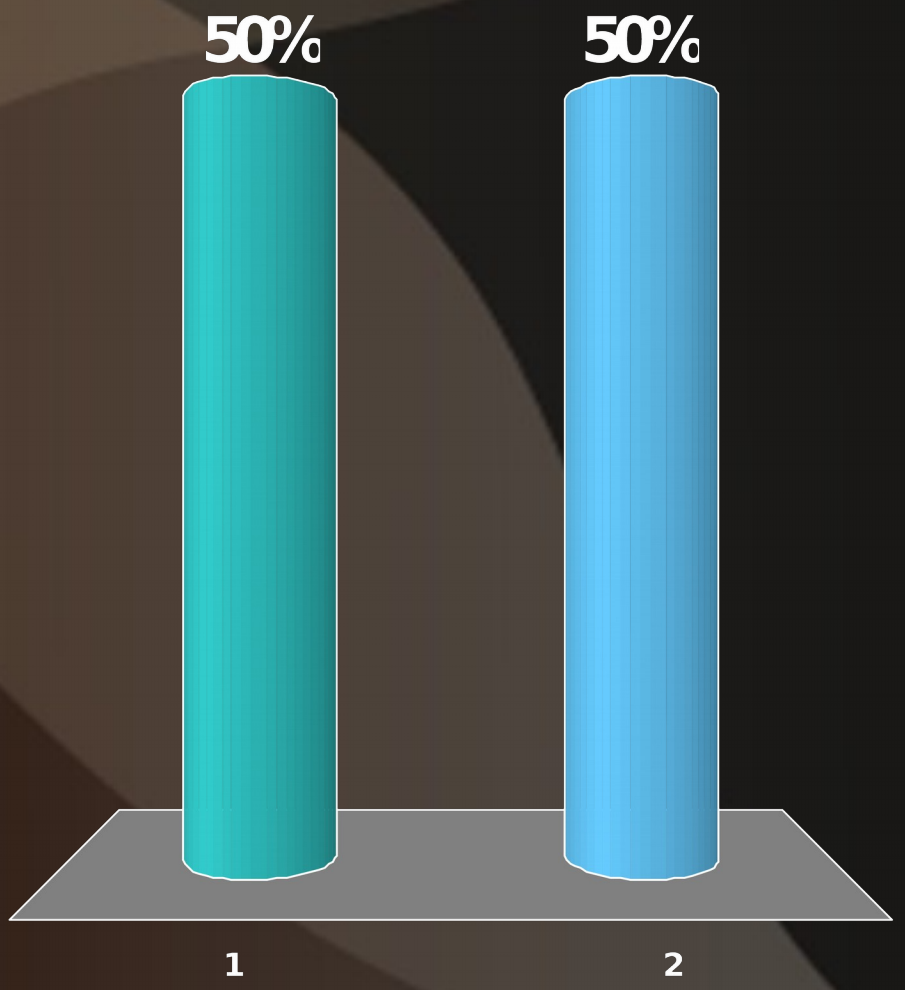
Solar Energy II

Solar Electricity

Original slides provided by Dr. Daniel Holland

Would you be willing to pay more for electricity generated with solar power?

1. Yes
2. No



Audio Link

How much more would you be willing to pay?

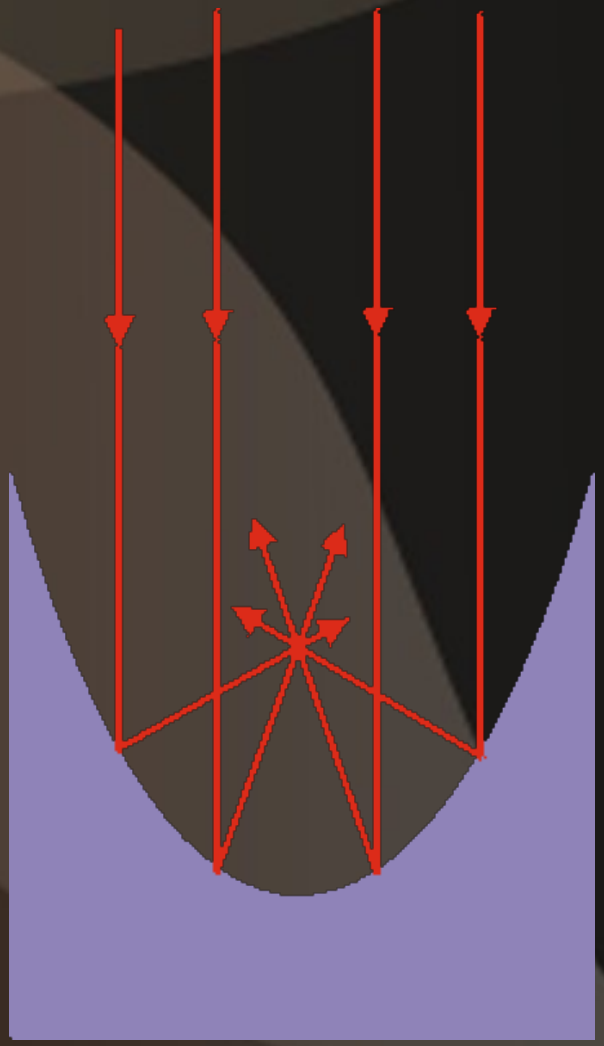
1. None
2. 10% more
3. 25% more
4. 50% more
5. 100% more
6. I'll pay whatever it costs

Technique 1

- Use mirrors to focus sunlight onto water.
- Boil the water
- Use a standard heat engine.

Parabolic Mirror

- The shape of the mirror causes all of the light rays to pass through a single point called the focus.

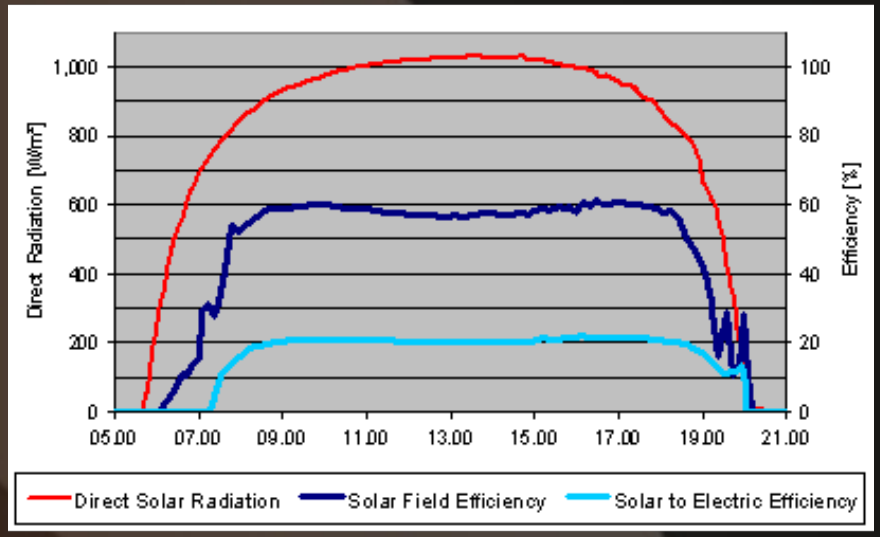


Trough and circular parabolic mirrors

Solar Oven

Trough System

Concentrates solar energy up to 100 times that of the sun.
Temperatures limited to ~400°C because heat exchange fluid (oil) breaks down.
Efficiency of ~20%.
Obviously varies throughout the day.



Improve Performance

- Use molten salt for heat exchange fluid.
- Allows for temperatures up to 565°C.
- Disadvantage is that freezing point of salt solution is 220°C. Possible problem of overnight freezing in pipes or waste energy keeping pipes hot.
- Trials underway in Sicily by Siemans

Solar Electric Generating System (SEGS)

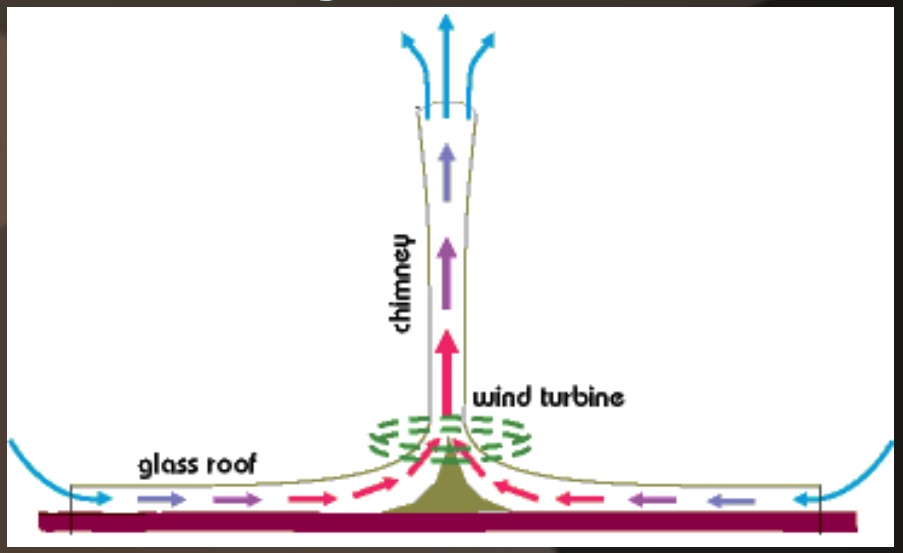
- Currently generates ~350 MW of power using 5 plants.

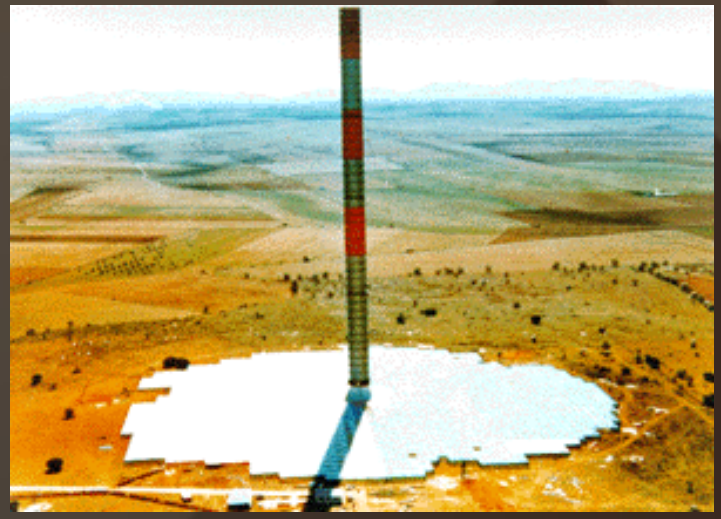
Heliostat

- Uses movable mirrors to focus light on a tower.
- Similar to parabolic mirror.
- Solar One Facility in Barstow, CA generates ~10MW

Solar Chimney

Air in a very large greenhouse (2 to 30 km diameter) is heated by the sun and channeled to a tall chimney where there is a wind turbine.





Manzanares, Spain

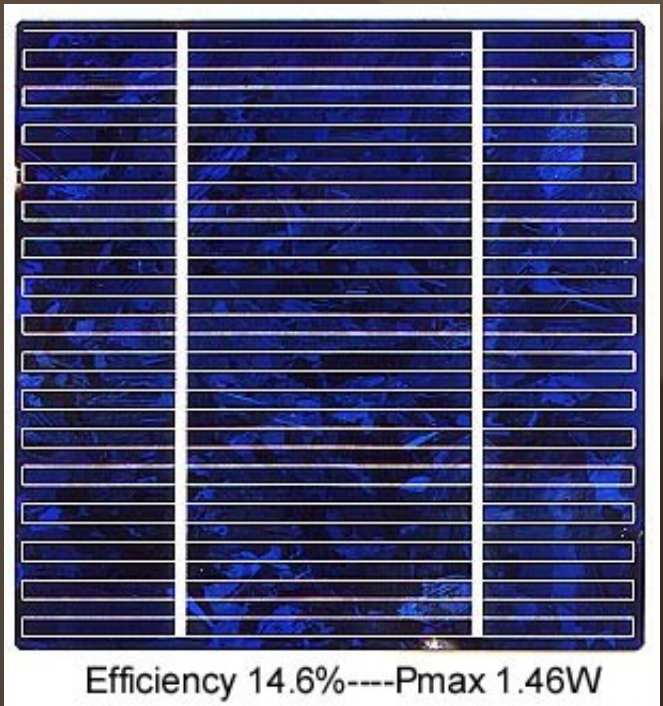
Photovoltaics

- Use Semiconductors to directly convert sunlight into electricity.
- In principle, 77% of sunlight can be used to produce solar electricity.

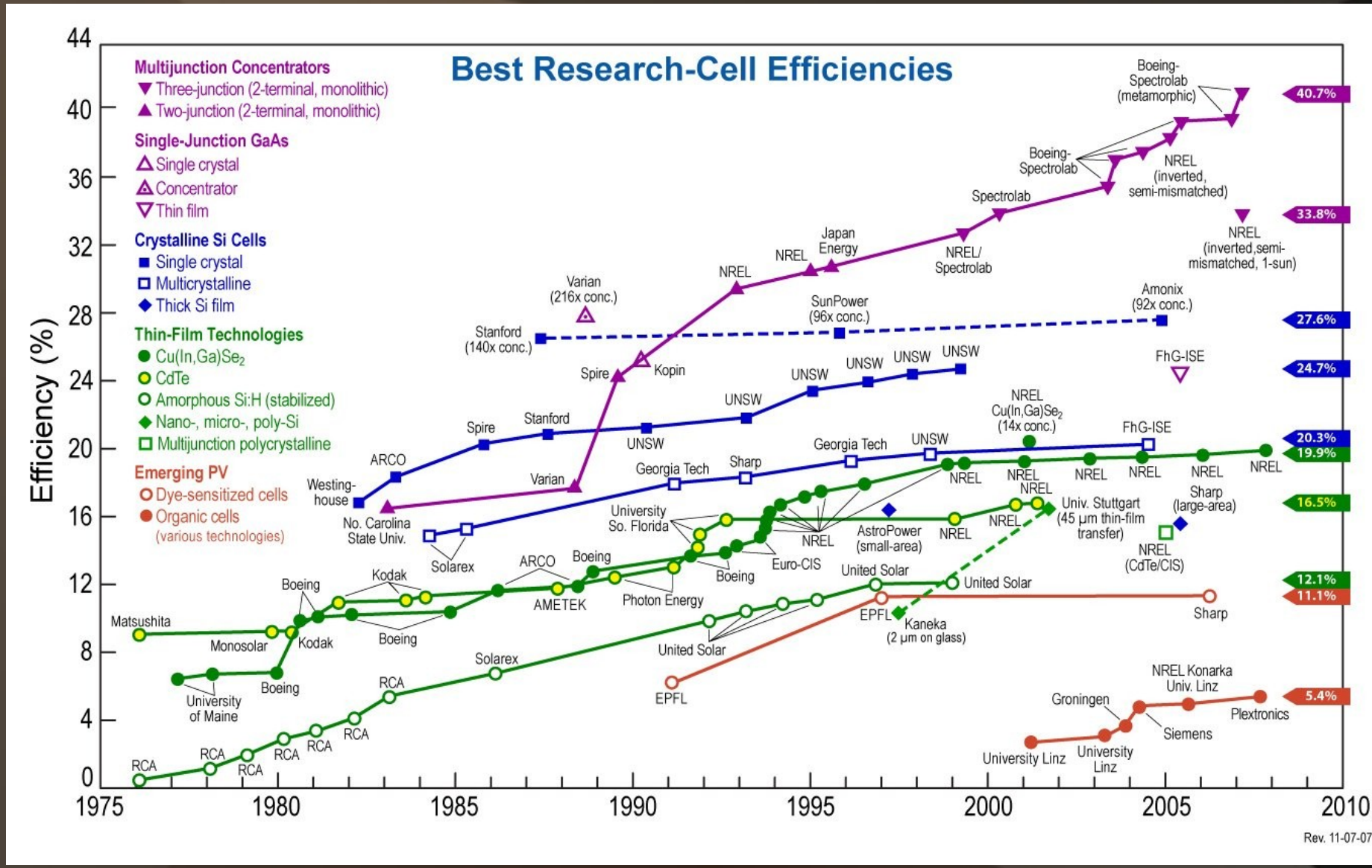
History

- 1954: Bell Labs discovered that silicon wafers are sensitive to sunlight
- Original cells required single crystal silicon. Very expensive to produce.
- New developments allow for polycrystalline cells. Much cheaper but less efficient.
- Best cells are single crystal Gallium-Arsenide.
- Up to 44% efficient with light concentration or 34% without

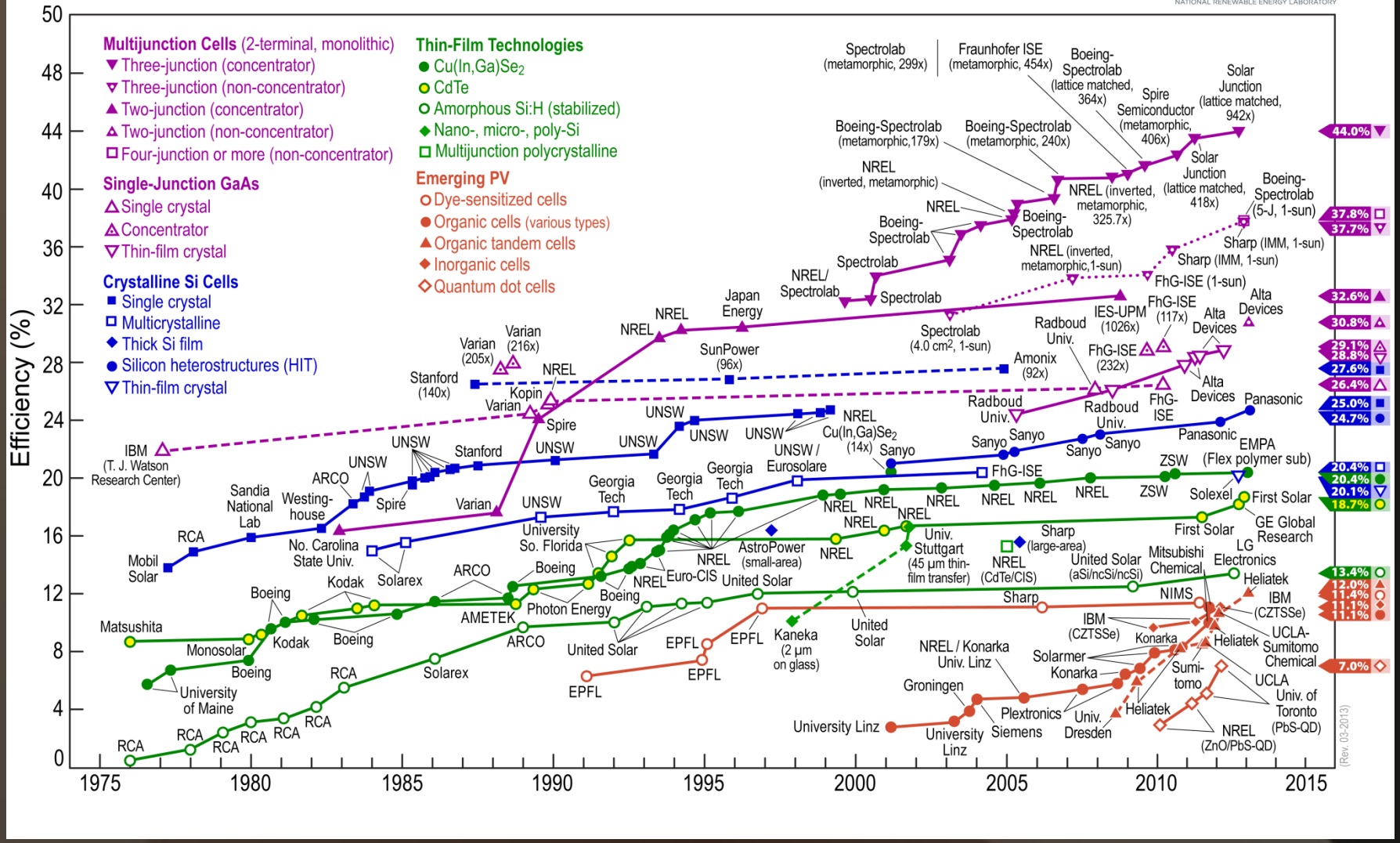
Single Crystal and Polycrystalline Cells



- Each cell produces ~0.5 volts. (Silicon single junction)
- Amount of current depends on the size/efficiency of the cell.
- To get higher voltages/power stack the cells up to make a solar panel.
- Industry average efficiency 14-18%
- High efficiency cells (>20%)are still relatively expensive.
- Lower efficiency cells (~14%) are much lower cost.


Best Research-Cell Efficiencies
Efficiency (%)
Multijunction Concentrators
Three-junction (2-terminal, monolithic)
Two-junction (2-terminal, monolithic)
Single-Junction GaAs
Single crystal
Concentrator
Thin film
Crystalline Si Cells
Single crystal
Multicrystalline
Thick Si film
Thin-Film Technologies
Cu(In,Ga)Se2
CdTe
Amorphous Si:H (stabilized)
Nano-, micro-, poly-Si
Multijunction polycrystalline
Emerging PV
Dye-sensitized cells
Organic cells
(various technologies)
40.7%
33.8%
27.6%
24.7%
20.3%
19.9%
16.5%
12.1%
11.1%
5.4%
Rev. 11-07-07

Best Research-Cell Efficiencies



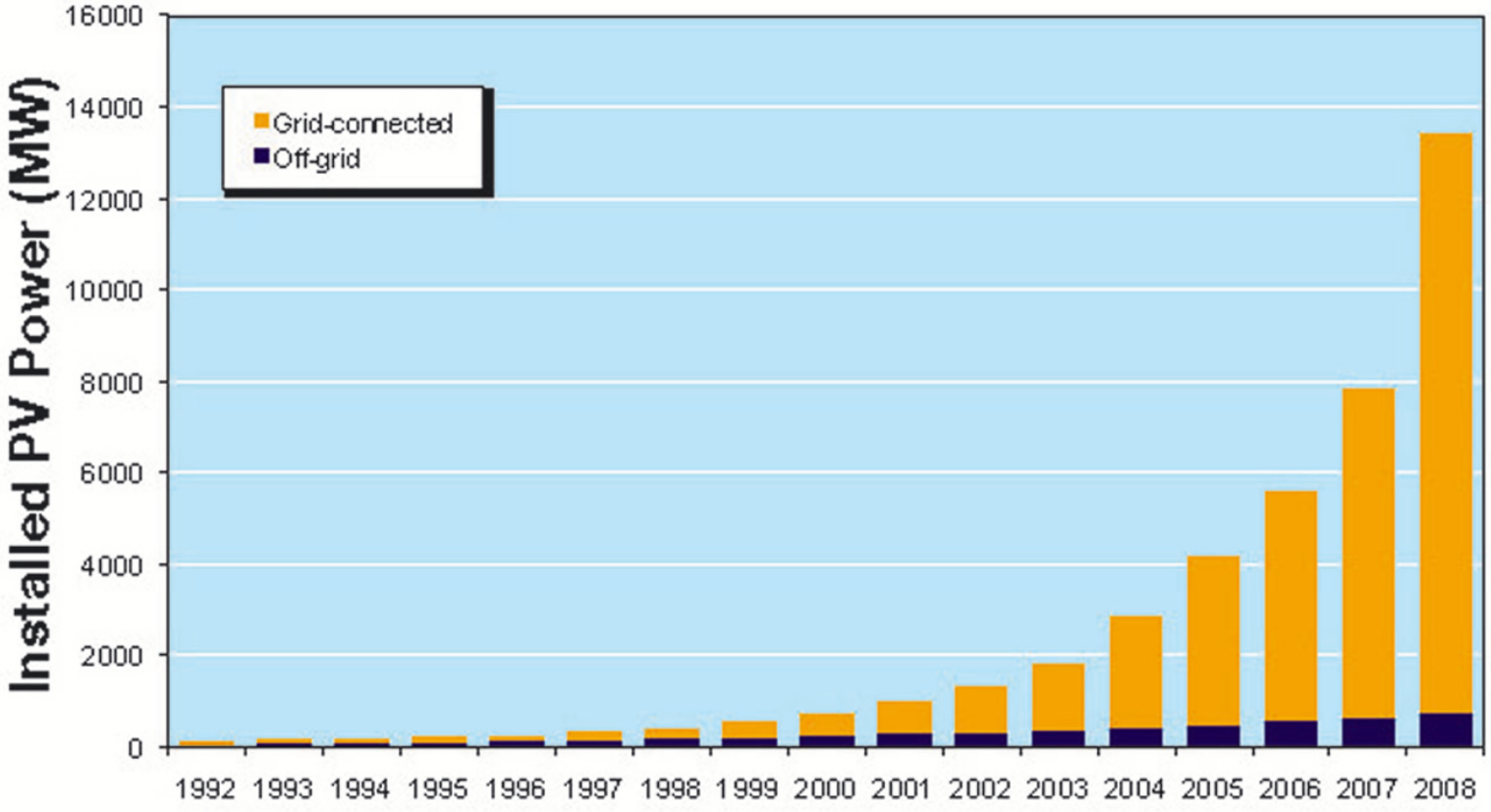
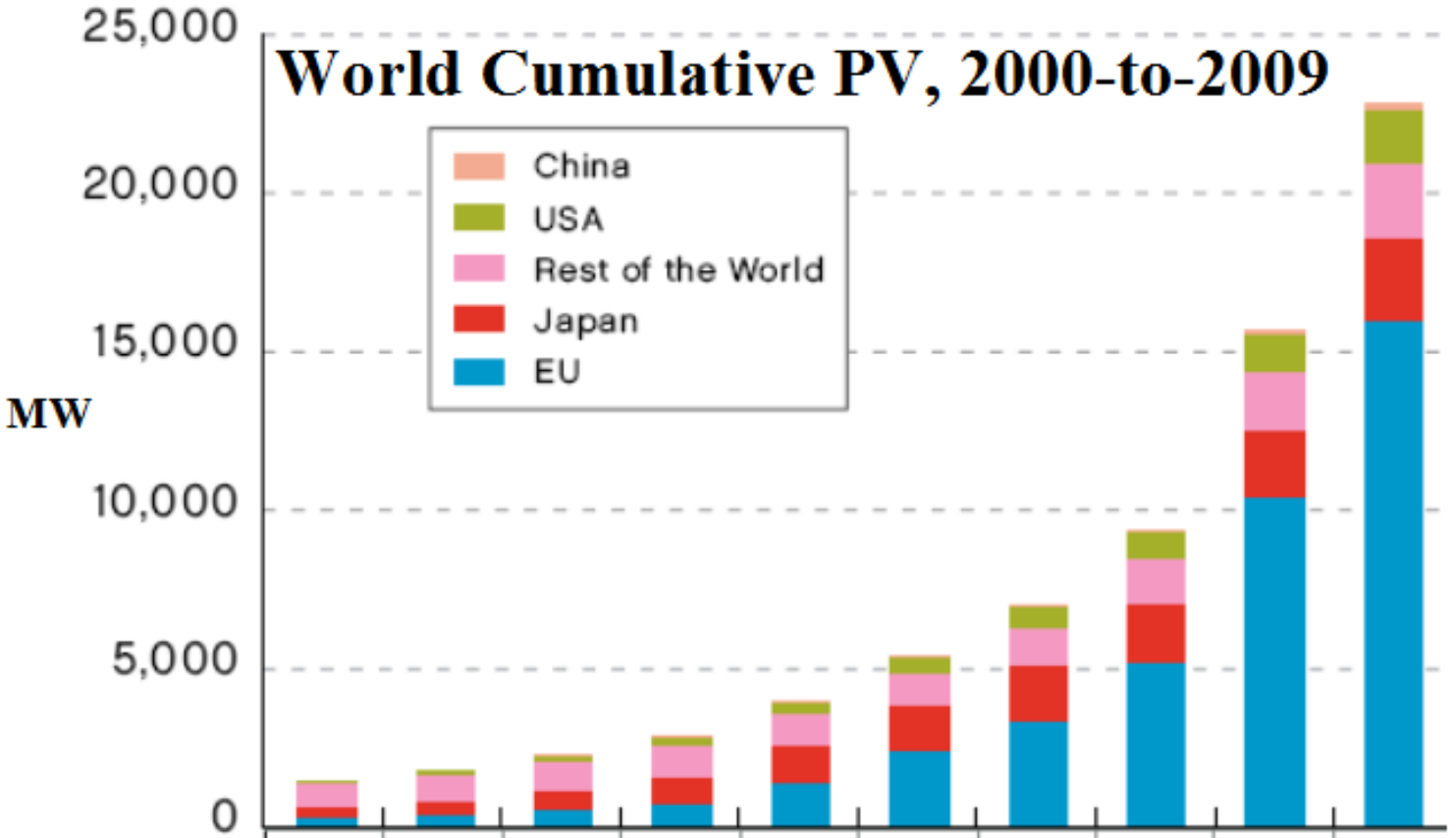


Figure 1 – Cumulative installed grid-connected and off-grid PV power in the reporting countries

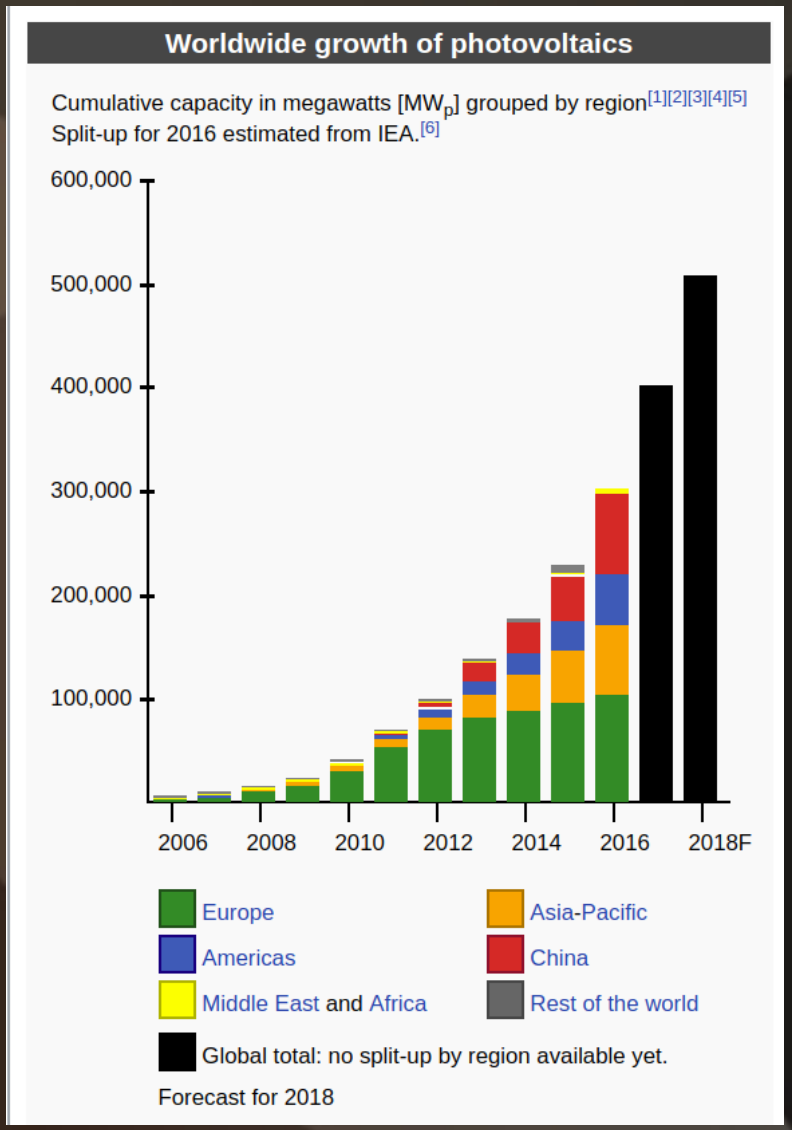
Name	Country	DC Peak Power (MW)	Notes
Sarina Photovoltaic Power Plant	Canada	97	Constructed 2009-2010
Montalto di Castro Photovoltaic Power Station	Italy	84.2	Constructed 2009-2010
Finsterwalde Solar Park	Germany	80.7	Phase I 2009 Phase II,III 2010
Rovigo Photovoltaic Power Plant	Italy	70	Completed 2010
Olmedilla Photovoltaic Park	Spain	60	Completed 2008
Strasskirchen Solar Park	Germany	54	
Lieberose Photovoltaic Park	Germany	53	Completed 2009
Puertollano Photovoltaic Park	Spain	50	Opened 2008



	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
China	19	30	45	55	64	68	80	100	145	305
USA	139	168	212	275	365	479	624	831	1,173	1,650
ROW	763	825	913	1,000	1,044	1,051	1,235	1,422	1,870	2,347
Japan	318	452	637	860	1,132	1,422	1,708	1,919	2,149	2,633
EU	189	286	422	633	1,319	2303	3,282	5,088	10,340	15,958

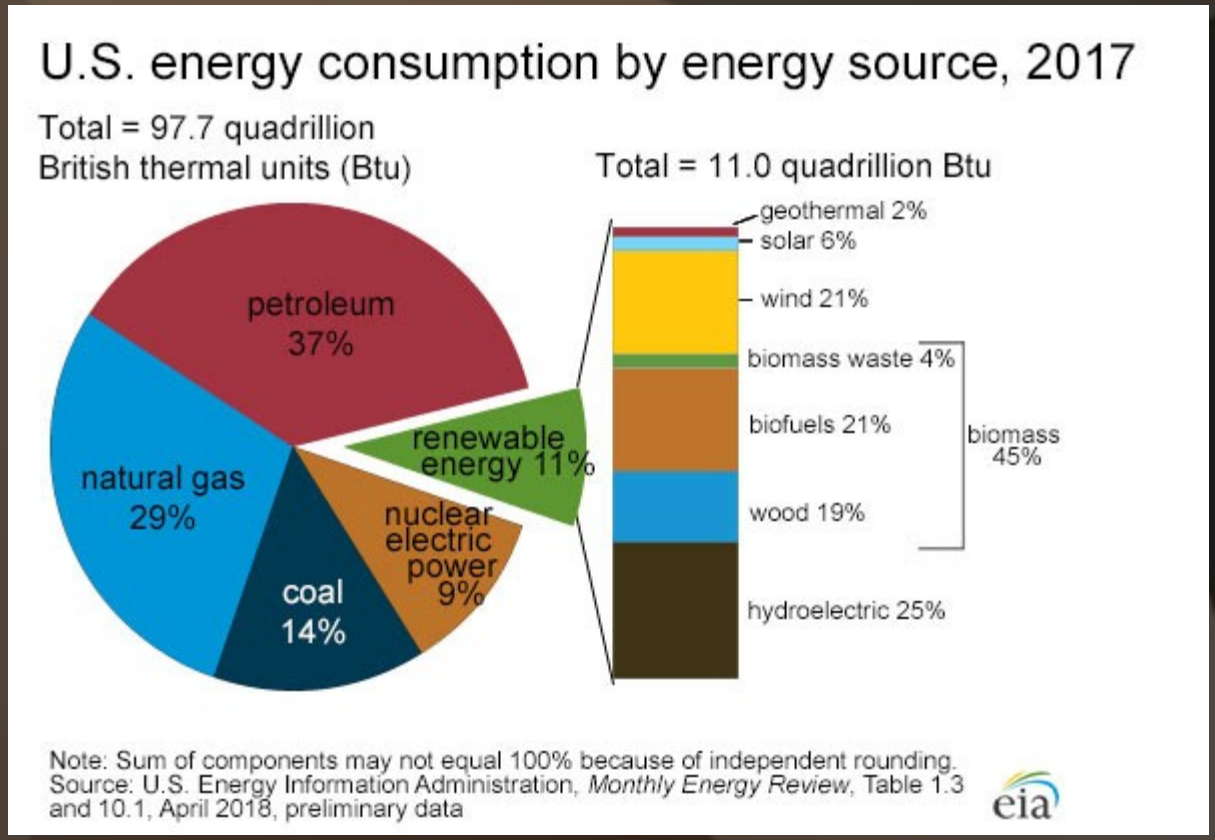
(from EPIA's *Global Market Outlook for Photovoltaics…*)

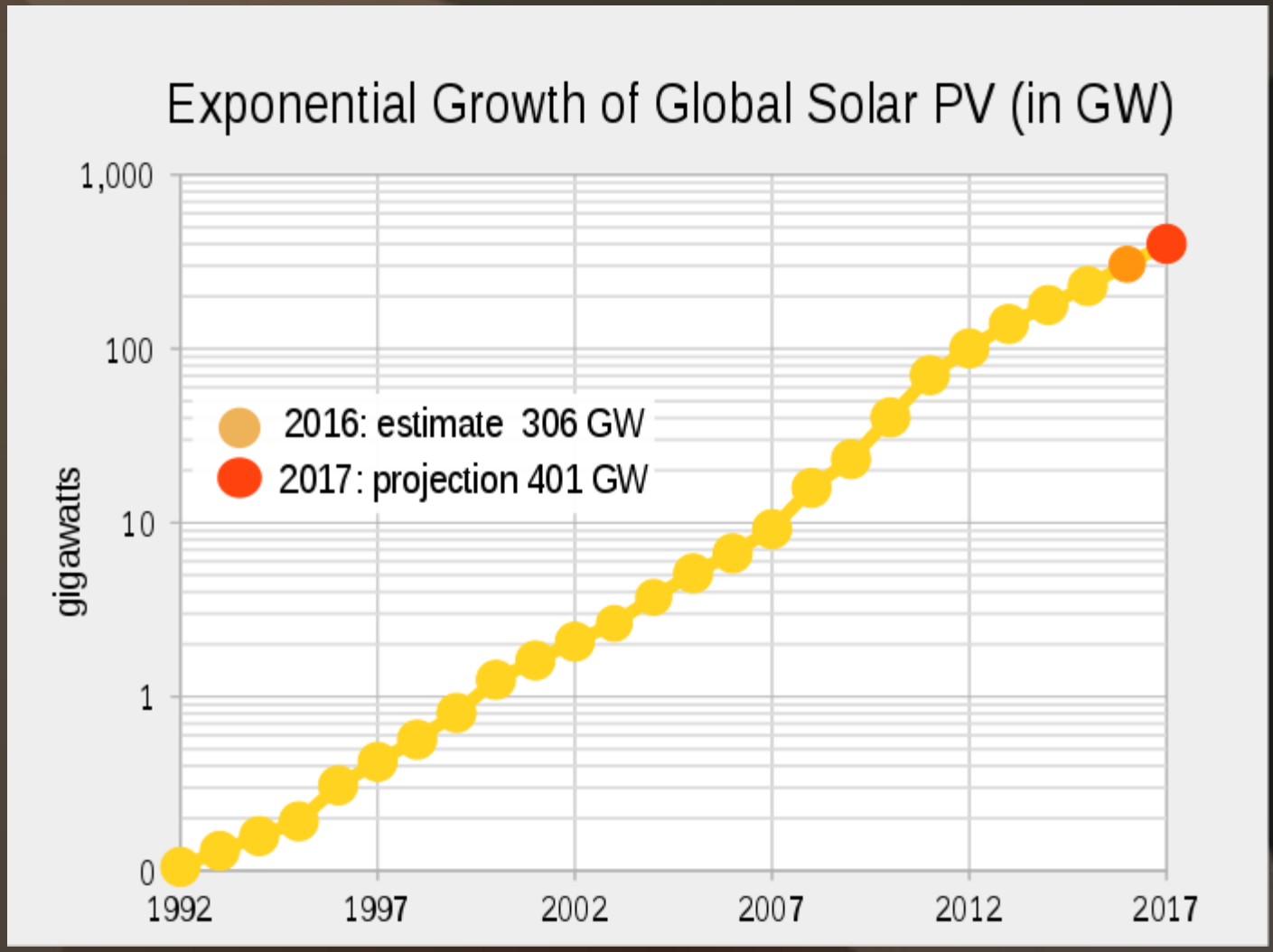
Notice the increase in capacity appears to have switched from exponential growth to linear growth.



https://en.wikipedia.org/wiki/Growth_of_photovoltaics

Just to keep things in perspective….





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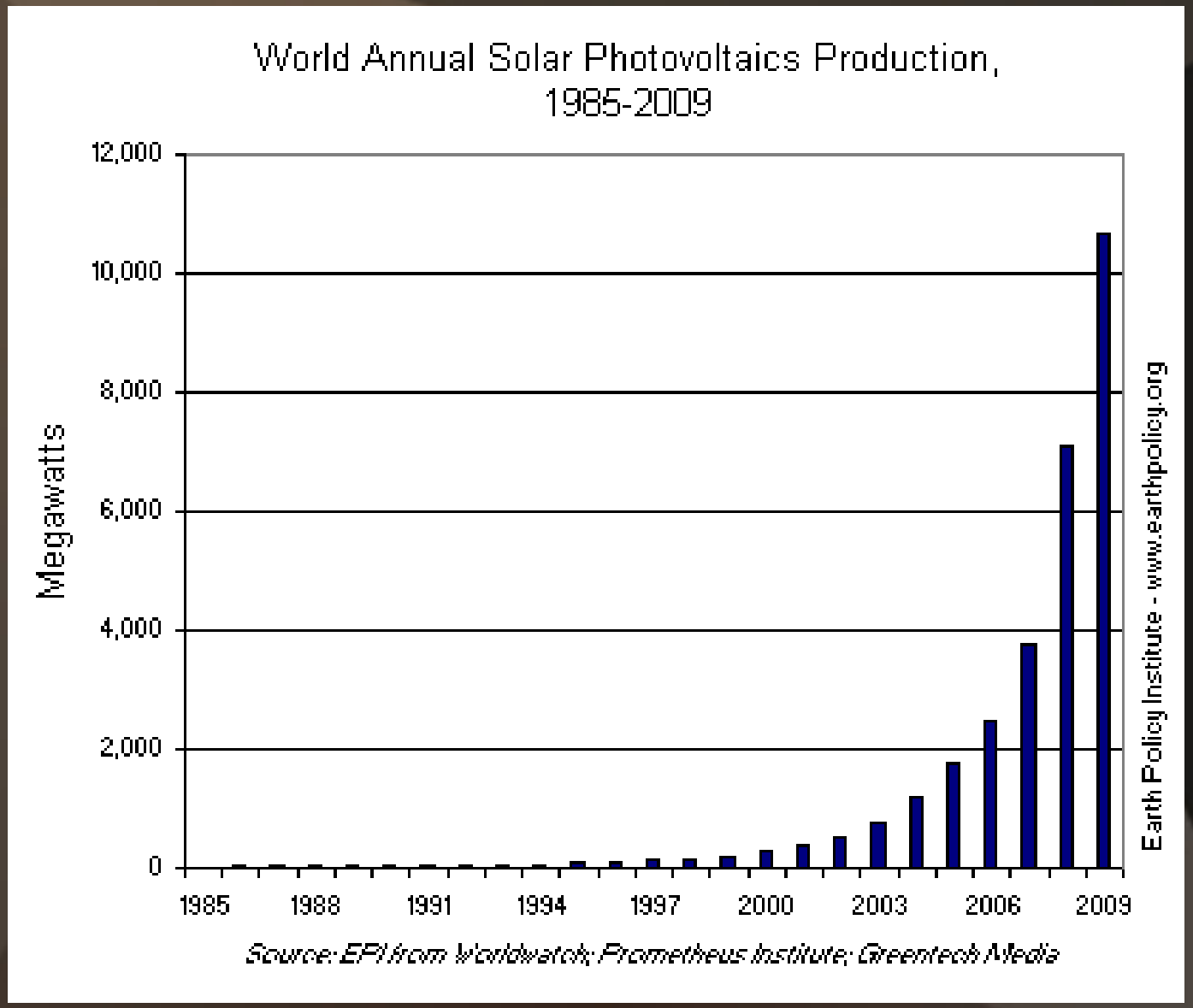
New Cell Production



Solar Power, Springerville, AZ

4.59 MW power station

- A lot of smaller installations used in locations where to difficult, expensive or environmentally damaging to take power lines or generators

Solar Shingles

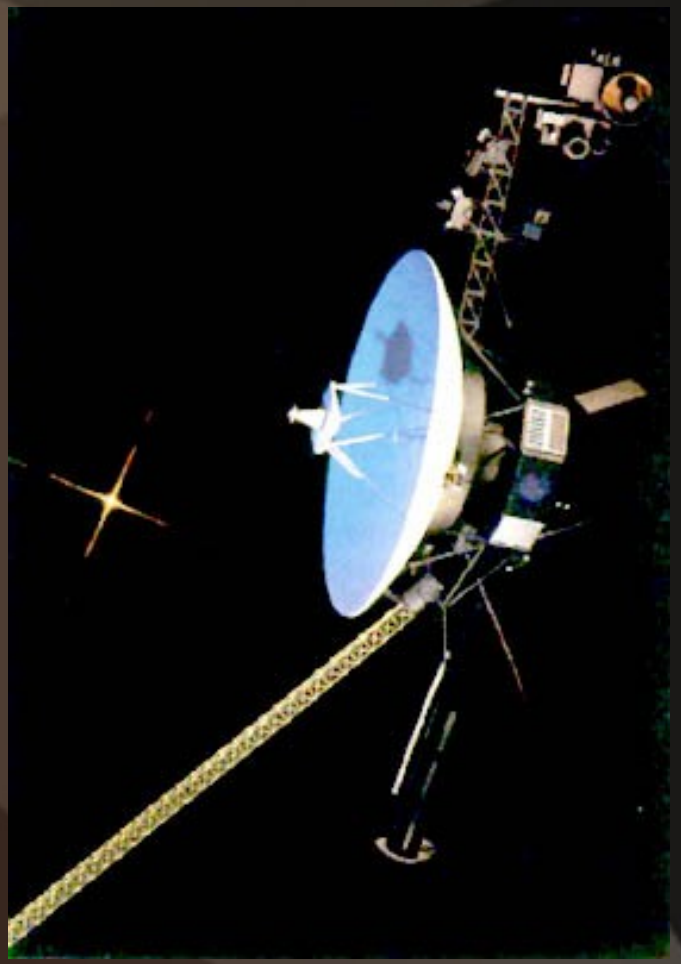
- For a typical residential system, you would likely install 1-3 kW of PV modules. Today's costs range from $8,000 to $10,000 per kW of fully installed capacity.

19 kW solar roof

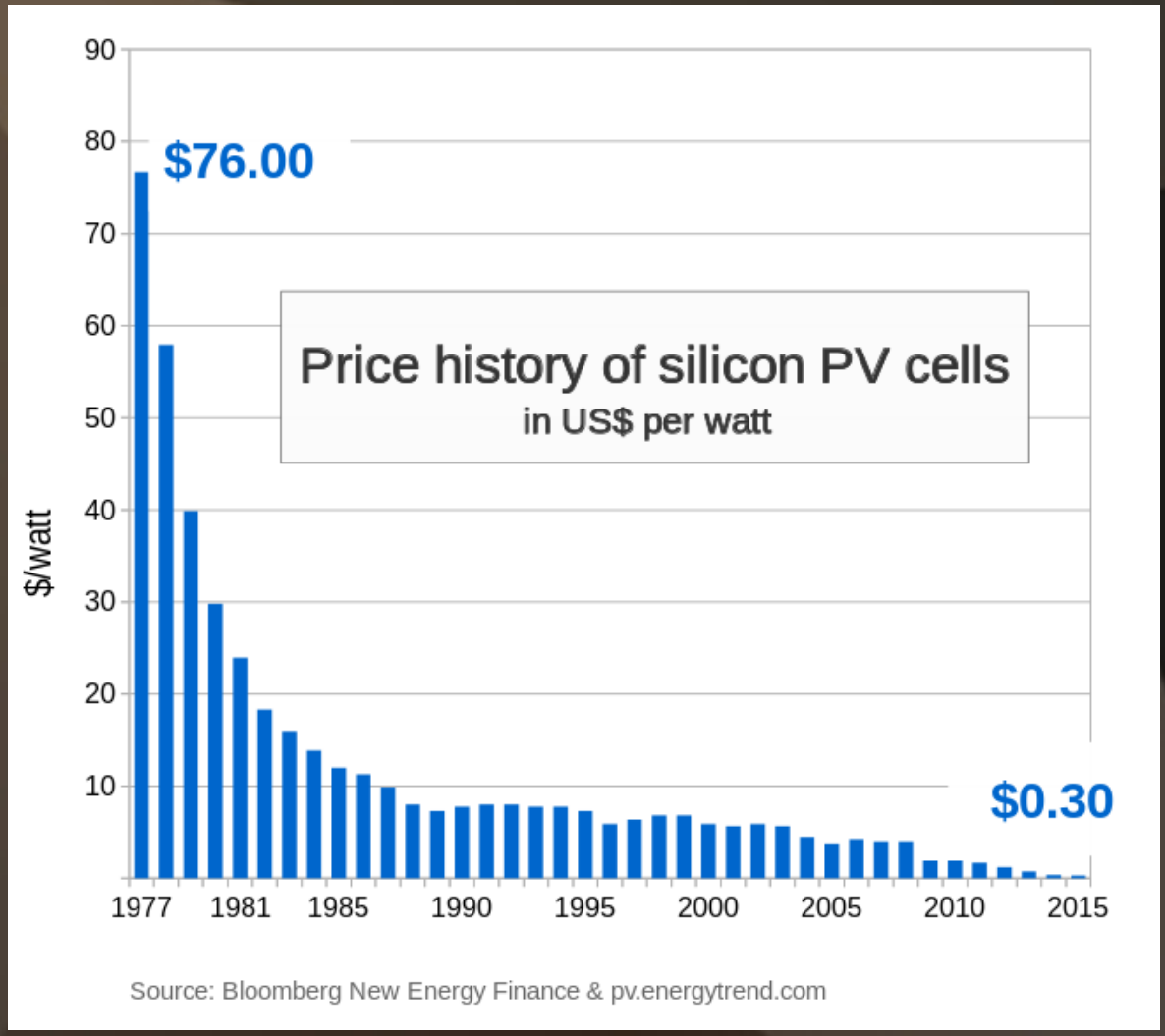
A lot of specialized Uses

Solar Power in Space

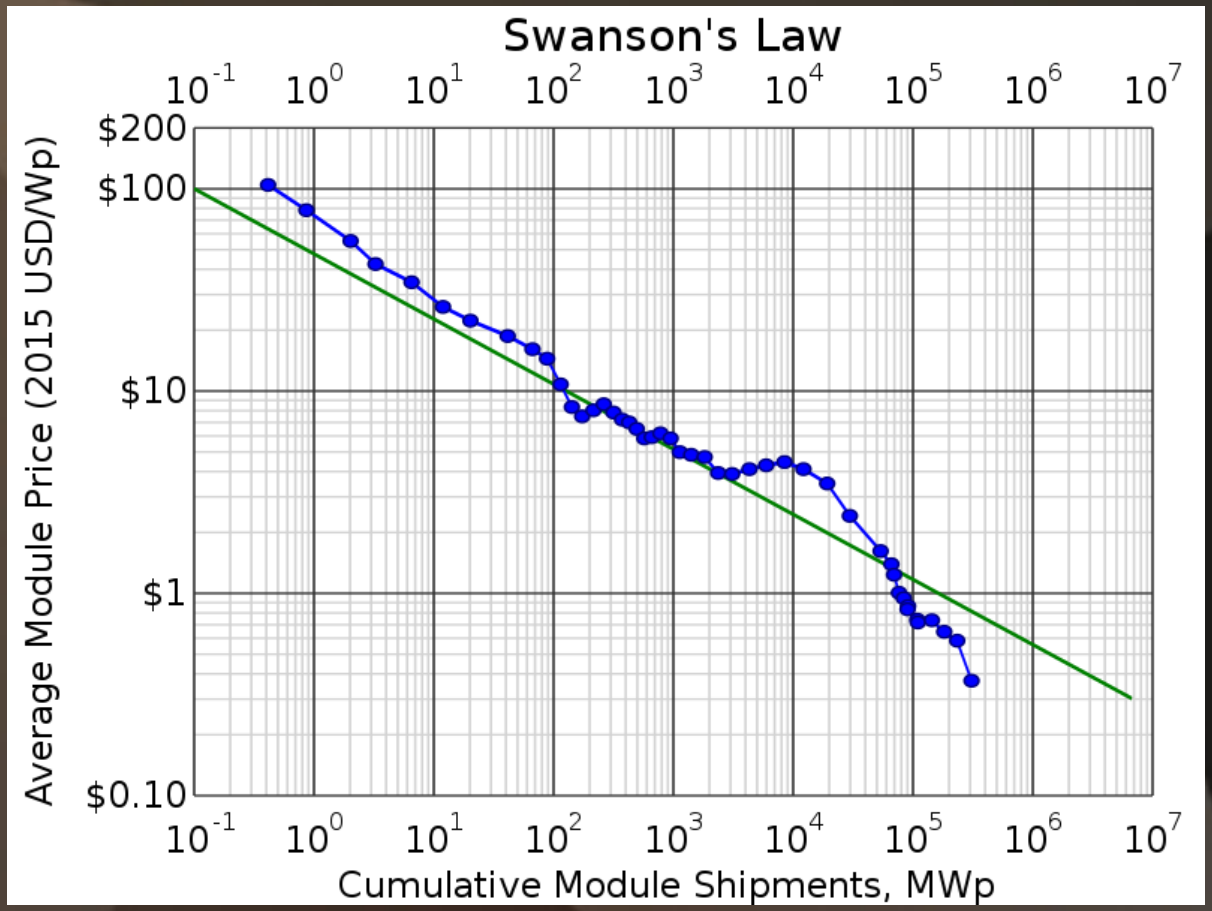
Deep Space Satellites Don’t Use Solar Power



Solar Cars



https://commons.wikimedia.org/wiki/File:Price_history_of_silicon_PV_cells_since_1977.svg



https://en.wikipedia.org/wiki/Swanson%27s_law#/media/File:Swansons-law.svg

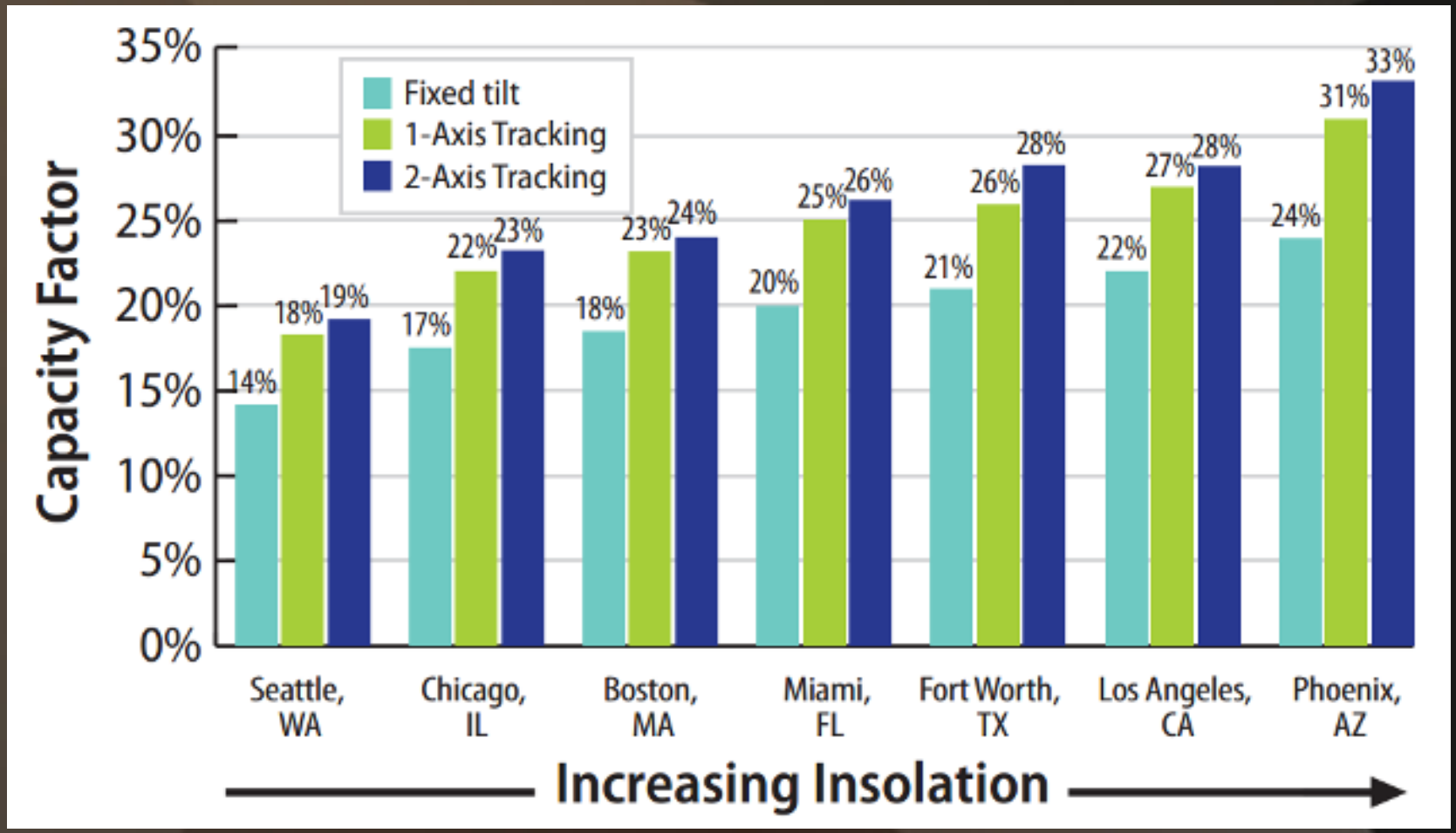
Levelized Cost of New Generation Resources 2012

- Levelized cost is often cited as a convenient measure of the overall competiveness of different generating technologies. It represents the per-kilowatthour cost (in real dollars) of building and operating a generating plant over an assumed financial life and duty cycle. Key inputs to calculating levelized costs include overnight capital costs, fuel costs, fixed and variable operations and maintenance (O&M) costs, financing costs, and an assumed utilization rate for each plant type.3 The importance of the factors varies among the technologies. For technologies such as solar and wind

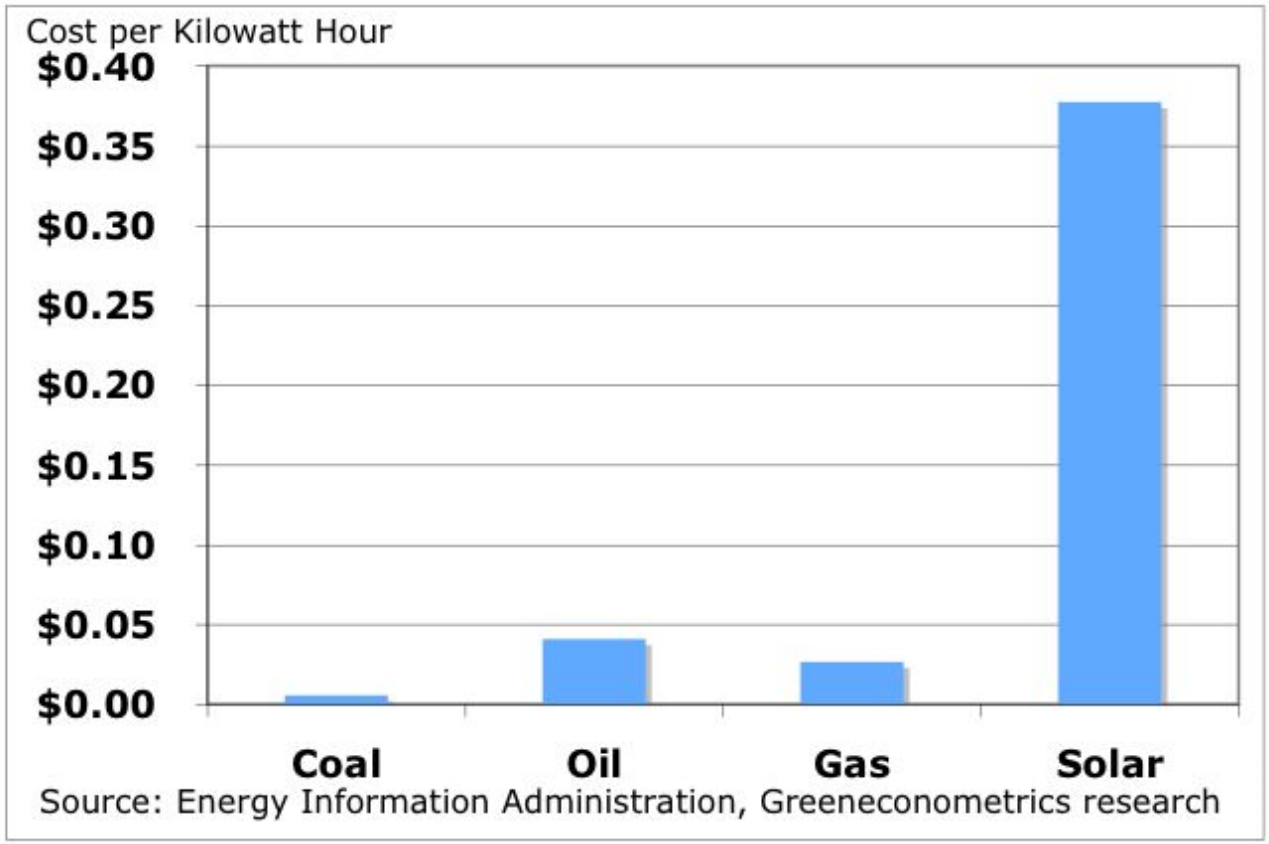
U.S. Average Levelized Costs (2010 $/megawatthour) for Plants Entering Service in 2017

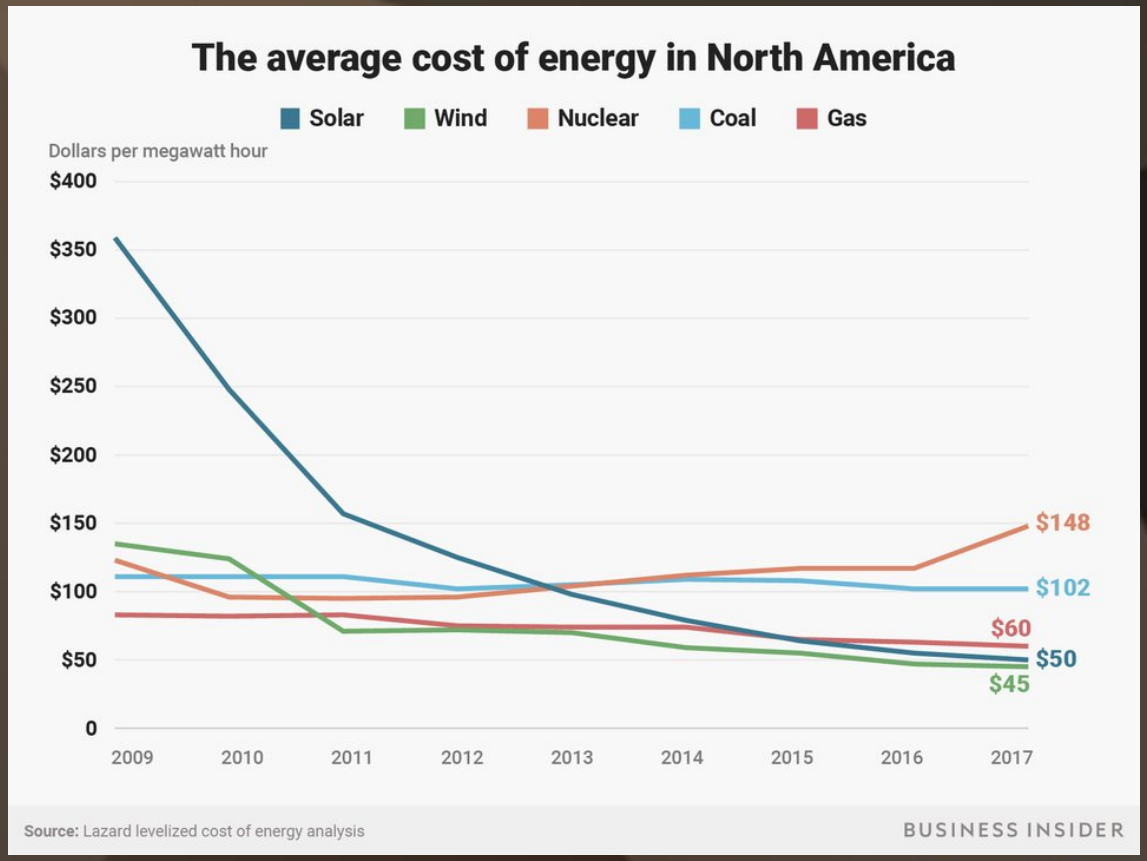
Plant Type	Capacity Factor (%)	Levelized Capital Cost	Fixed O&M	Variable O&M (including fuel)	Transmission Investment	Total System Levelized Cost
Conventional Coal	85	64.9	4.0	27.5	1.2	97.7
Natural Gas-fired						
Conventional Combined Cycle	87	17.2	1.9	45.8	1.2	66.1
Advanced Nuclear	90	87.5	11.3	11.6	1.1	111.4
Geothermal	91	75.1	11.9	9.6	1.5	98.2
Biomass	83	56.0	13.8	44.3	1.3	115.4
Wind	33	82.5	9.8	0.0	3.8	96.0
Solar PV1	25	140.7	7.7	0.0	4.3	152.7
Solar Thermal	20	195.6	40.1	0.0	6.3	242.0
Hydro2	53	76.9	4.0	6.0	2.1	88.9

Capacity Factor



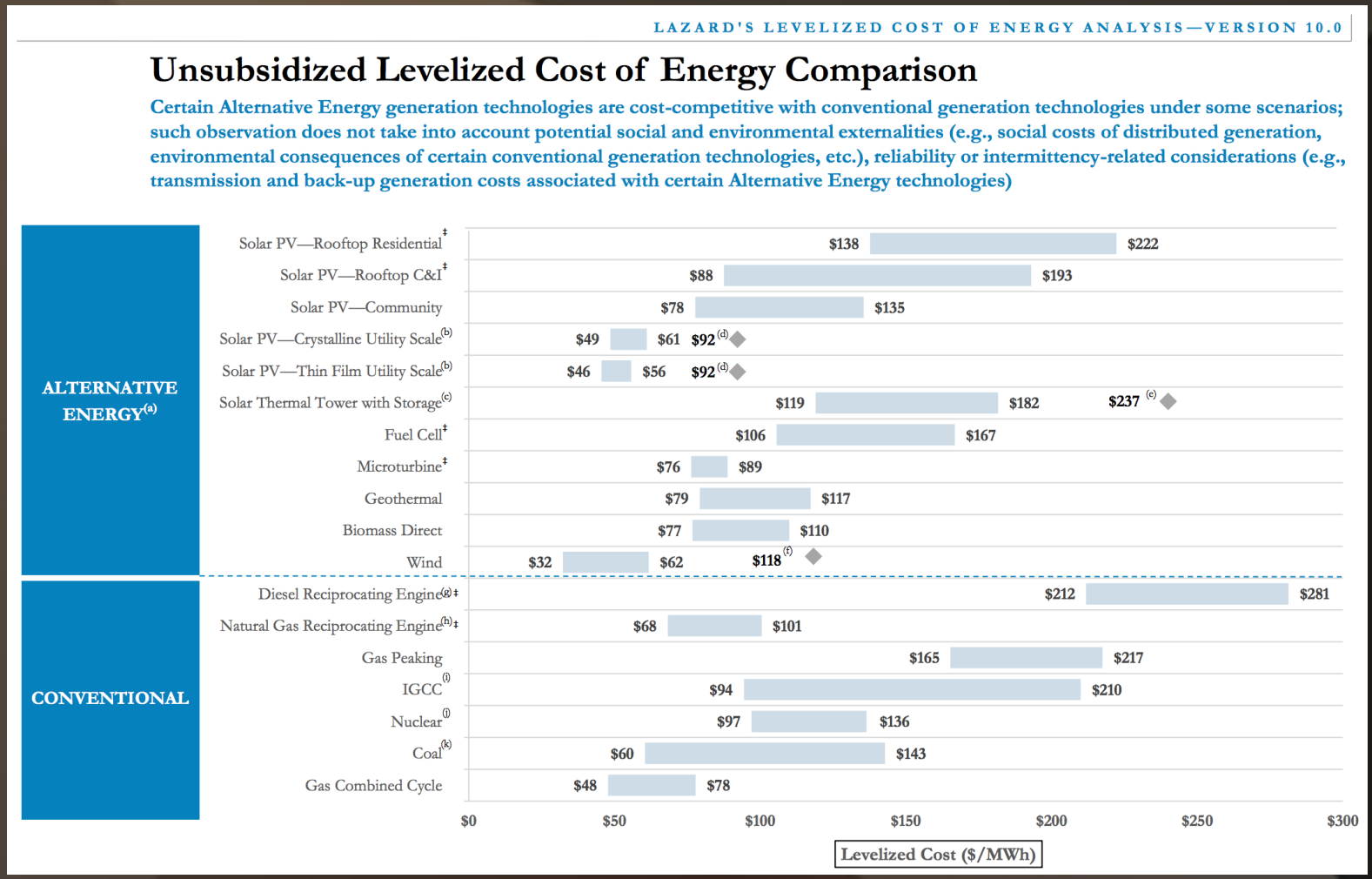
2007 Cost Comparison





http://www.businessinsider.com/solar-power-cost-decrease-2018-5

2016 Cost Comparison



https://cleantechnica.com/files/2016/12/solar-energy-costs-wind-energy-costs-LCOE-Lazard.png

Major goal is to reduce cost

- Use amorphous silicon (thin films)
- Other materials
- Concentrating collectors
- Sun tracking systems
- Economy of scale