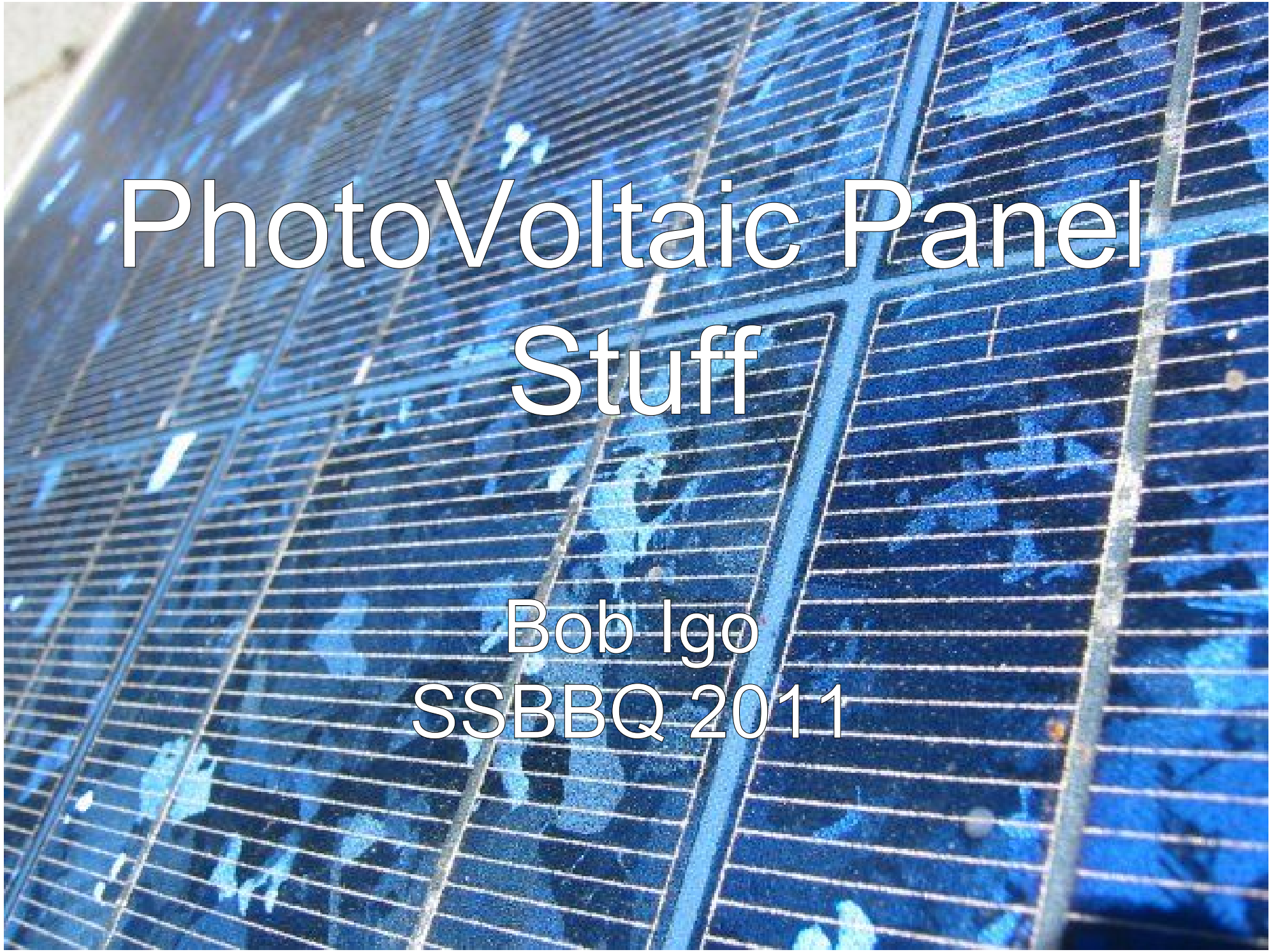


PhotoVoltaic Panel Stuff

Bob Igo

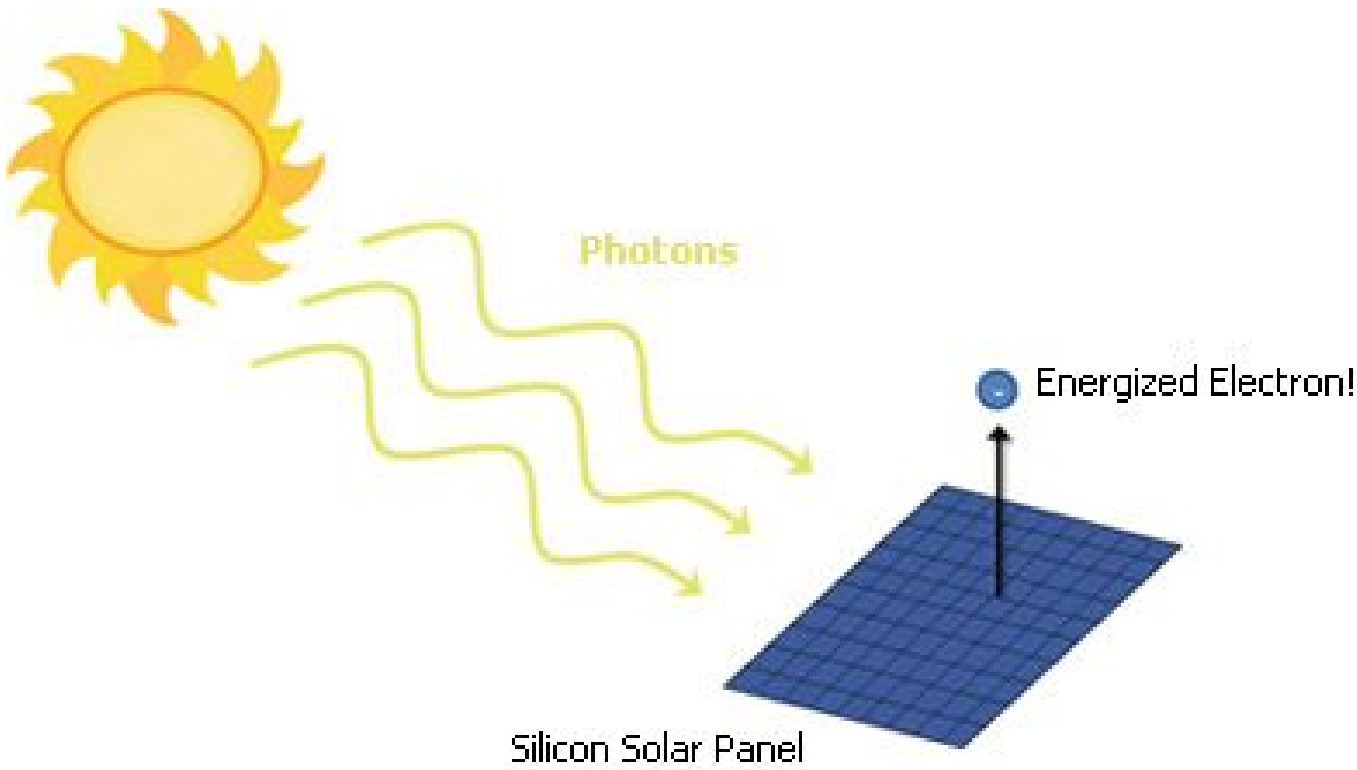
SSBBQ 2011

Topics

- Function
- Material
- Rating and Entropy
- Money

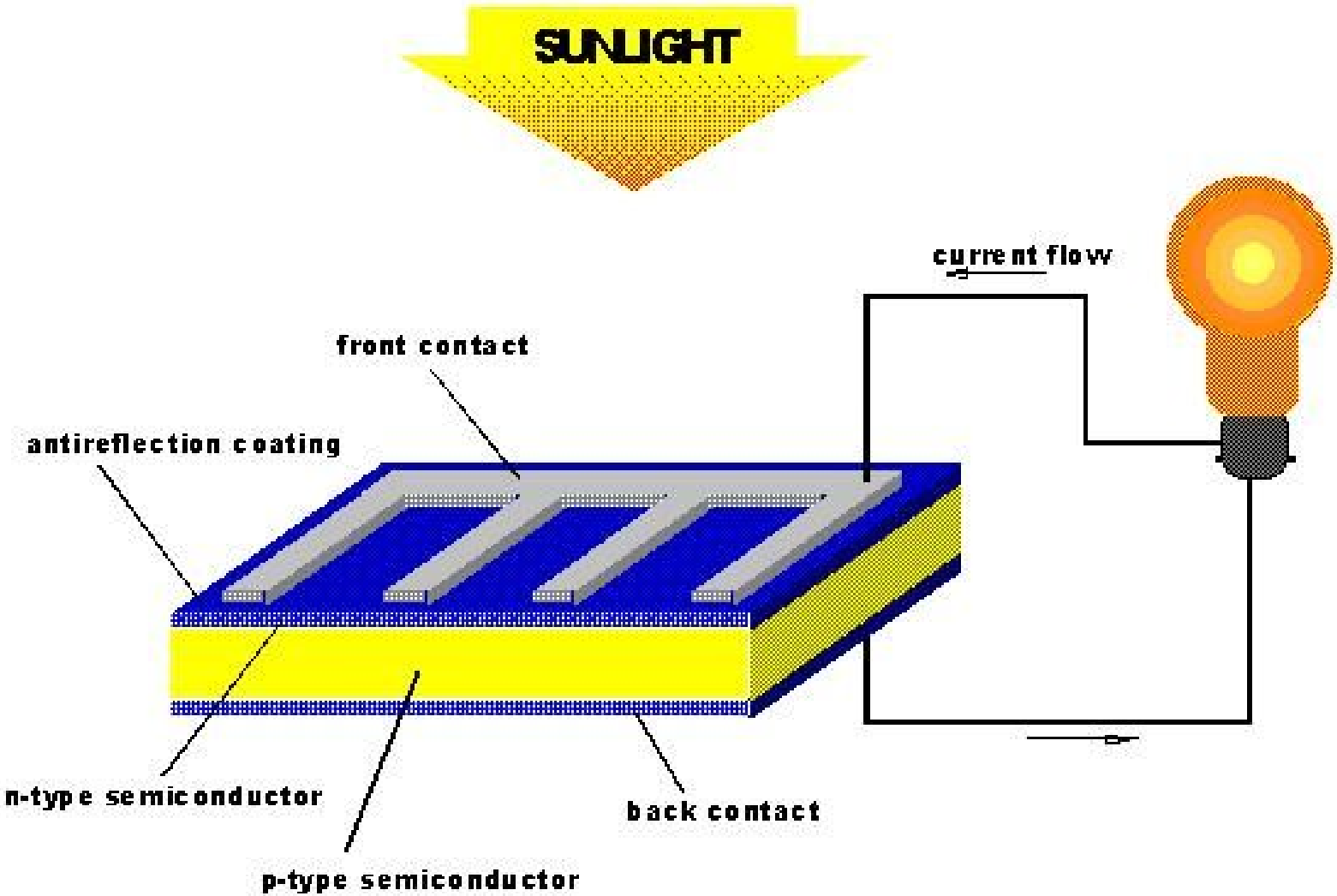
Function: The Physics

Photons with the right amount of energy strike the panel and temporarily knock electrons loose.



The excess electrons flow out of the panel, into your TV, and back into your panel, completing the circuit.

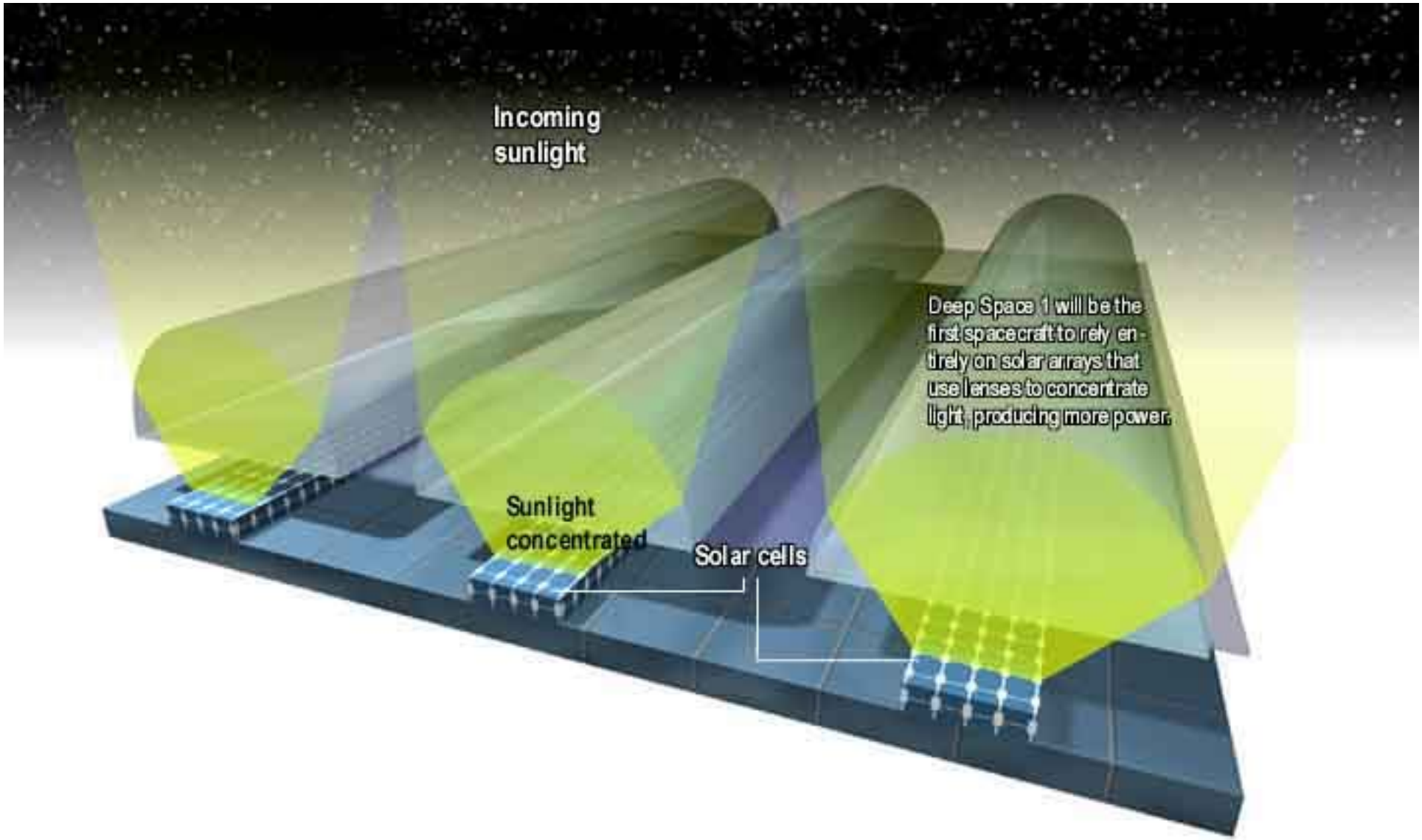
Function: The Physics



Material: Types of PV panels

- All of them are semi-conductors
- Concentrating vs Non-concentrating
- Monocrystalline
- Polycrystalline
- thin film

Concentrating

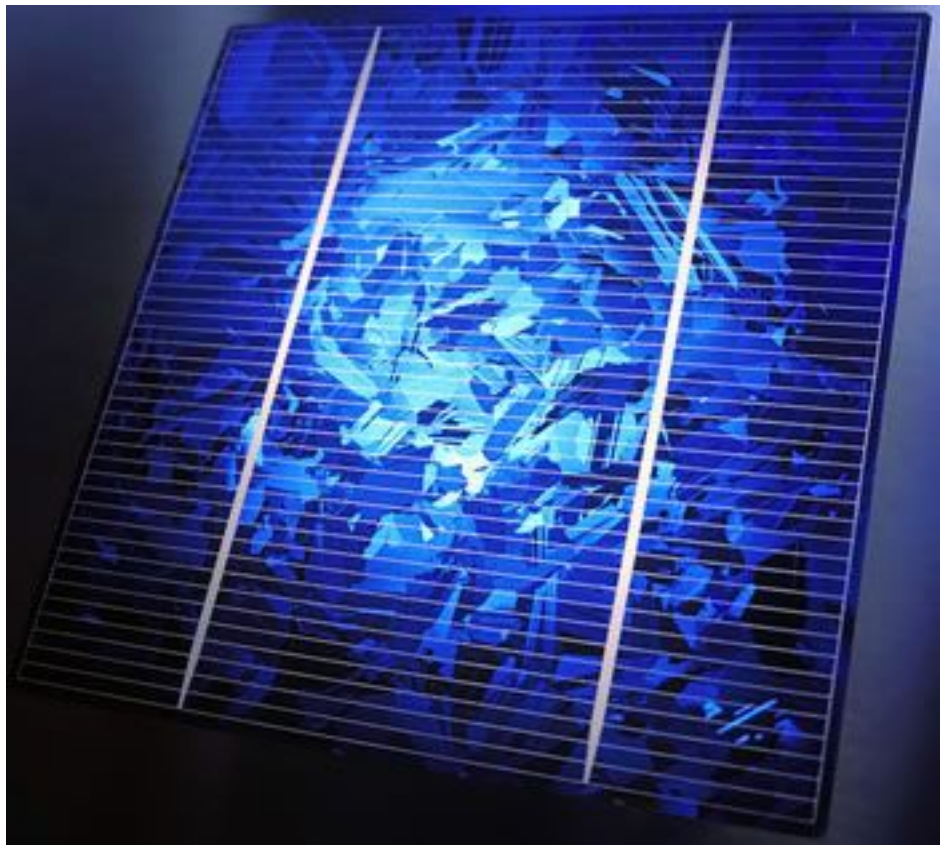


Non-concentrating

Monocrystalline

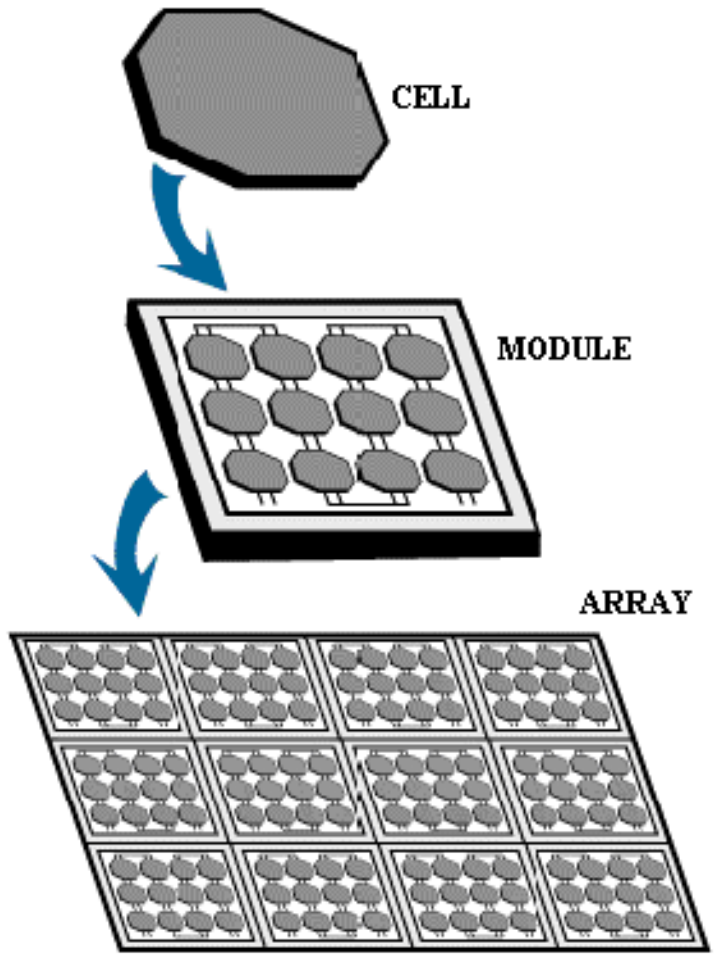
Polycrystalline

Manufacturing imperfections are pretty



Thin Film

Material:
Cell < Panel (or Module) < Array



Material: Array Types

- Fixed
- Tracking

Fixed Array

Tracking Array

Function + Material: Cost and Efficiency

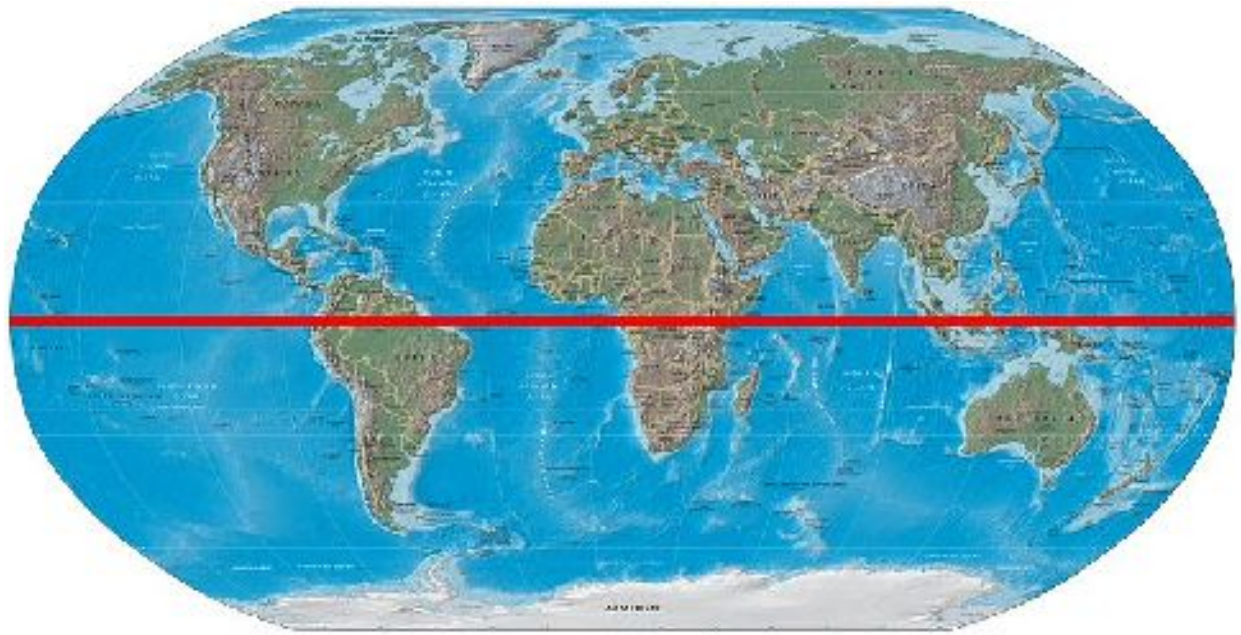
- In general, for a given panel Wattage
  - cost
    - monocrystalline > **thin film** > **polycrystalline**
    - concentrating > non-concentrating
    - tracking = 2x fixed (parts + installation)
  - efficiency
    - monocrystalline > **polycrystalline** > **thin film**
    - concentrating > non-concentrating
    - tracking = 2x fixed

Rating

- Panels rated in Watts
- Standard rating method across all manufacturers
    - Exaggerates what most customers can expect

Rating: Peak Solar

- "Peak Solar" rating = Watts produced by panel during "Peak Solar" irradiance of $1000 W/m^2$
- This is how much energy is in the sunlight that hits *the equator* on a *sunny day*.



Rating Example

- A "200W" panel produces $200W$ if bathed in $1000W/m^2$ of sunlight.
  - many sizes of panel could be rated at $200W$
  - smaller $200W$ panels are necessarily more efficient than larger $200W$ panels
- For easy example math, assume a $1m^2$ panel
  - 20% efficient.

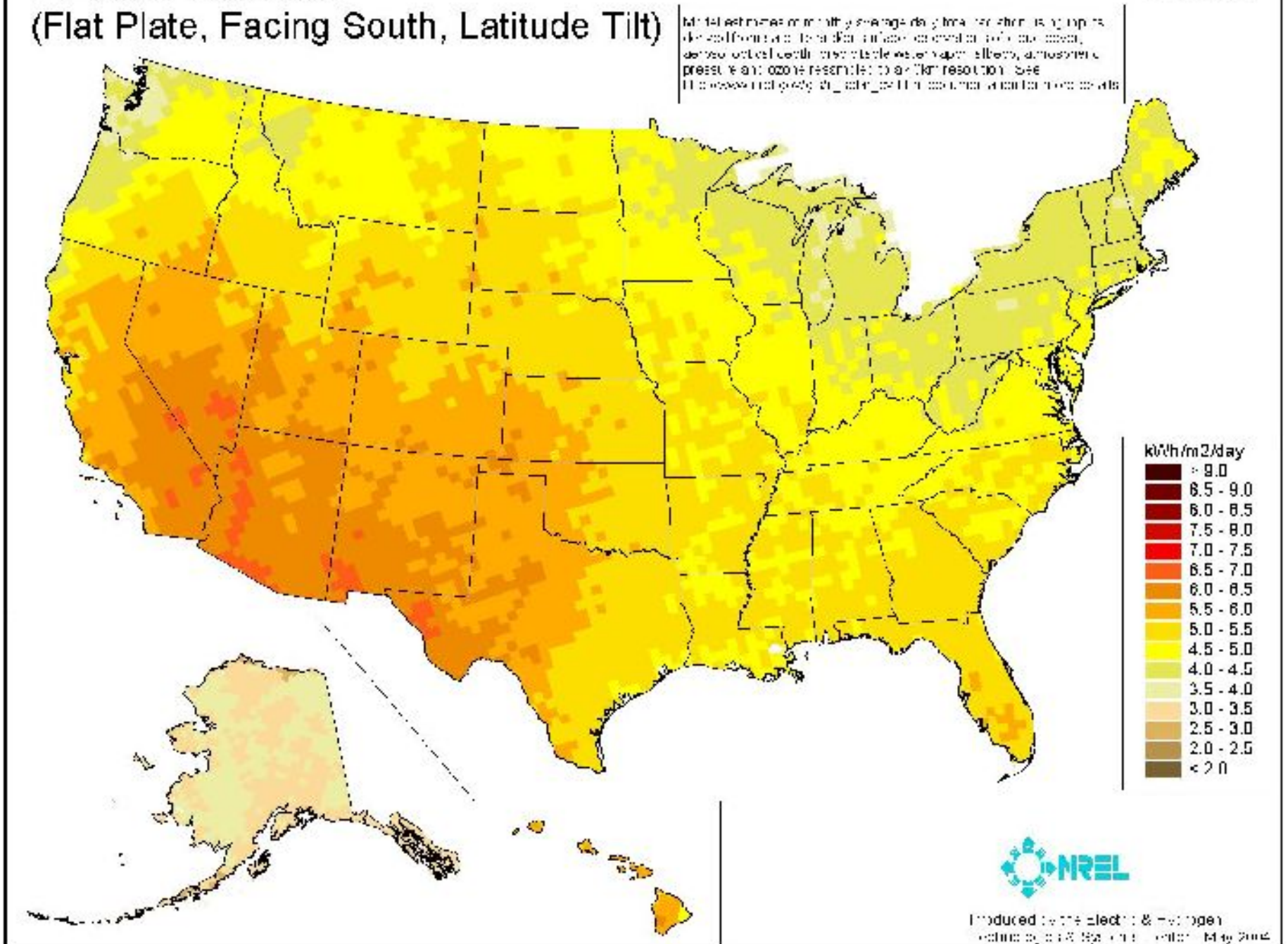
Rating: How Much Will a "200W" Panel Produce Here?

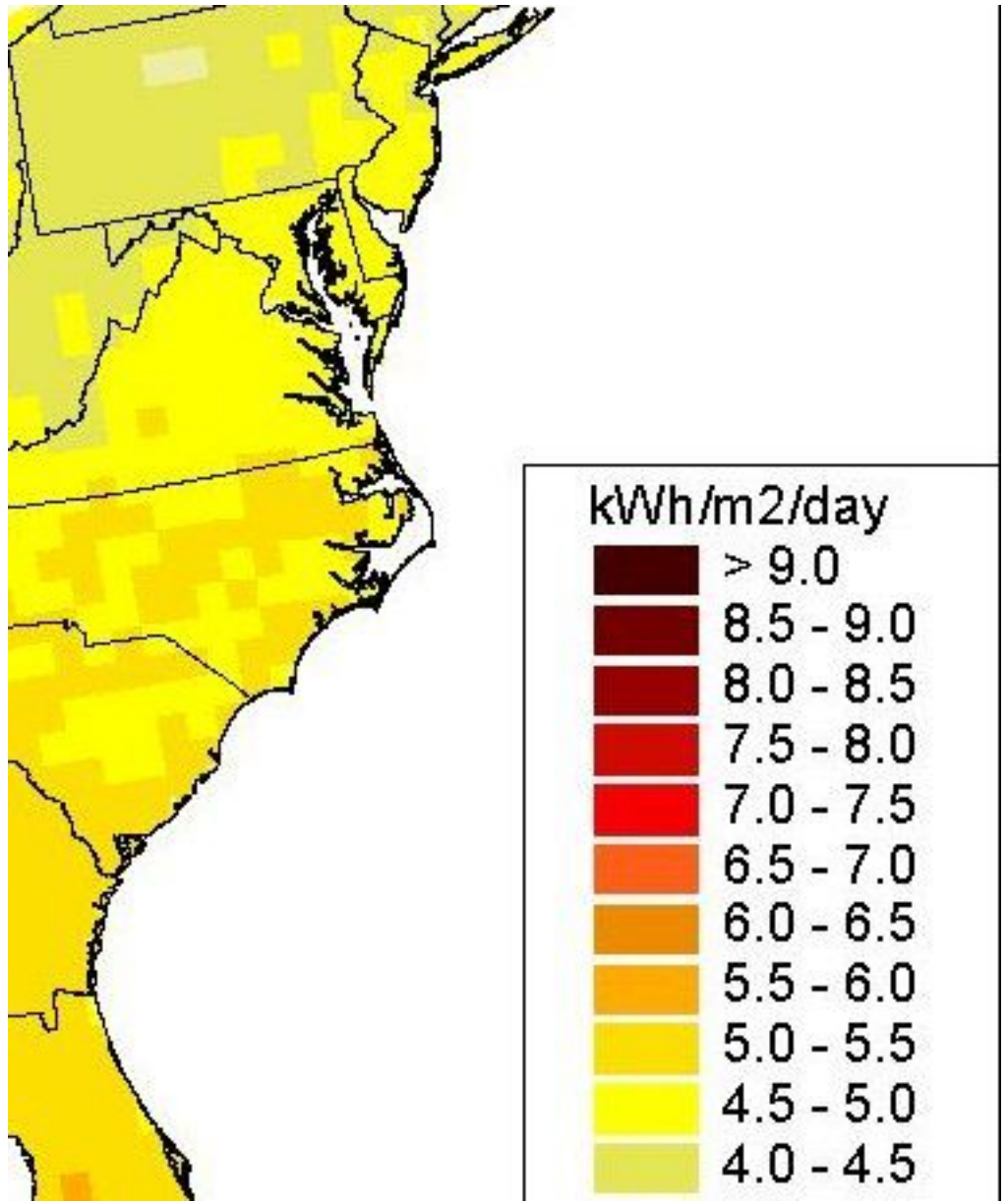
- peak solar irradiance is much less than $1000 W/m^2$

- let's see what our expected energy input is

PV Solar Radiation
(Flat Plate, Facing South, Latitude Tilt)

Annual




kWh/m2/day
> 9.0
8.5 - 9.0
8.0 - 8.5
7.5 - 8.0
7.0 - 7.5
6.5 - 7.0
6.0 - 6.5
5.5 - 6.0
5.0 - 5.5
4.5 - 5.0
4.0 - 4.5

Digression

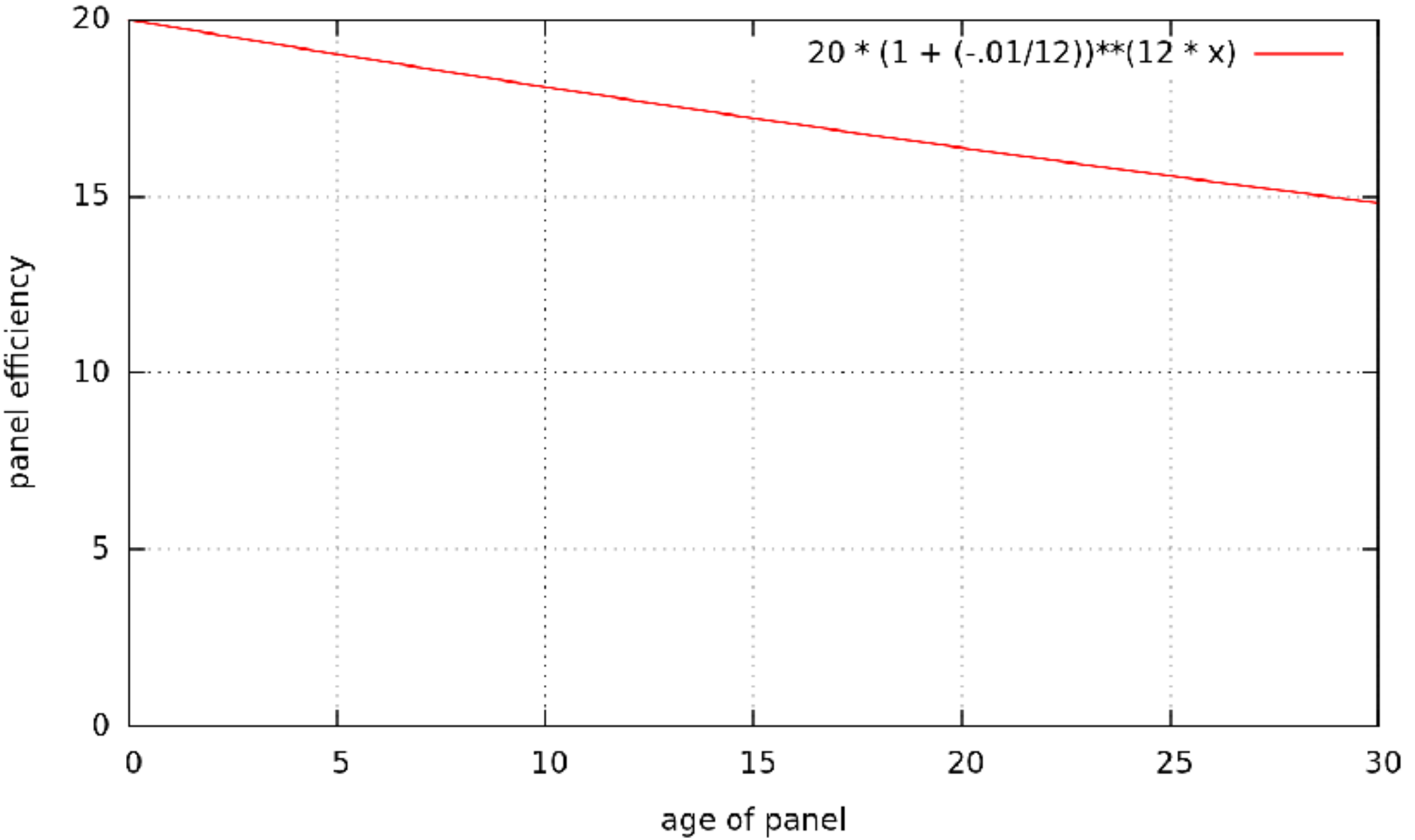
Sunfall is measured with fixed-angle pyranometers.

There's a pyranometer in a parking lot near the Monroe Twp municipal building.

Rating: De-Rating

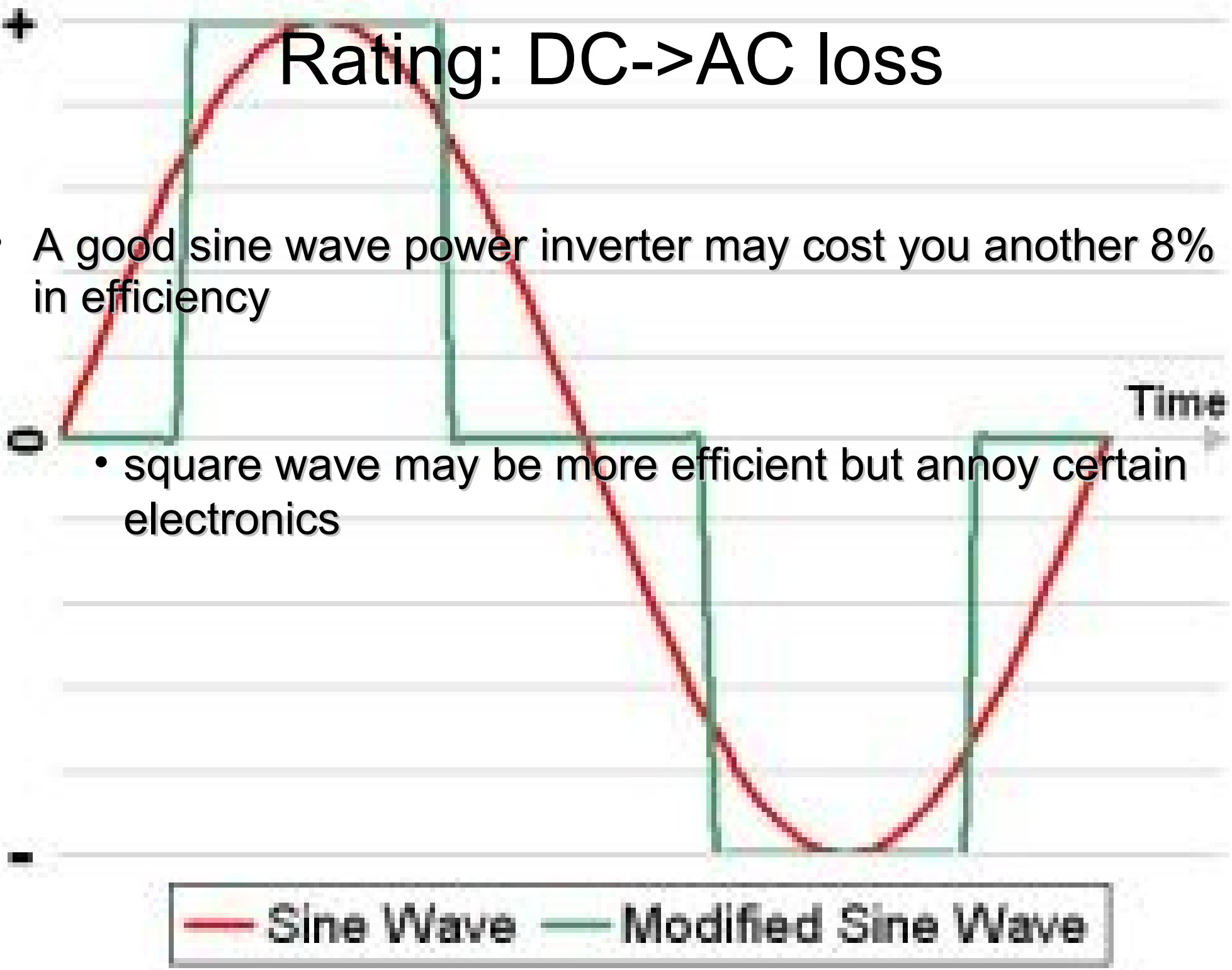
- As your panel ages, it slowly loses efficiency.
  - 1% of starting efficiency per year
    - 20% efficient panel is 14.8% efficient at the end of year 30
    - efficiency_at_end_of_year_**Y** =

      20 * (1 + (-.01/12))^(12 * ***Y***)


20 * (1 + (-.01/12))**(12 * x)
panel efficiency
age of panel
0
5
10
15
20
25
30

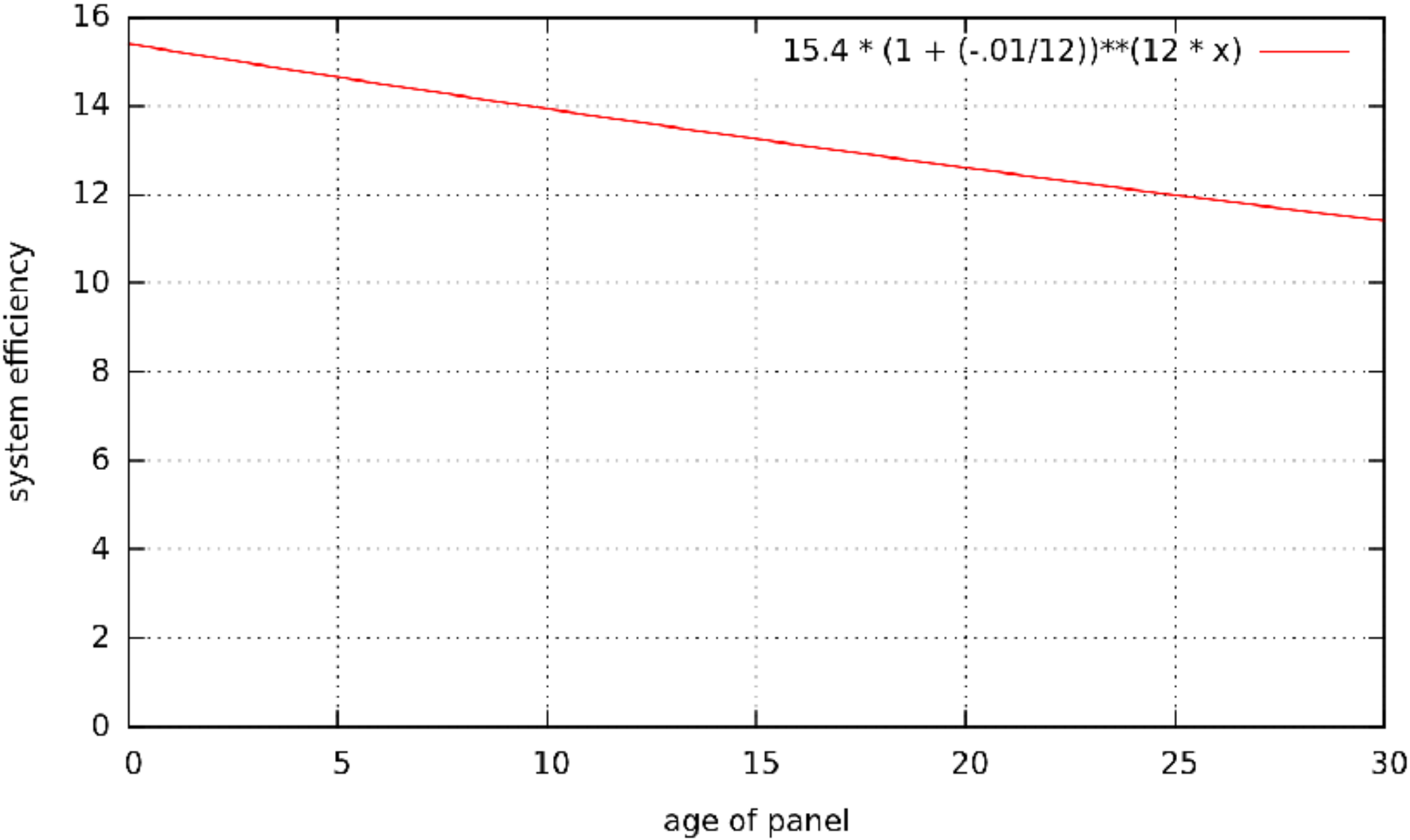
Rating: DC->AC loss

- A good sine wave power inverter may cost you another 8% in efficiency
  - square wave may be more efficient but annoy certain electronics



Rating: total De-Rating

- The equipment that lets you use the power produced by your panels causes you to lose some power to heat.
- There are also environmental factors like dust and shade.
- A full system may have about a `23%` loss in efficiency.
- When it's actually hooked up and in use, our `200W` panel becomes a `154W` panel *on the equator at noon*.


15.4 * (1 + (-.01/12))**(12 * x)
system efficiency
age of panel
0
2
4
6
8
10
12
14
16
0
5
10
15
20
25
30

Entropy: How/why panels fail

- Research suggests it's largely environmental
- Glass coatings can
  - crack
  - be scratched
- Plastic coatings can become opaque from UV
- Seals can fail

Entropy: Lifespan

- Warranties cover about 20 years for 80% output
  - matches 1% annual decline
- Some biased and non-biased sources suggest 30–40 years is feasible; some original panels still working
  - unclear if 1% annual decline continues
- Some total failures can be repaired.

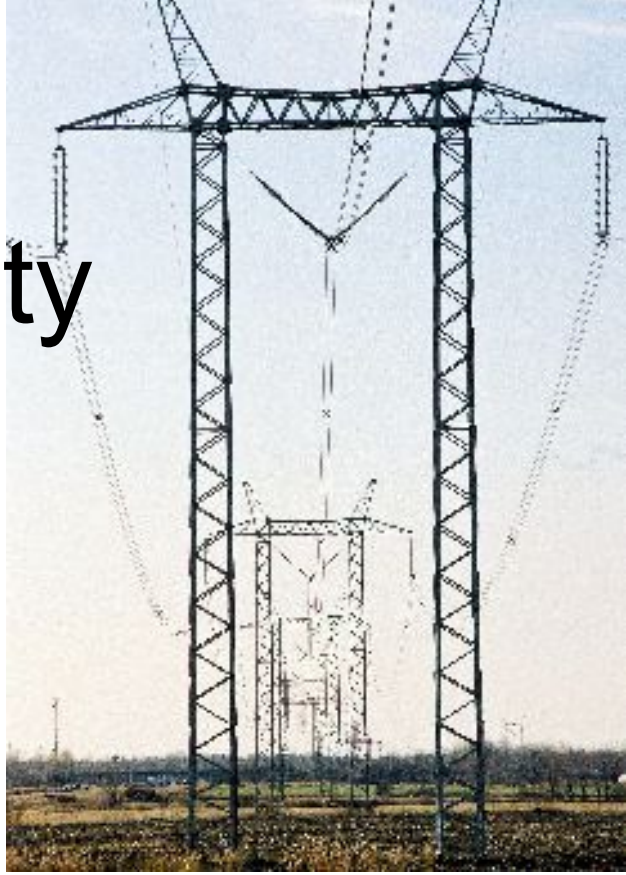
Money: Electricity Production

Money: Electricity Production

Our 154W panel would see an average of $4500 Whr/m^2/day$ in sunfall

- at the start of year 1, it recovers 15.4% of it
- at the end of year 30, it recovers 11.39% of it
- the average efficiency over that time is 13.4%
  - average of 220.25kWhr each year
  - total of 6607.37kWhr over 30 years

Money: Power Utility



- The fixed monthly cost of electricity from MetEd is about $9.34
- The cost per kWhr works out to about $0.13
  - 6607.37kWhr over 360 months from MetEd:
  - (360 * $9.34) + (6607.37 * $0.13) = $4221.36
- Of course, MetEd's future costs are unknown.

Money: Selling it Back

- Net metering
  - the meter runs backwards (sometimes the minimum bill is $0)

Money: Selling it Back

- Some people switch from fixed-rate plans to peak-rate plans
  - sell excess production to utility company during peak hours
  - buy supplemental electricity as needed (nights, clouds, snow)

Money: Incentives

- There may be Federal and State tax credits available for PV installations
  - Remember, they only reduce taxable income
    - A $3000 tax credit only means you're not taxed on $3000 of your income – it doesn't mean you pay $3000 less in taxes, unless you're taxed at 100% normally
- Some utility companies subsidize PV installations

Money: MetEd Still Relevant

- Basic installations lack storage
  - storage also decreases efficiency

- Still need to buy electricity when panels are not meeting need

Money: Cost Effectiveness

- You can probably generate more electricity than the installed system cost, over its lifespan
- A reasonable mutual fund might earn you more over that period
- Older homes may benefit more from efficiency upgrades
  - also tax credits for that

Unknowns

- Future cost of power line electricity unknown
  - *relative* per-kWhr cost has remained fairly flat for about 20 years
  - We rely on a lot of fossil fuel to generate electricity
- Lock in to old technology?
  - Available panel technology hasn't had a breakthrough in a while.
  - You could buy panels, and 5 years later, same money would get you more efficiency
  - There is currently a market for used panels

Miscellany

- In the first few weeks of operation, panels may be 10% more efficient than their rating
- Freedom/independence may be more important than cost effectiveness

Questions?

Sources

- http://upload.wikimedia.org/wikipedia/commons/2/2c/Us_pv_annual_may2004.jpg
- http://www.nrel.gov/learning/re_photovoltaics.html
- http://rredc.nrel.gov/solar/calculators/PVWATTS/system.html
- http://www.nrel.gov/learning/media/includes/pv_1_320x240.flv (at 2:58)