid to generate steam, which goes through a standard heat cycle.



Solar Energy to Chemical

Solar energy may be utilized chemically.

- Photochemically (like using a photo-catalyst).
- Thermochemically (like reforming fuels or metal oxide hydrogen cycles).



Originally from `http://www.rel.mae.ufl.edu/research.html`

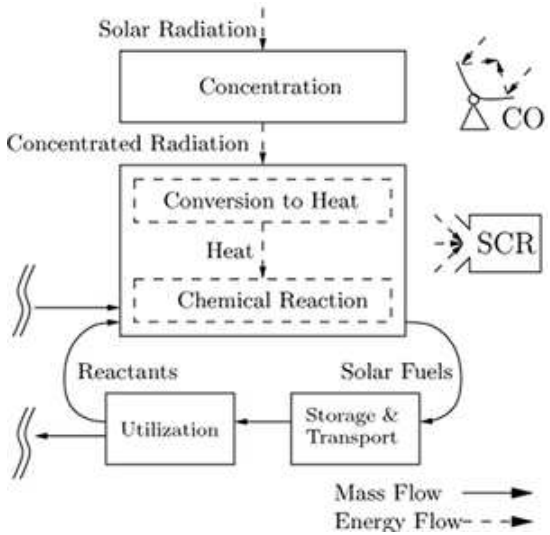
Photochemical Processes

- A photocatalyst, such as titanium dioxide, is used help drive a chemical reaction.
- Titanium dioxide (TiO_2) is used to generate hydroxyl radicals (^{-}OH).
- Can be used for water detoxification (Goswami).

Thermochemical Processes

- Can drive reforming cycles.

$$CH_4 + H_2O + heat \rightarrow CO + 2H_2$$



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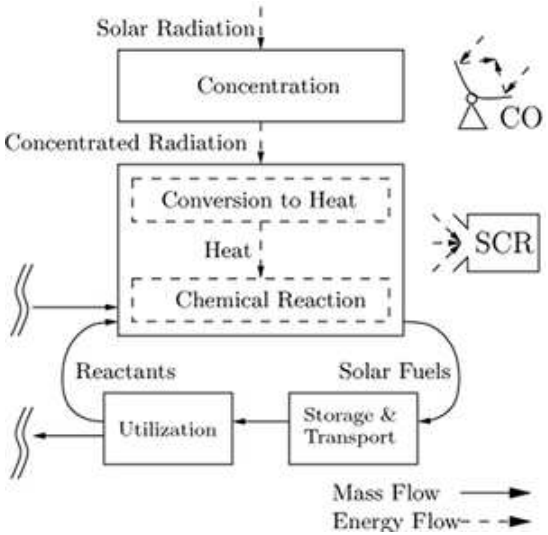
- $CO + 2H_2$ (synthesis gas) may be used to synthesize hydrocarbon fuels.



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Thermochemical Processes

- Solar heat can drive thermochemical water-splitting cycles to generate hydrogen.

$$ZnO + heat \rightarrow Zn + \frac{1}{2}O_2$$

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- The hydrogen production:

$$Zn + H_2O \rightarrow ZnO + H_2$$

Summary

Solar Energy can be used at home for:

- Heating.

At the utility scale sunlight may be used to:

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References

Duffie, J. A., Beckman, W. A. *Solar Engineering of Thermal Processes 3rd Ed.* Wiley, Hoboken. 2006.

Goswami, D. Y., Kreith, F., Krider, J. *Principles of Solar Engineering. 2nd Ed.* Taylor and Francis, Philadelphia. 2000.

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Questions

Questions/Discussion