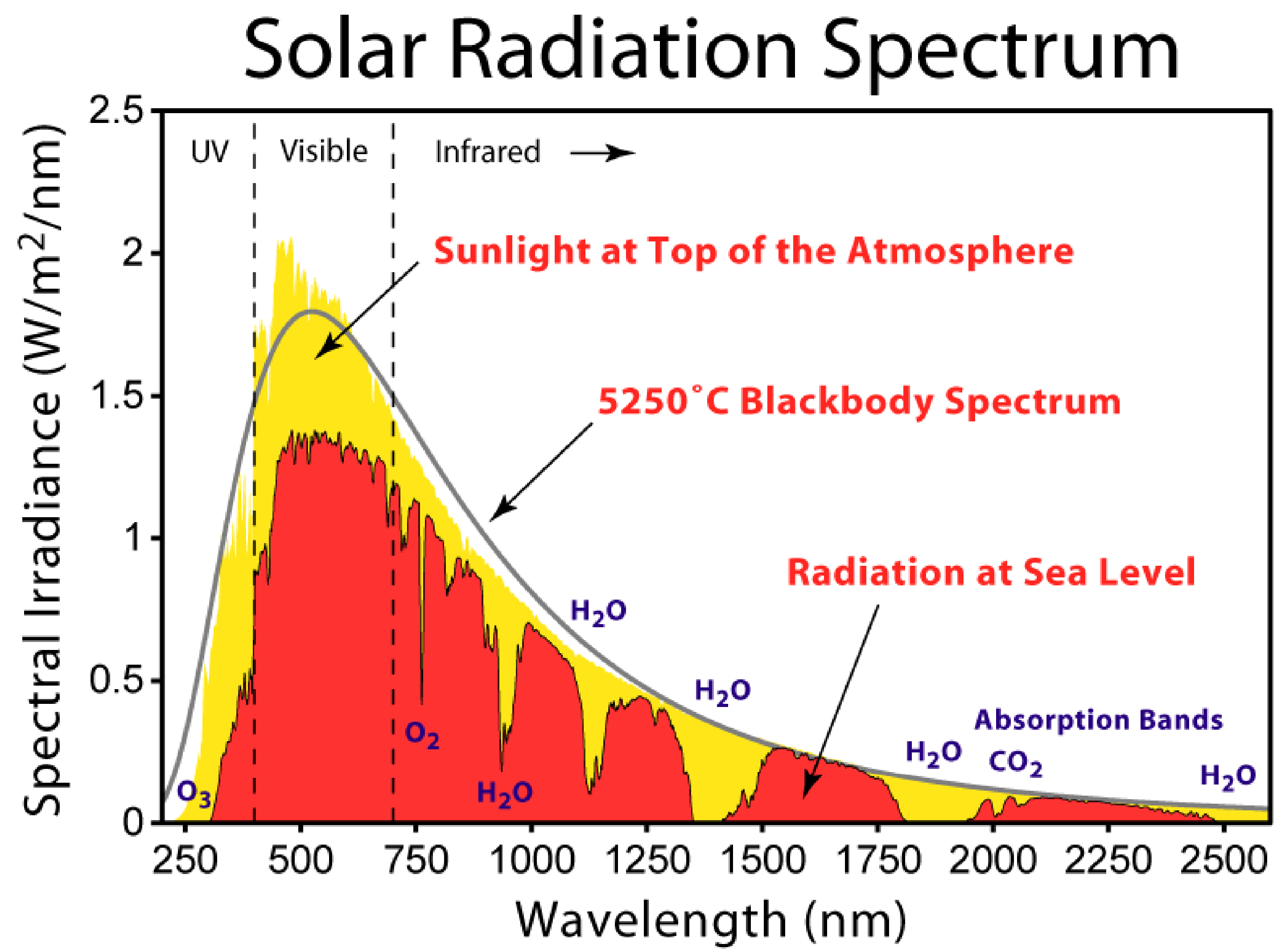
Solar Energy Primer

- The Earth's surface receives about 89 petawatts(10^{15} W) of incoming solar radiation (insolation) – 100 mW/cm^2 = AirMass1.5 conditions
- In one year, the total solar energy absorbed by Earth's atmosphere, oceans and land is approximately 3,850 zettajoules (10^{21} J)
- More energy from sunlight strikes the earth in 1 hr (4.3×10^{20} J) than all the energy consumed on the planet in 1 yr (4.1×10^{20} J in 2001)
- The world energy consumption rate was 13.5 terawatts (10^{12} W) in 2001, and is expected to grow to 27 TW by 2050.
- The US consumption of total power (gas, electricity) was 3.34 TW in 2005. The US electricity consumption was about 0.7 TW (winter 2006-2007)
- A half day of sunlight (in winter) striking the US (9×10^{15} watts) can provide all the US energy for a year (29,000 TW-hr).

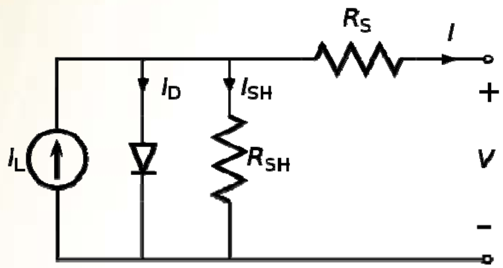
Solar Energy Primer

- Solar irradiance spectrum above atmosphere and at surface



Solar Energy Primer

- 1 Gallon of Gas = 37 KW-h (125,000 BTUs in a gallon of gas divided by 3,400 BTUs in 1 KWH)
- 1 Gallon of Gas = 500 hours of human work output (37 KWH in 1 gallon of gas divided by human work output in agriculture of .074 KW)
- Sometimes energy units are in "quads" where 1 quad = 1quadrilion (10^{15}) BTU (heat to raise 1 pound of water 1˚F) = 1.055 exajoules (1.055×10^{18} J) = 290 terawatt-hr
- The most efficient solar cells convert over 23% of illumination power to electric power (record is about 42%)



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Solar Energy Primer

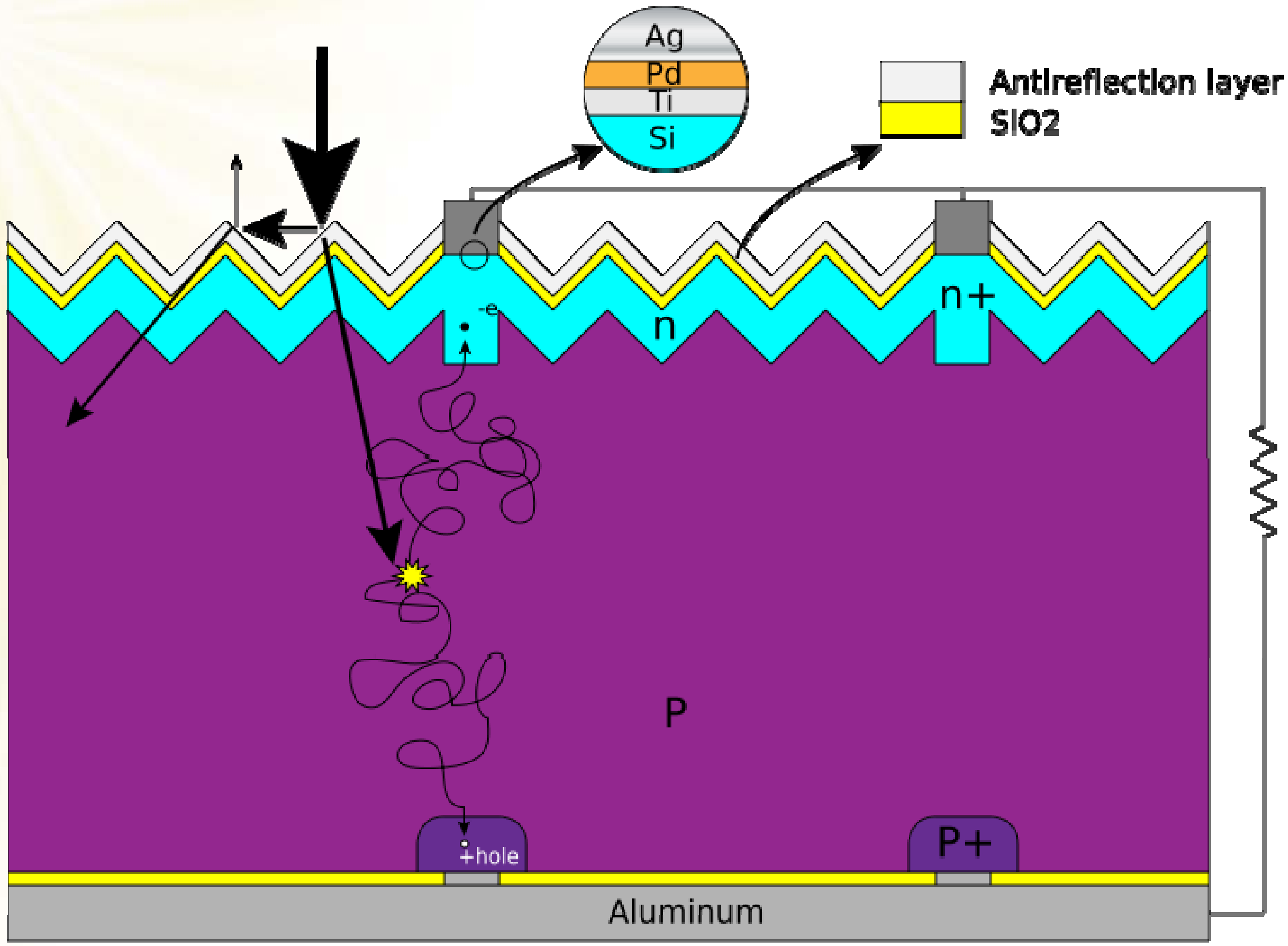
- The sale price of converted electrical energy should pay back the initial cost of the solar energy system over 30-yrs. At 10% efficiency, and \$3/W (peak) (or \$300 per m^2) typical of Si-based modules, an electricity price of \$0.35 /[kW-hr] is required
- At the end of 2007, according to preliminary data, cumulative global photovoltaic production was 12,400 megawatts
- The 14 MW Nellis Solar Power Plant is the largest solar photovoltaic system in North America, at Nellis Air Force Base northeast of Las Vegas. It generates 25 million kilowatt-hours of electricity annually and supplies 25 percent of the base’s power
- The world's largest photovoltaic (PV) power plant is a 60 MW unit in Spain

Solar Energy Primer

- Calculate land area needed to supply US electric peak power during daylight hours.
- Solar illumination under AM1.5 conditions is $1KW/m^2$. At 20% cell efficiency (sold by Sanyo in 2008), the available peak power is $200W/m^2$. To obtain the US peak usage of 1 TW, we need: Area = peak power/ conversion density = 1 TW/0.2 KW/ m2 = $5x10^9$ m^2 = $5x10^3$ km^2 = $(71\ km)^2$ = $(44\ mi)^2$. This is 0.05% (not 3 % as in some textbooks!) of the US land area of 9,161,923 SQ KM.
- So a region of south western desert, 44 miles square, would provide the US with peak power during the day (about 6 hours). Maybe quadruple this to get a full 24 hours worth, plus storage would be needed. Year 2008 module price is about $5/W (peak) with efficiency near 20% for Si-based modules

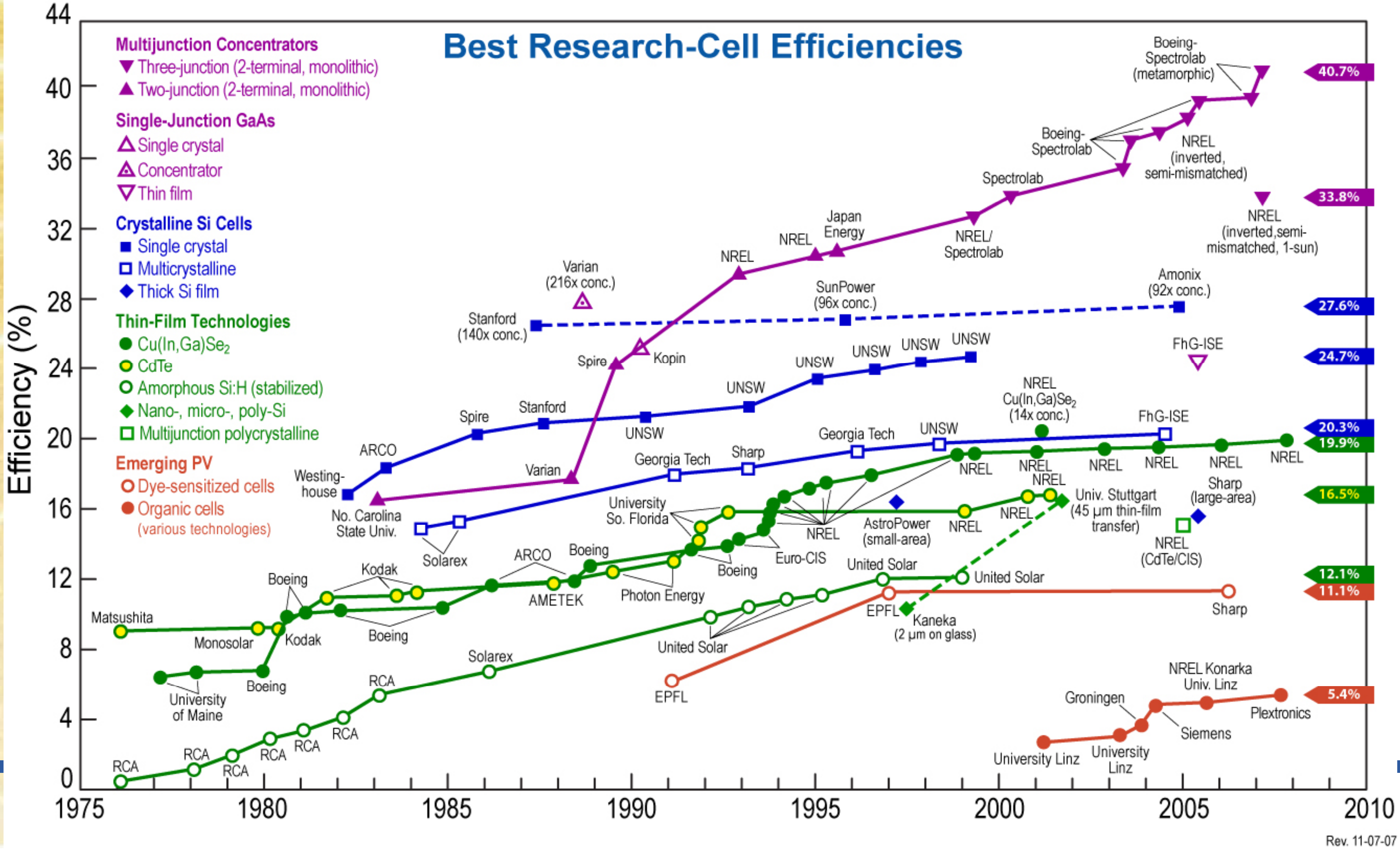
Solar Energy Primer

- Photovoltaic cell cross section



Solar Energy Primer

- Reported timeline of solar cell energy conversion efficiencies (from National Renewable Energy Laboratory, USA)



Solar Energy Primer - References

- Wikipedia – that wonderful website.
- "Powering the planet: Chemical challenges in solar energy utilization," Nathan S. Lewis and Daniel G. Nocera
- Nature, v. 443, 19-22 (7 September 2006), "Solar energy: A new day dawning?: Silicon Valley sunrise," Oliver Morton.