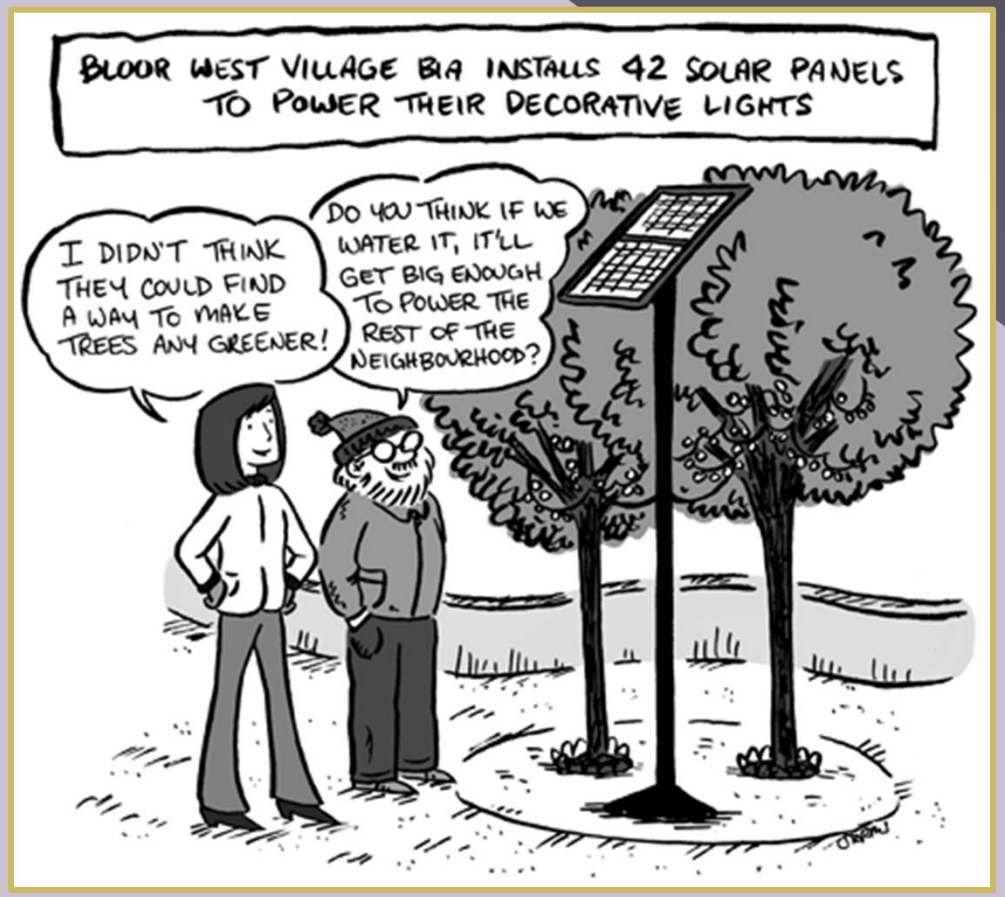
Engineering Solar Power



Alex Walker

ECE 3080

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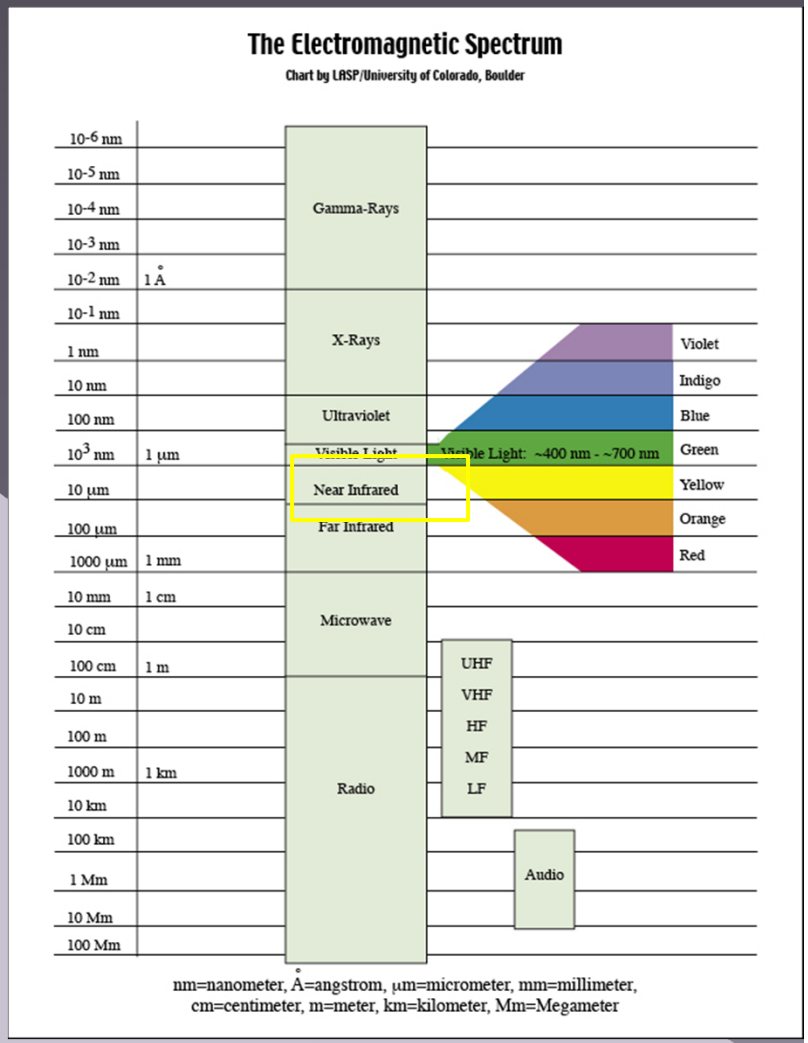
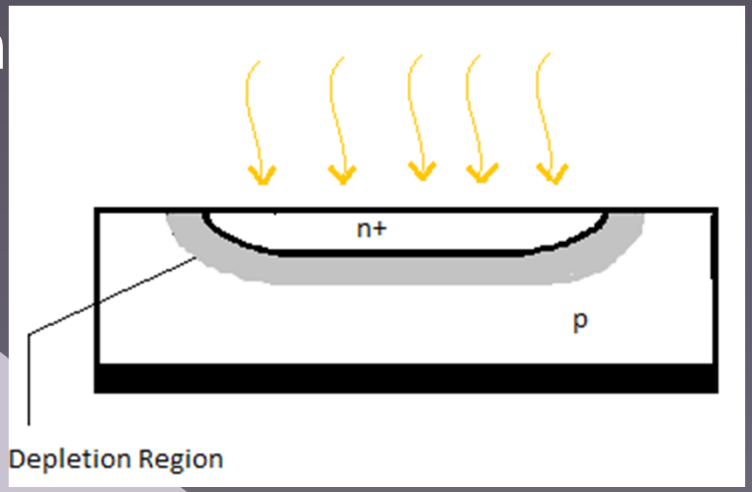
Photodetectors and Photodiodes

- Near infrared to visible light
- Photodetectors are used to measure amount of light energy present
  - Contains PN junction
  - Light enters through the top



Photodetectors and Photodiodes

- Photons with greater energy than the bandgap create electron h pairs
  - $E_{ph} = hv$
  - $E_{ph} > E_g$
  - $E_{ph} < E_g$
  - Spectral cutoff at $\lambda = 1.24/E_{ph}$
- Pairs are separated in depletion region
- Photocurrent is in "reverse bias" direction



Collection of Current

$$I_{total} = I_F - I_L$$
$$= I_s(e^{\frac{qV}{kT}} - 1) - I_L$$

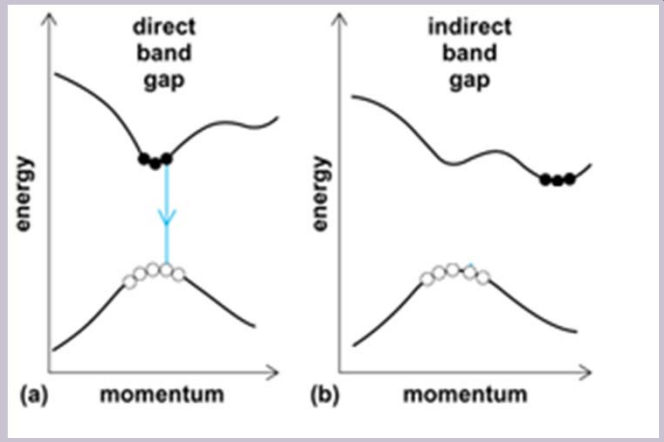
I_F=forward bias current

$I_L = photocurrent$

$I_S = ideal\ reverse\ saturation\ current$

Photodetectors and Photodiodes

- Direct and Indirect Band Gaps
- Conservation of energy and wave vector
- Direct bandgaps absorb light easier than indirect
- Indirect:
  - Three particle collision: photon, phonon, and electron

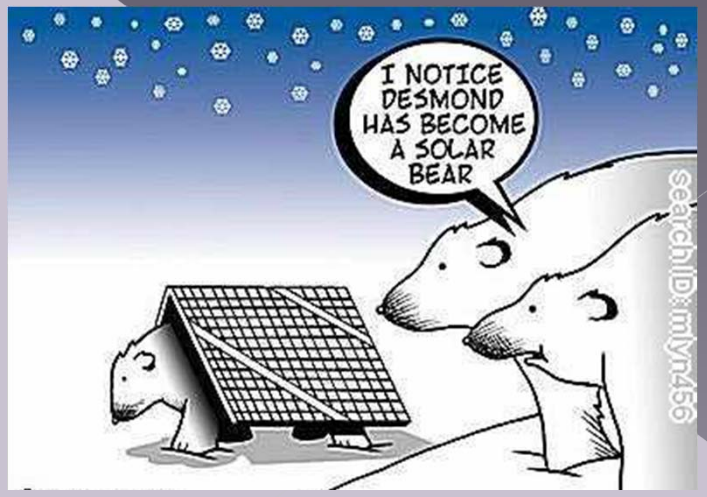


Absorption

- Absorption coefficient, α
- Penetration Depth $1/\alpha$
- Low α, penetration depth increases
- High α, penetration depth is reduced and photons are absorbed closer to the surface
  - Recombination increases
- High field in the depletion region
  - Quicker response for carriers

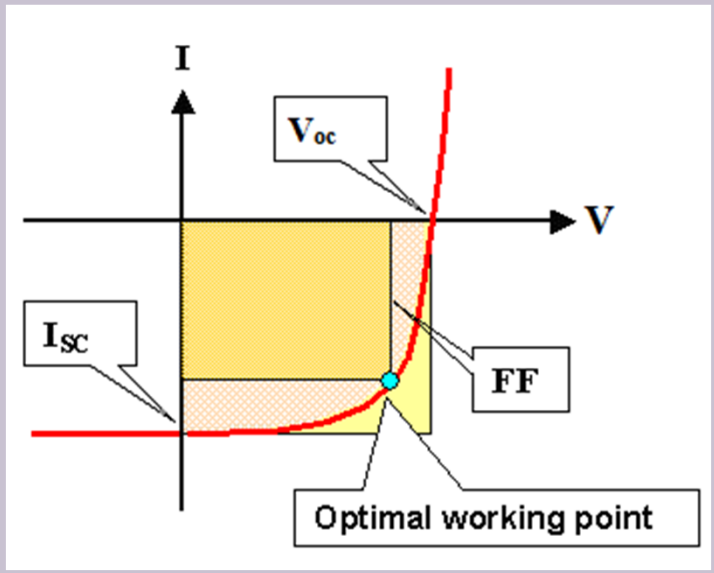
Absorption

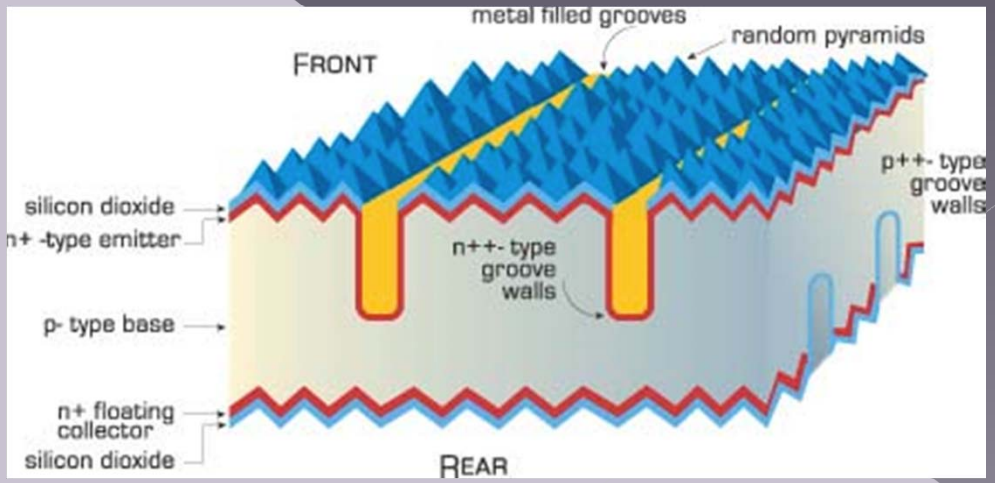
- Short Circuit current is directly proportional to light intensity
- Open circuit voltage increases logarithmically with intensity
  - We want Voc as large as possible for solar cells



Solar Cells

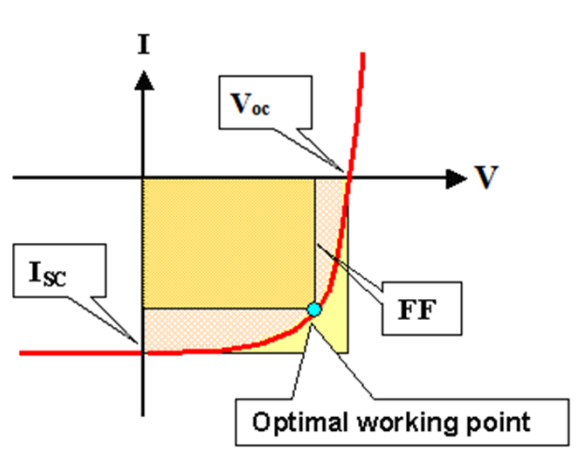
- Comprised of photodetectors used to generate DC power – minority carrier devices
- Several square centimeters
- Operating point (I_m, V_m) P = IV





Fill Factor (FF)

- Fill factor measures how well the shaded box in quadrant IV is filled



$$FF = \frac{V_m I_m}{V_{oc} I_{sc}}$$

$$\eta = {P_{max}}/{P_{in}}$$

$$= \frac{V_m I_m}{P_{in}}$$

$$= FF \frac{V_{oc} I_{sc}}{P_{in}}$$

Power Conversion Efficiency, η

$$\eta = {}^{P_{max}}/_{P_{in}}$$

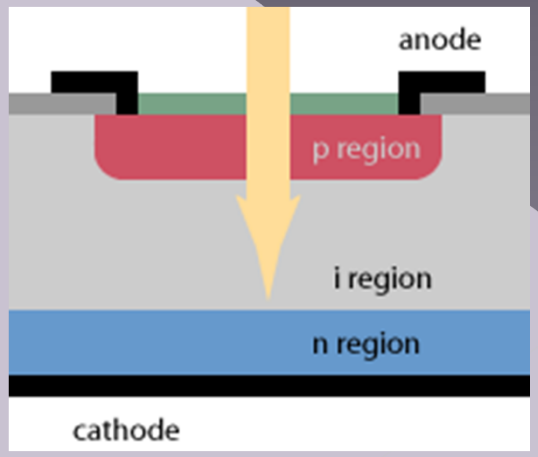
- Dependant on short circuit current and open circuit voltage
  - Solar spectrum of the output of the sun affects absorption
    - Minority diffusion length, probability of creation of pairs, and probability of collection
  - Air Mass 0 (AM0) – sunlight satellites receive
  - Air Mass 1 (AM1) – entered earth's atmosphere

Power Conversion Efficiency, η

- Band gap affects η when photons less than the band gap are not absorbed and cannot contribute to photocurrent
- For example, Si solar cells loose 20% of incident photons due to energy below the band gap
- Additional energy is lost due to phonon (heat)
- Silicon's max energy conversion is ~40%
- Diffusion coefficient should be large to increase collection of photogenerated carriers

PIN Photodetector

- PIN is great because of the existence and tailorability of the intrinsic region
- Intrinsic width can be equal to $1/\alpha$
- Frequency response is enhanced
- For high speed of response, sensitivity is sacrificed



Engineering Solar Cells

- High Efficiency Si Cell
  - Fingers: less allows for max light penetration
  - However, series resistance of few ohms can be detrimental
  - Avoid "shadowing"

Efficiency of Solar Cells

- Reflection
  - To minimize, surface is "textured"
  - Antireflective coating
  - Inverted pyramids
- Maximizing Absorption
  - Bottom surface oxide forms a mirror that reflects light back into the silicon – "Light Trapping"

Efficiency of Solar Cells

- Maximizing the collection of carriers
  - Minimize carrier recombination
  - Long minority diffusion lengths
  - Reduce top and bottom surface recombination

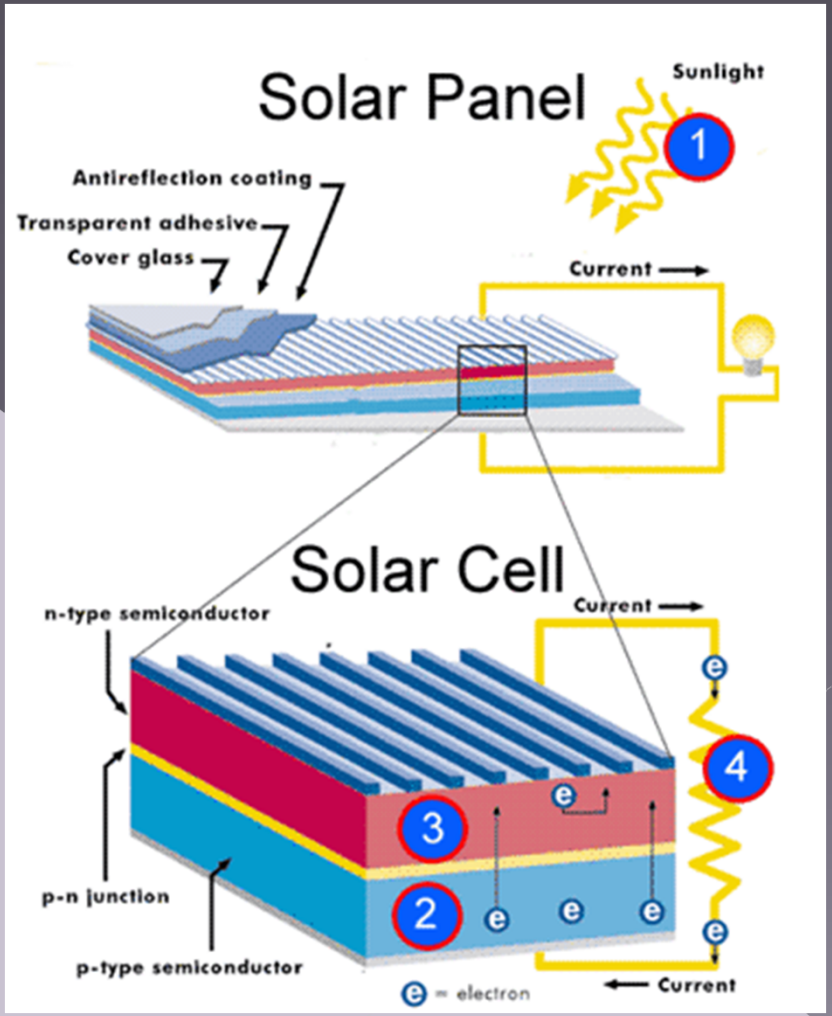
We should also consider the environment of the cell – keeping it clean of dust, weather conditions, location, and orientation of the surface, etc.

Types of Solar Cells

- Thin-film
  - Amorphous or polycrystaline film
  - CdTe and CuInSe
- Single-crystal
  - Si or GaAs
- Concentrator
  - Designed to operate under light intensitites of 100 suns or more
  - Primarily Si and GaAs
  - Concentrated solar power are systems that use lenses or mirrors to concentrate a large area of sunligh onto a small area

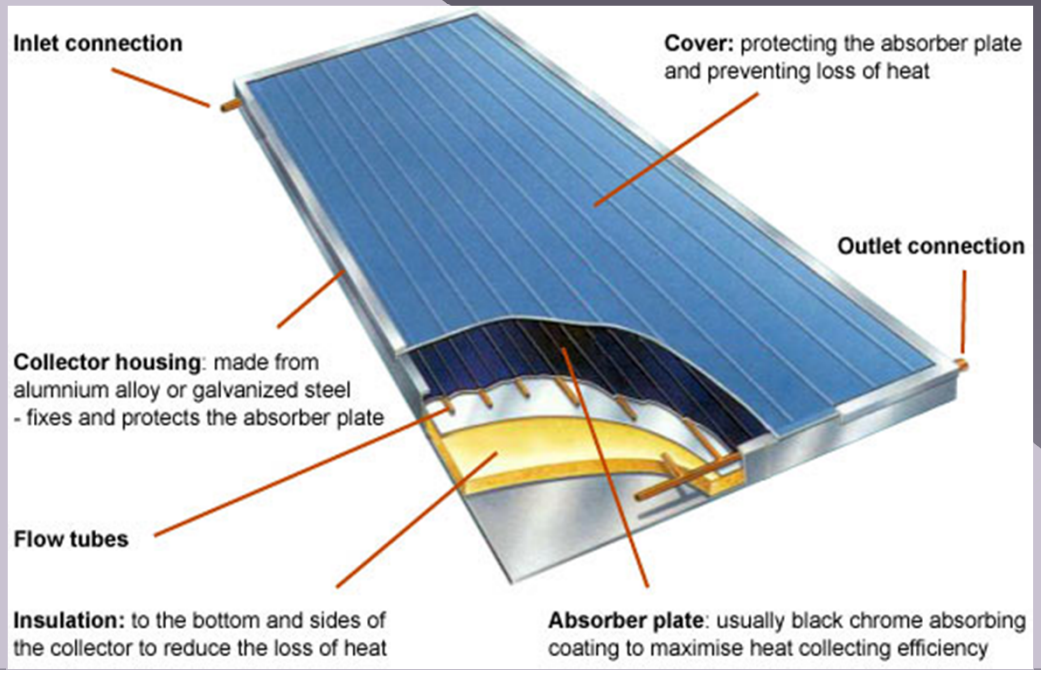
Making the Panel/Collector

- Ohmic contacts from the solar cell collect the carriers
- Solar cells are wired either in series or in parallel



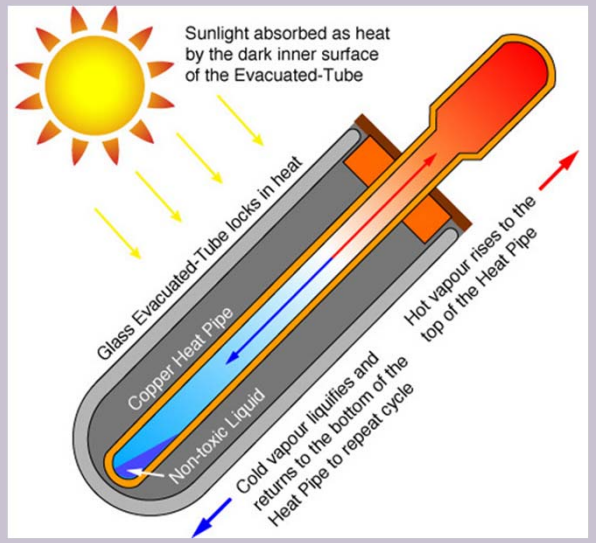
Types of Solar Collectors

- Flat Plate Collector
  - Dark flat-plate absorber of solar energy
  - a transparent cover
  - a heat-transport fluid (air, antifreeze or water) to remove heat from the absorber
  - a heat insulating backing



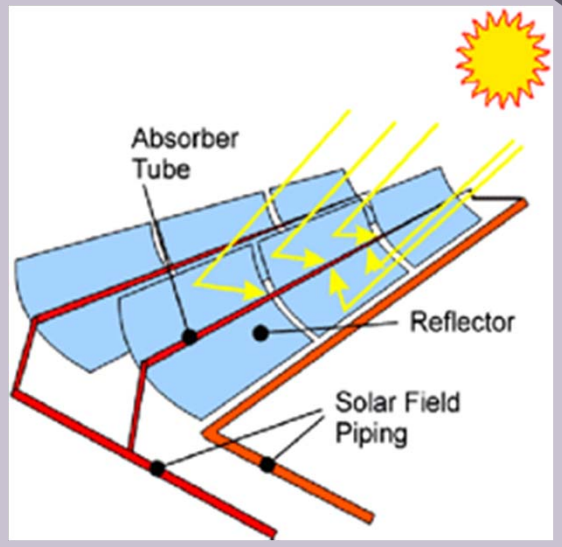
Evacuated tube collectors

- Vacuum tube collectors use heat pipes for their core instead of passing liquid directly through them.
- Evacuated heat pipe tubes (EHPT's) are composed of multiple evacuated glass tubes each containing an absorber plate fused to a heat pipe

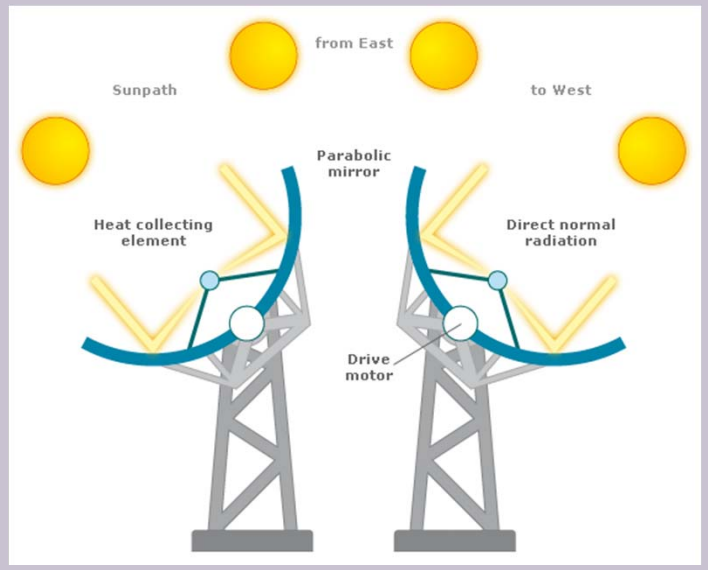


Parabolic Trough & Parabolic Dish

- Parabolic Trough

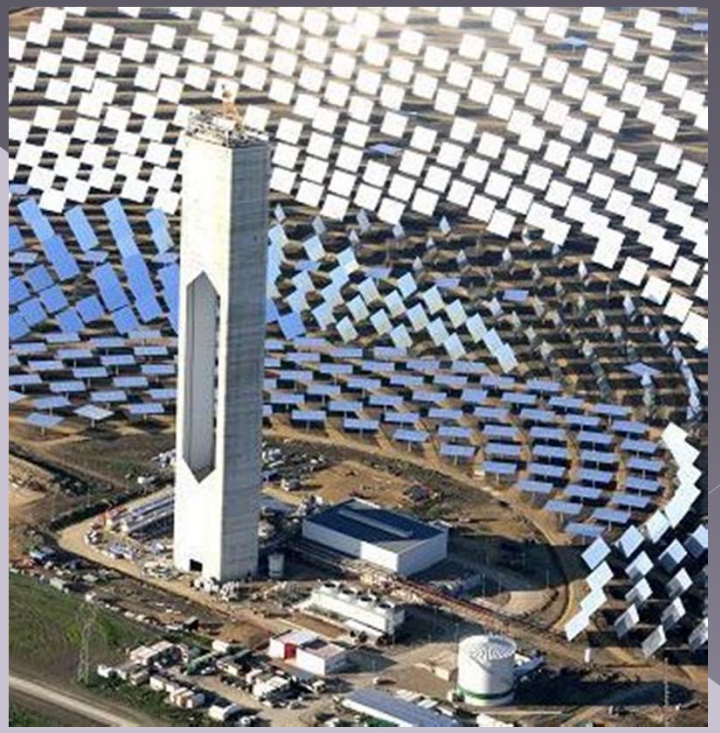


- Parabolic Dish – most powerful, concentrates light at a single focal point



Solar Power Tower

- is a type of solar furnace using a tower to receive the focused sunlight
- Uses Heliostats



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NO ONE TOLD ME THAT I WAS GOING TO HAVE TO WORK WITH HER!
SCHRÖDINGER
N.HARDING


SO WE'RE PREDICTING A NICE COMFORTABLE FLIGHT TODAY FOLKS, UNLESS OF COURSE WE RUN IN TO ANY CLOUD COVER
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