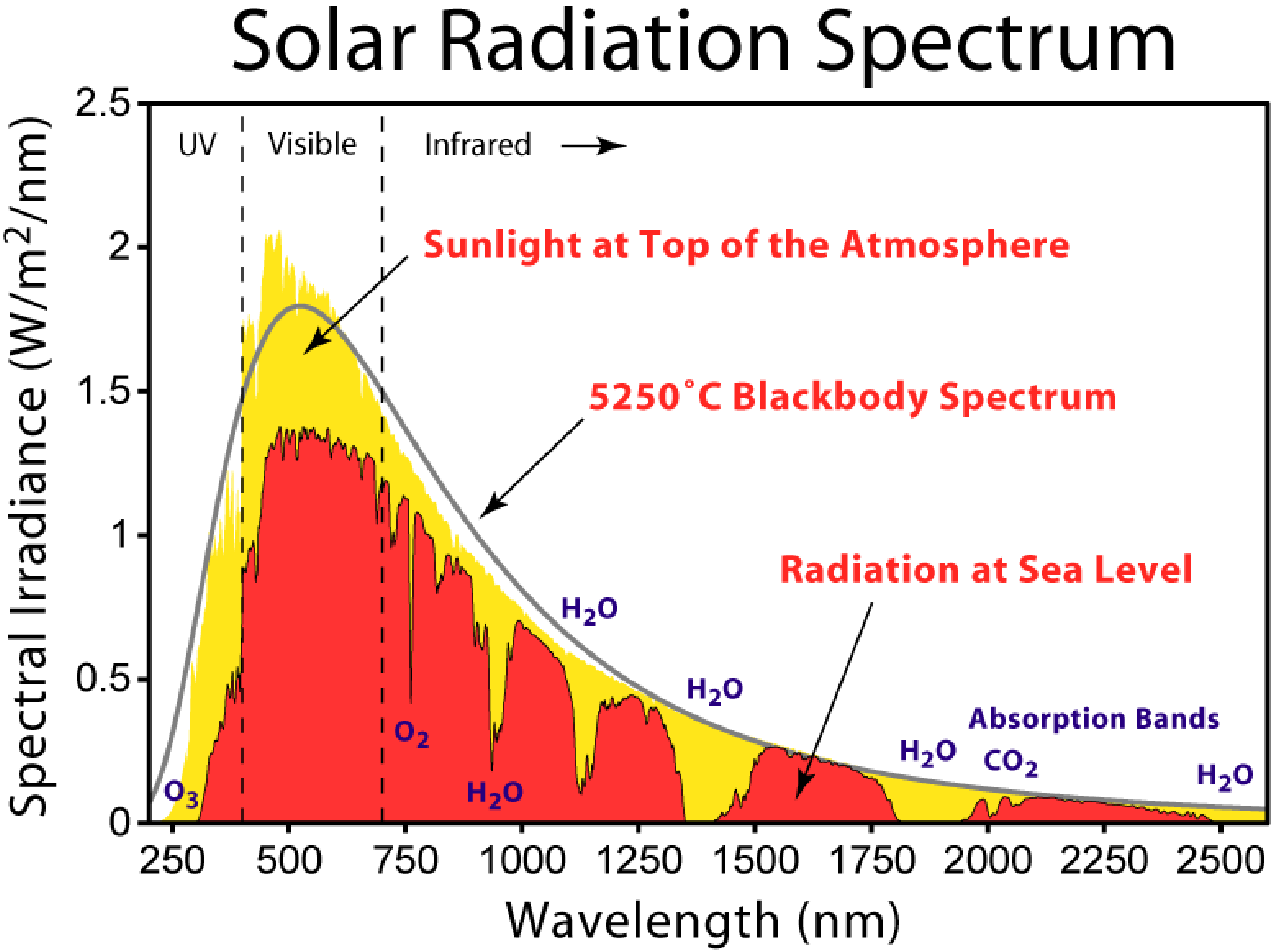
A. A bit about Photovoltaics, and **B**. Programming with LabVIEW

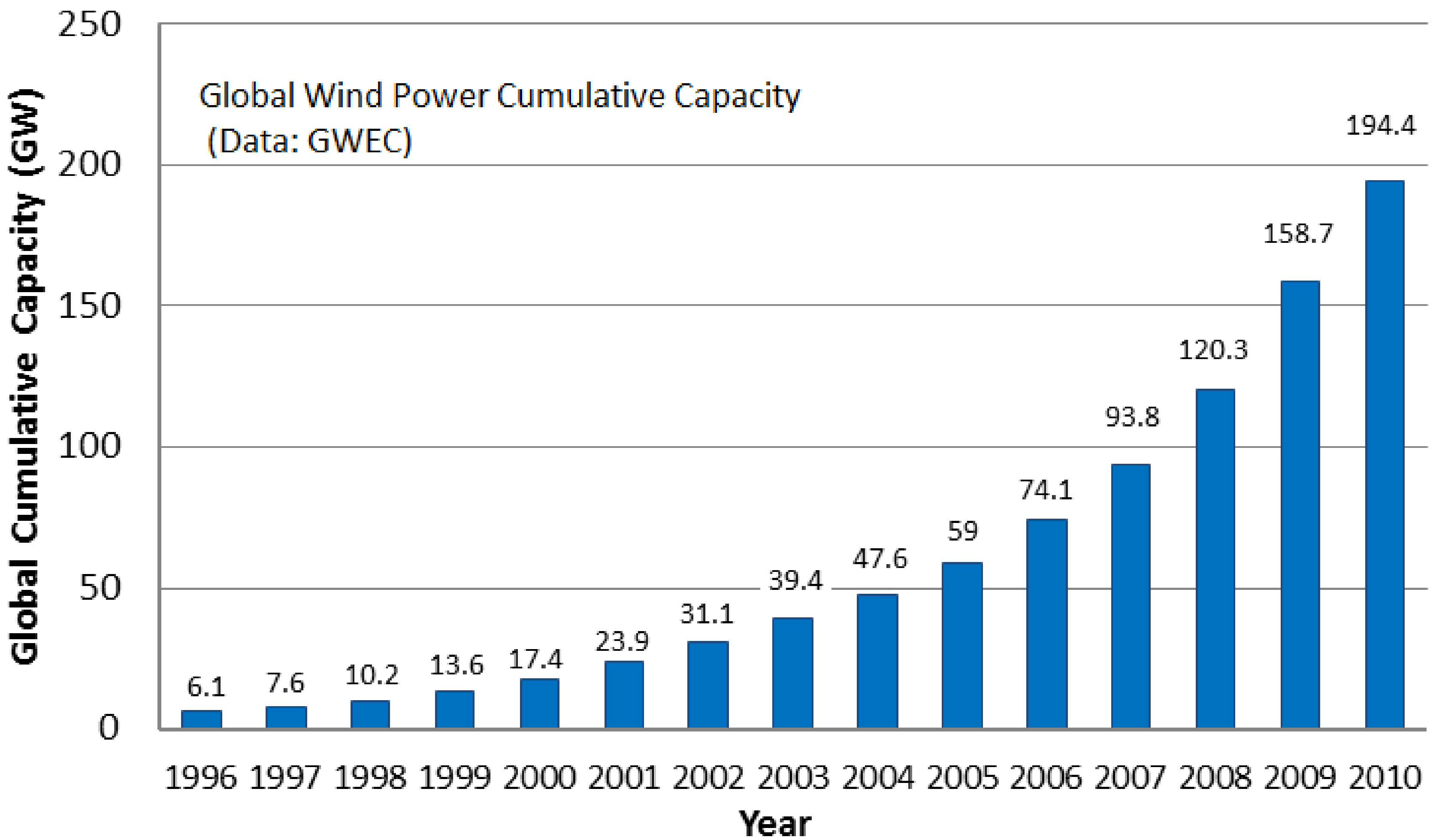
Week of Aug. 27, 2012

Molecular and Condensed Matter Lab
(Physics 4580)
PV Materials and Device Physics Lab
(PHYS 6/7280)
The University of Toledo
Instructors: R. Ellingson, M. Heben

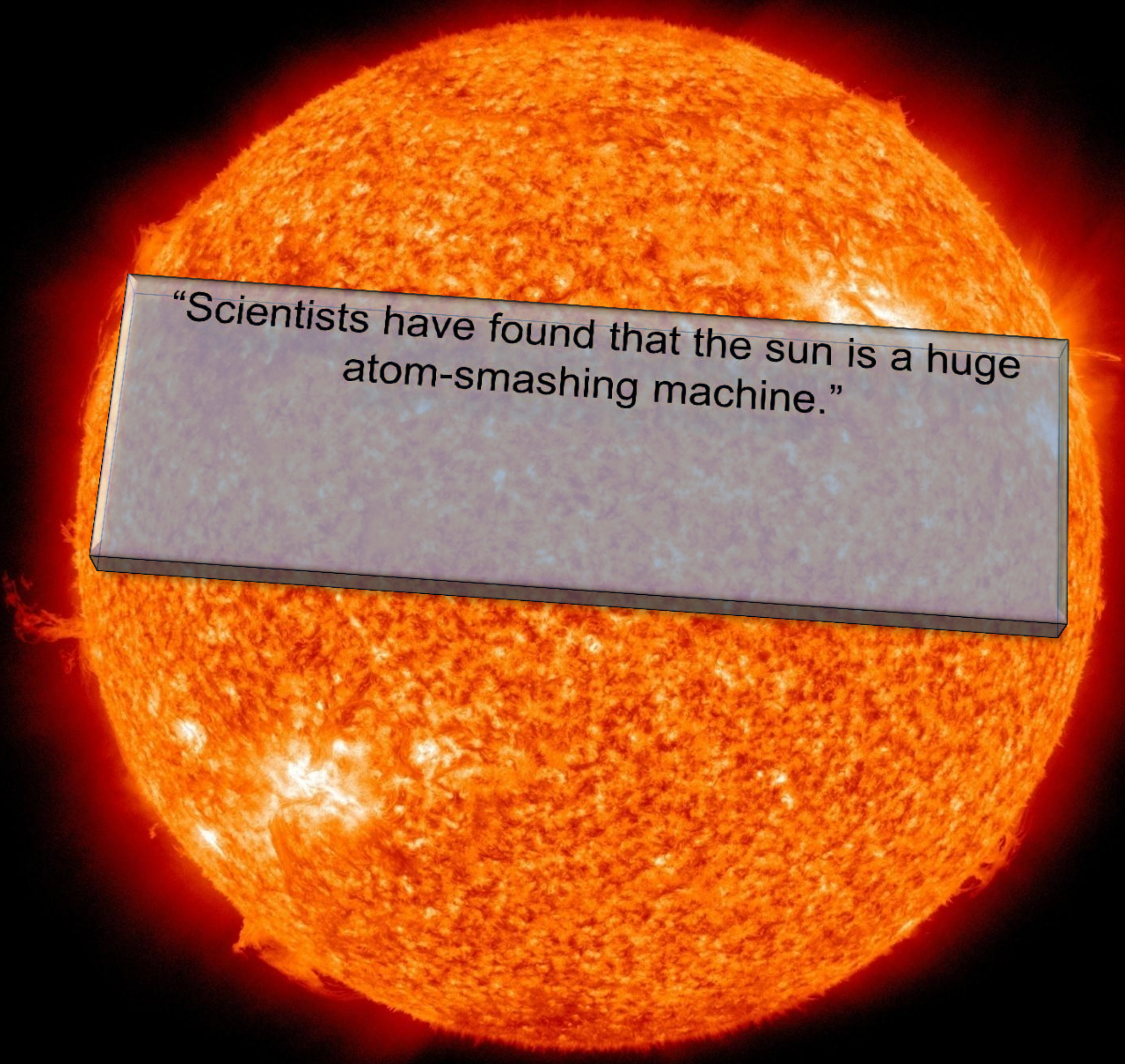

Solar Radiation Spectrum
Spectral Irradiance (W/m²/nm)
Wavelength (nm)
UV
Visible
Infrared
Sunlight at Top of the Atmosphere
5250°C Blackbody Spectrum
Radiation at Sea Level
Absorption Bands
O_3
O_2
H_2O
CO_2
0
0.5
1
1.5
2
2.5
250
500
750
1000
1250
1500
1750
2000
2250
2500

Global Wind Power

22% year-over-year growth in 2010



The Sun (worth revering)



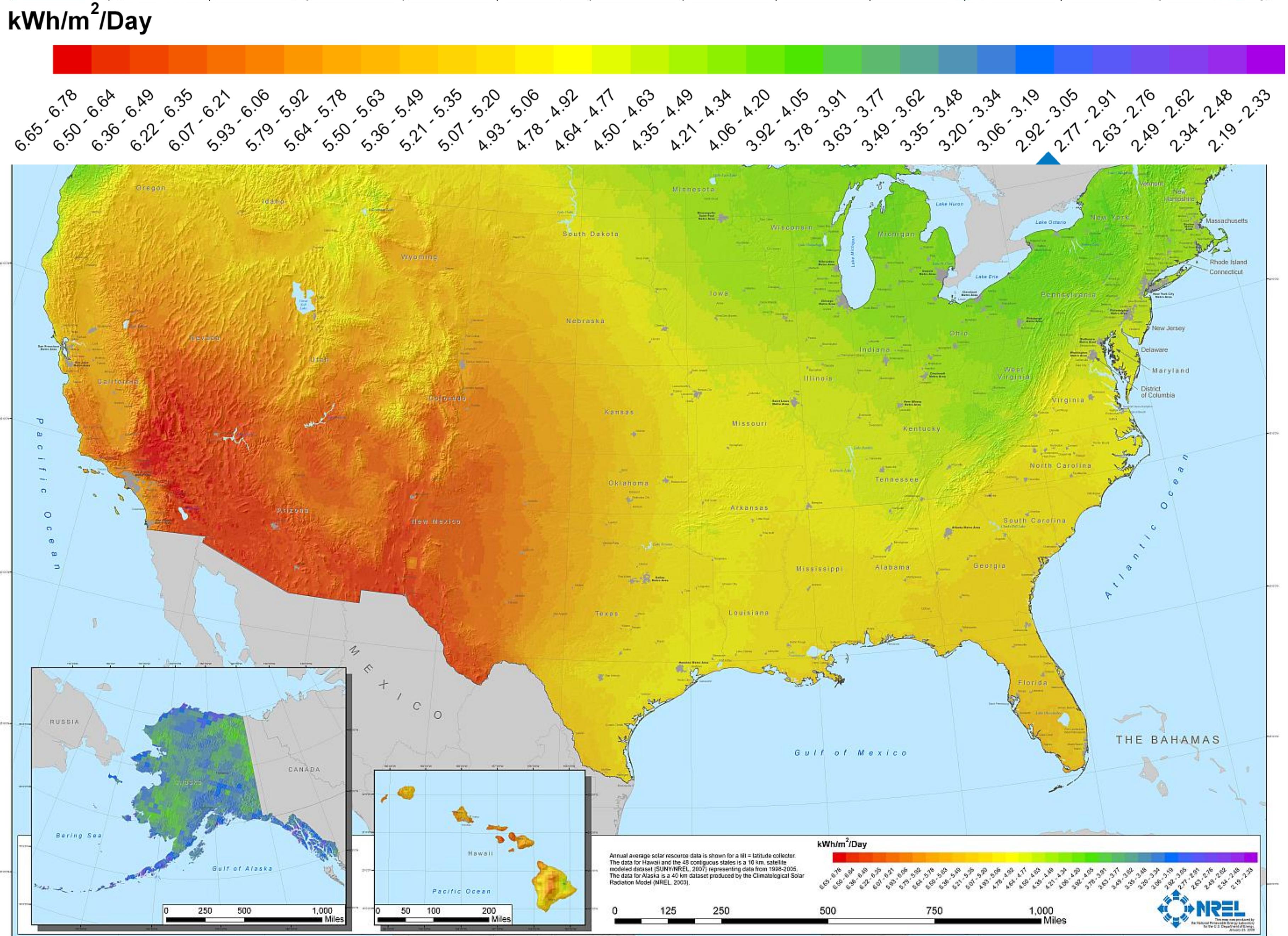
"Why Does the Sun Shine?"
by *They Might Be Giants*

The sun is a mass of
incandescent gas
A gigantic nuclear furnace
Where hydrogen is built into
helium
At a temperature of millions
of degrees

Yo ho, it's hot, the sun is not
A place where we could live
But here on Earth there'd be
no life
Without the light it gives

We need its light
We need its heat
We need its energy
Without the sun, without a
doubt
There'd be no you and me

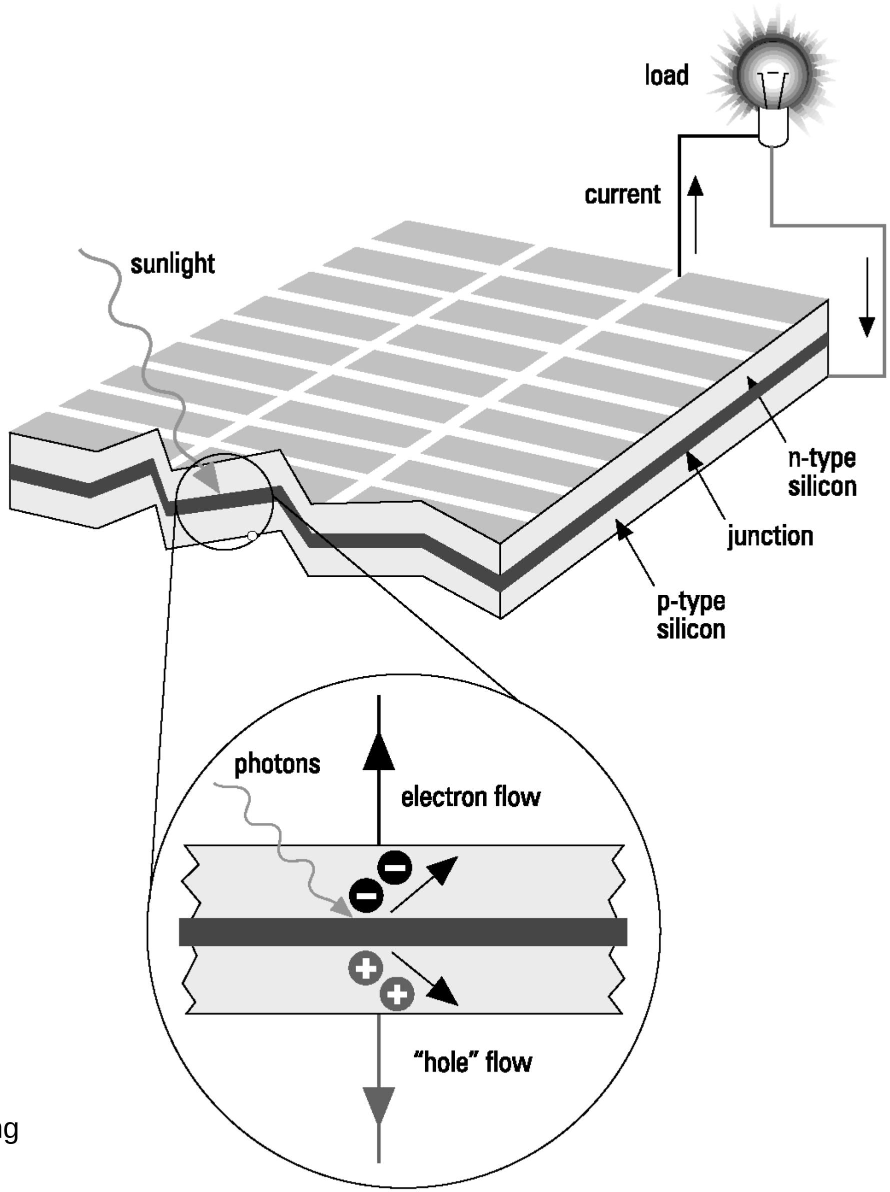
United States Photovoltaic Solar Resource : Flat Plate Tilted at Latitude



Basic silicon photovoltaic (solar) cell operation

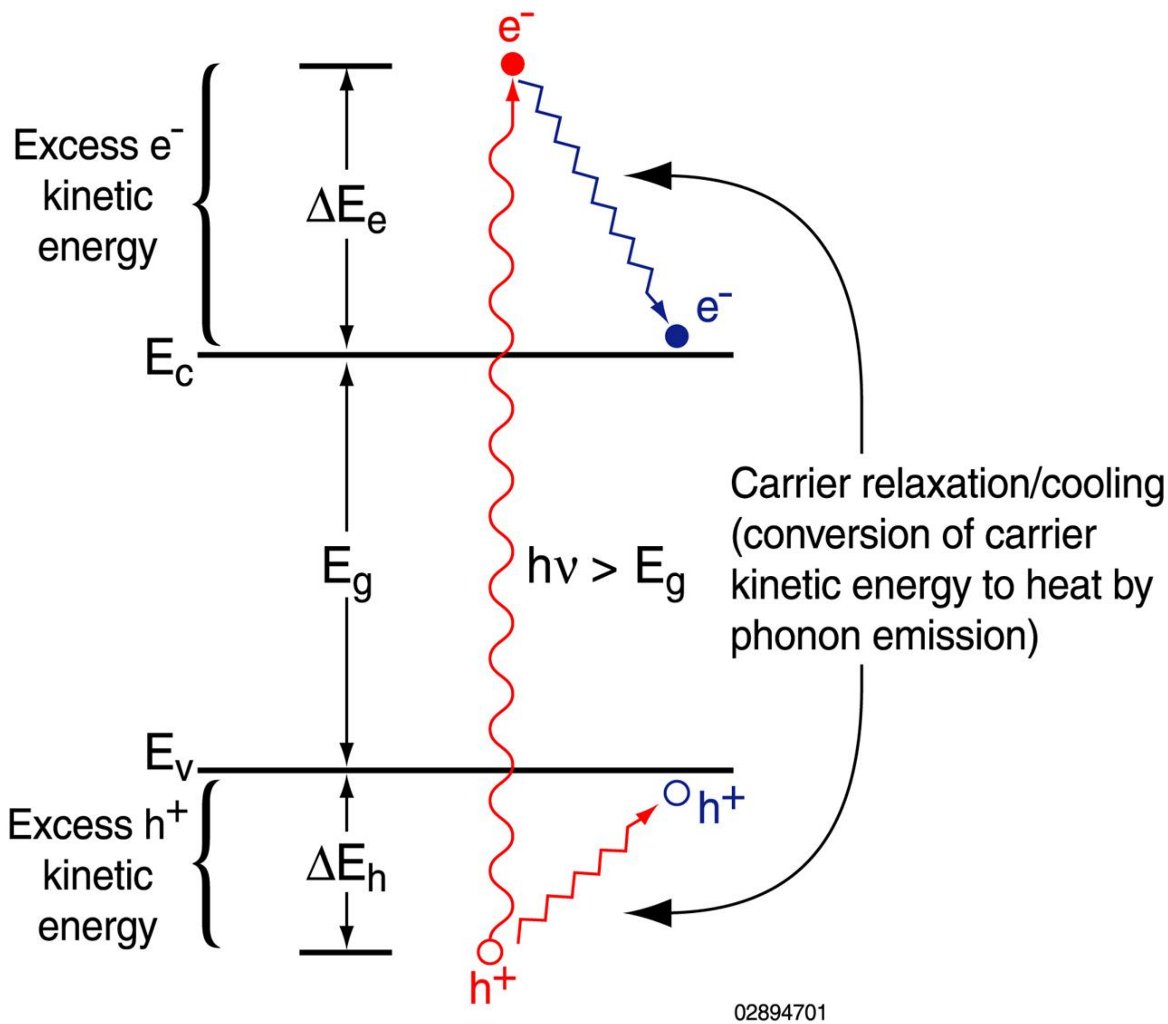
Key functions of a solar cell

- absorbs sunlight efficiently
- separates charge (electrons from "holes")
- creates an electrical current and voltage when illuminated
- acts like a battery under sunlight



http://www.emeraldinsight.com/fig/0870210205001.png

Thermalization losses



For *c*-Si (E_g = 1.1 eV)
at T = 300 K, AM1.5G

η_{max} = 32.9%

<u>Losses</u>

transmission = 18.7%

radiative em. = 1.6%

heat = 46.8%

Attained vs. attainable efficiencies

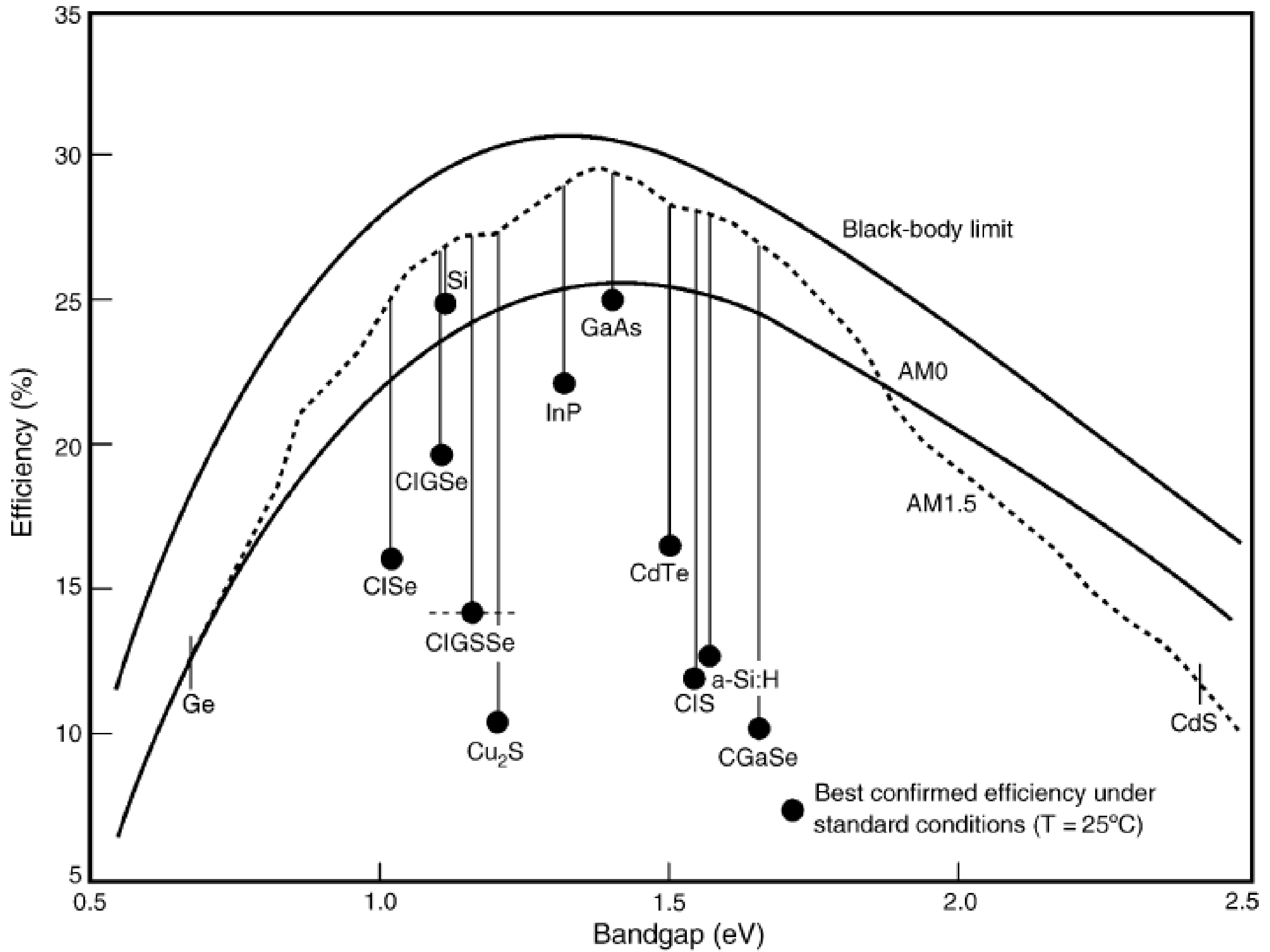
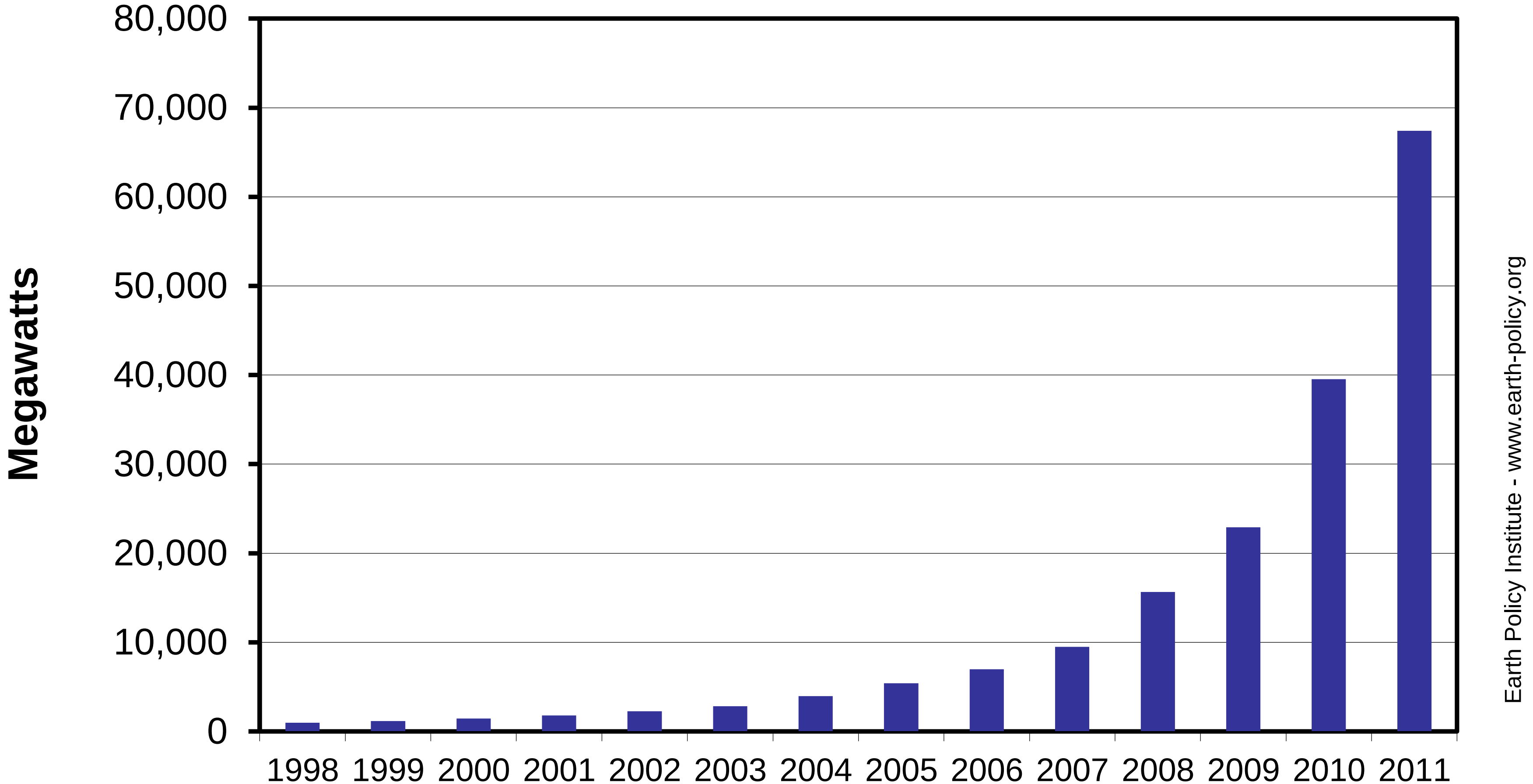


Fig. 3. Performance gaps between best device efficiencies in the laboratory and attainable efficiencies for several solar cell technologies.

L.L. Kazmerski / Journal of Electron Spectroscopy and Related Phenomena 150 (2006) 105–135

World Cumulative Solar Photovoltaics Installations, 1998-2011

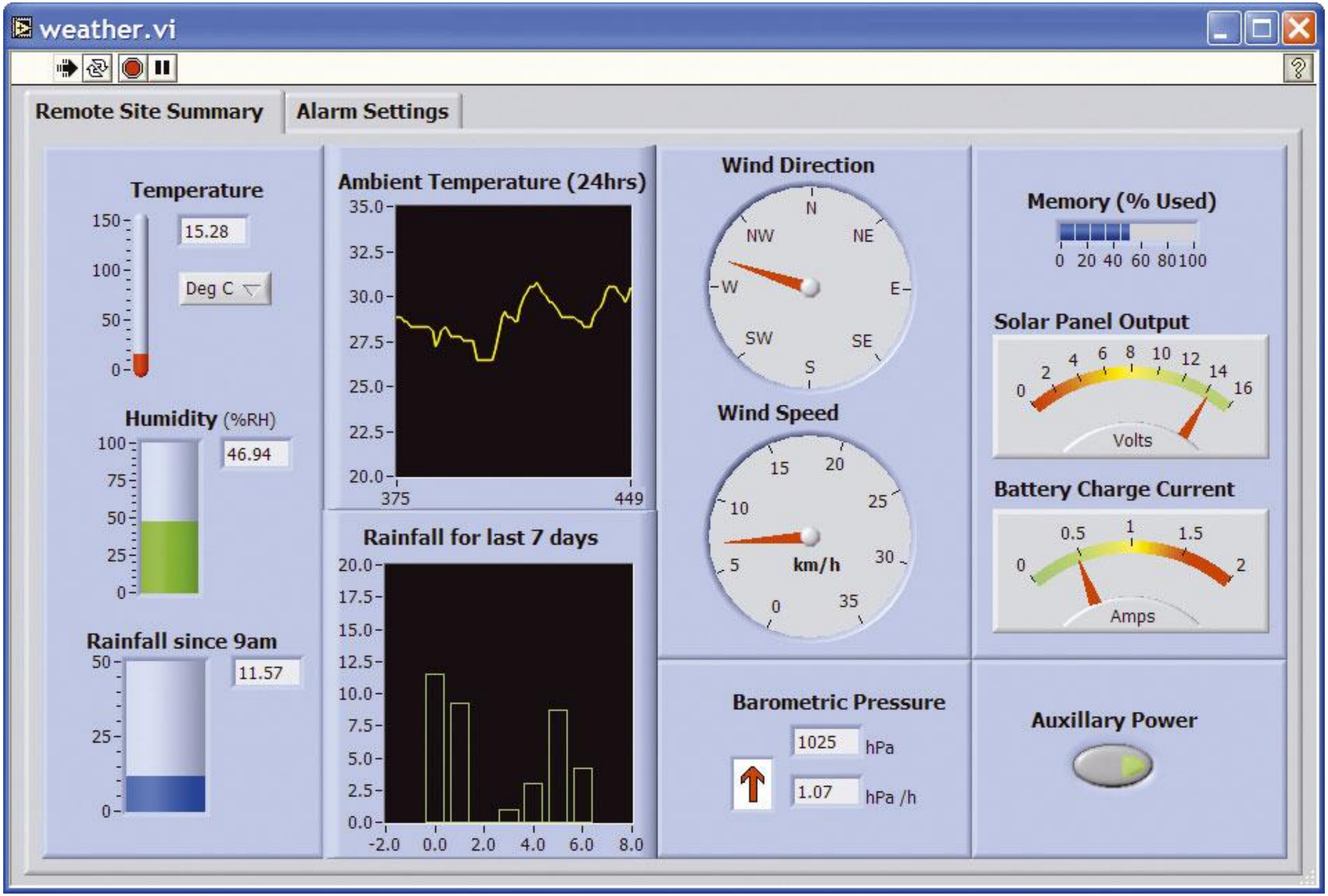
70% year-over-year growth in 2010



Source: EPI from EPIA

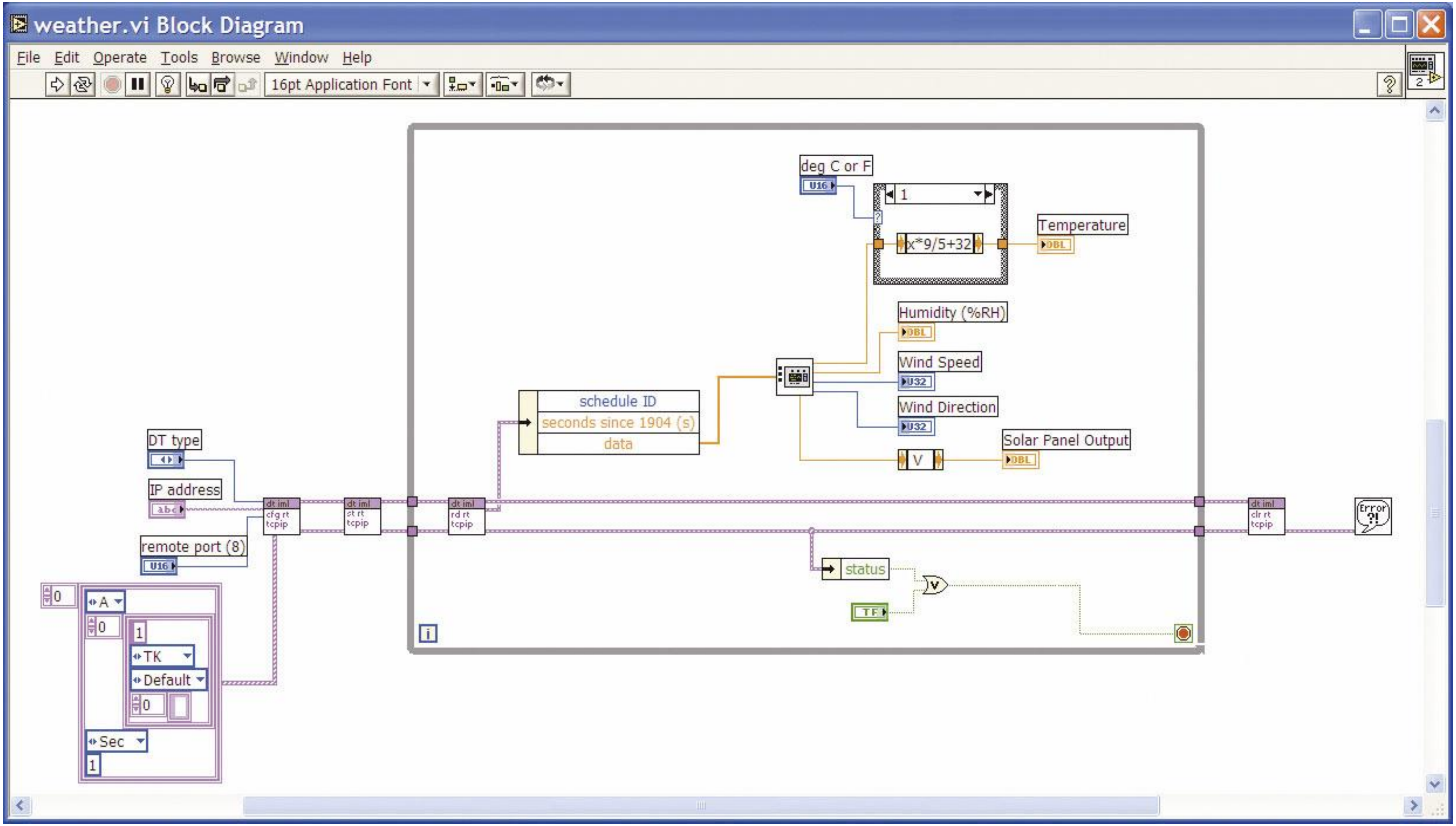
Instrument Control (LabView Virtual Instruments)

LabView .vi Front Panel



Instrument Control (LabView Virtual Instruments)

LabView .vi Block Diagram



http://www.ni.com/academic/students/learnlabview/

Data Acquisition with LabView Virtual Instruments

DAQ = "Data Acquisition"

Select Hardware Features →

- ADC resolution (analog-to-digital), e.g., 12 bits, or 16 bits: determines the ultimate resolution of converting an analog (continuous) voltage to a digital value. For example, on a 0-10 V scale, a 16-bit resolution gives you a least-significant bit voltage value (resolution) of $10\ V/2^{16} = 153\ \mu V$ (0.153 mV, or 1.53×10^{-4} V).
- Sampling Rate (of ADC): maximum rate at which sequential A-to-D conversions can proceed. E.g., 250 kS/sec indicates that 250,000 samples per second is possible.

Multi-Function DAQ Hardware

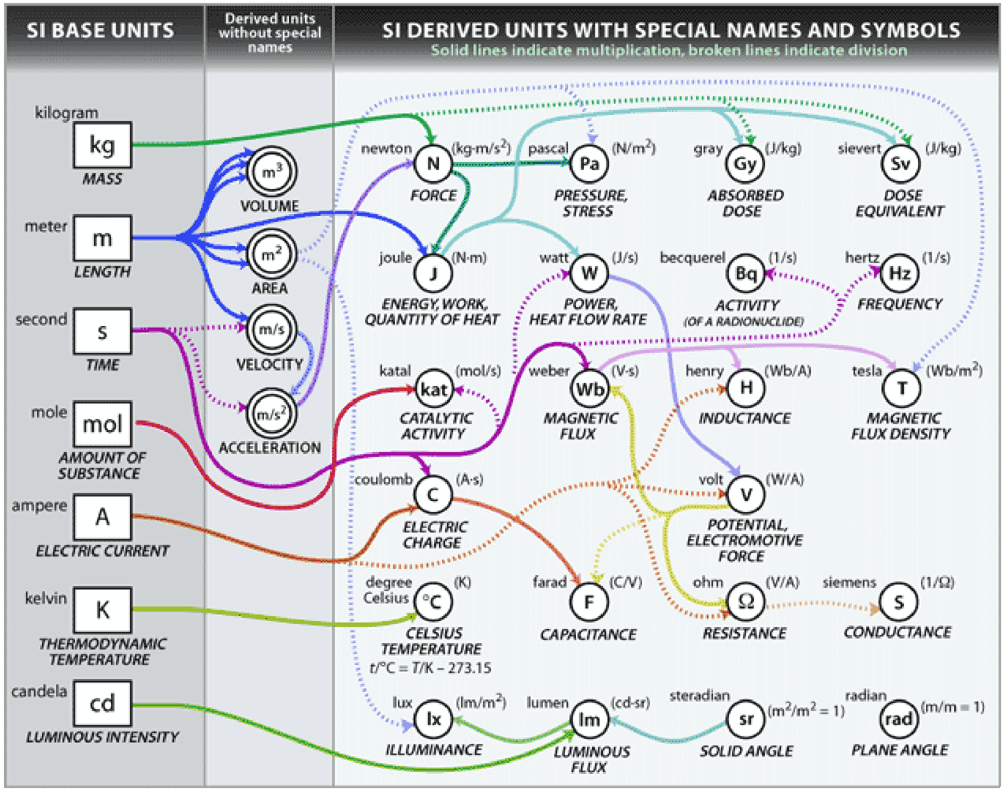
- Typical multi-function DAQ hardware (e.g., from National Instruments) includes capabilities of Analog In (AI), Analog Out (AO), Digital Input-Output (DIO), and Pulse Counter hardware.
- AI refers simply to analog to digital conversion.
- AO refers to essentially using the multi-function DAQ as a voltage source (e.g., to drive an LED, or provide a logical (digital) value to a circuit or instrument input).
- DIO refers to single digital lines. Digital in general means that the line (wire, or terminal) will have either 0 V or 5 V applied to it ("high" or "low"); more specifically, TTL is often used as the gauge for high/low settings.
- TTL = "Transistor-Transistor Logic", for which "low" is 0 V to 0.8 V and "high" is 2.0 V to 5.0 V.
- Pulse counting refers to electronics which can count digital pulses which conform to "digital" specifications.

Laboratory Safety

- Utmost importance -- avoid injury to yourself or others, and maintain health and well-being.
- Specific safety issues:
  - **Electrical dangers**: electrocution dangers exist, especially with potentially high-current electronics. Typical circuit breakers switch at ~100x the lethal current; only a GFCI-protected circuit is designed to protect against electrocution. Do not mess with (attempt to repair, or otherwise test or modify) power supplies or other electronics not part of the standard laboratory procedure. And most importantly, think about the connections you make to reduce the likelihood of unintended results.
  - Laser safety amounts to avoiding exposure to the very intense (highly directed, collimated, and often concentrated through focusing) laser light source. While damage can occur from laser-induced burn, the primary risk is that of exposure to the eye.

Units

- Use Standard International units (SI units) wherever possible to: improve accessibility and value of your data, establish good practices (data make sense to the widest audience), and (often) simplify the science.
- If you feel it is appropriate to use a non-SI unit, please note this in your synopsis/report, and if at all possible, provide the information necessary to convert to SI units. Example of non-SI units: eV commonly used for photon energy.
- Please double-check your work using units analysis to confirm that your answer makes physical sense!



Error analysis, uncertainty, precision, accuracy

- Errors from unavoidable uncertainty in measurements.
- Errors should be characterized and analyzed systematically.
- *Systematic* errors result from repeatable problems that tend to shift all measured values in the same direction away from the true value.
- *Random* errors vary from one measurement to the next, due to (e.g.) response of instrument to input, noise (electronic, etc.), or statistical processes.
- *Poisson statistical processes* occur at random times with an average rate. When counting such events for a given time interval, these processes result in an error $\Delta n = (n)^{1/2,}$ where n is the average number of events during the given time interval.
- *Precision* refers to the degree to which repeated measurements fall reliably at or very near the same value (which may or may not be the correct value).
- *Accuracy* refers to the degree to which the measured value(s) fall at or very close to the true value.

Lasers – high spectral purity