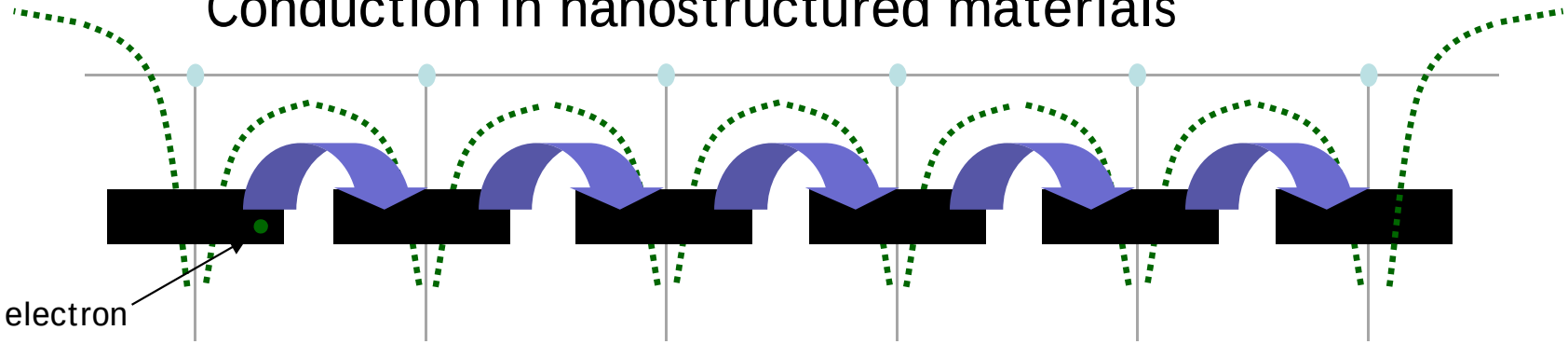
# *Solar Cells*

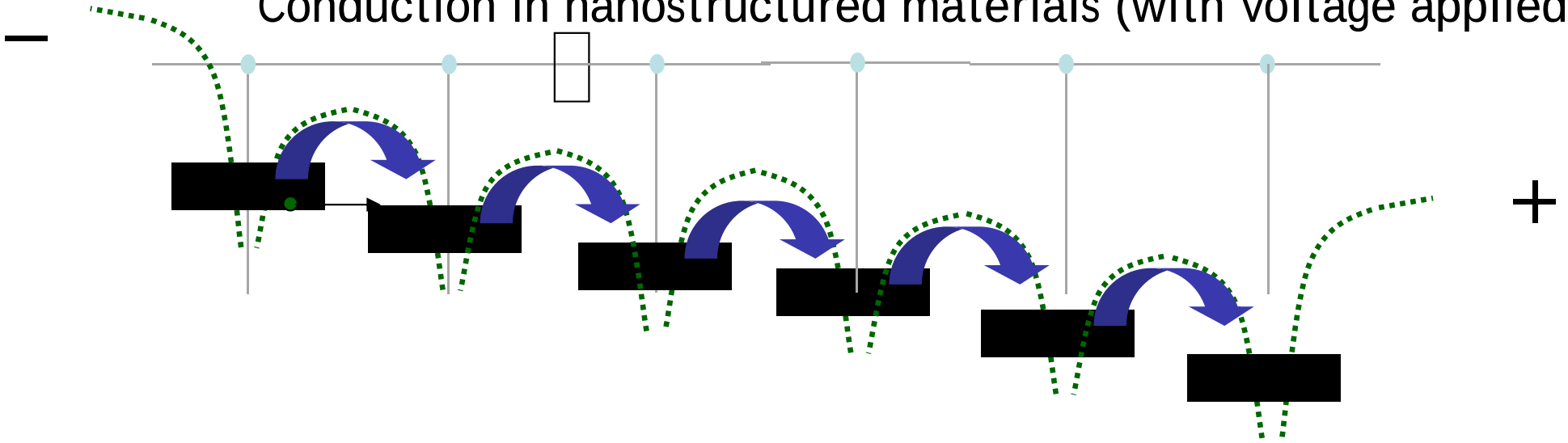
## Outline

. Single-Junction Solar Cells
. Multi-Junction Solar Cells

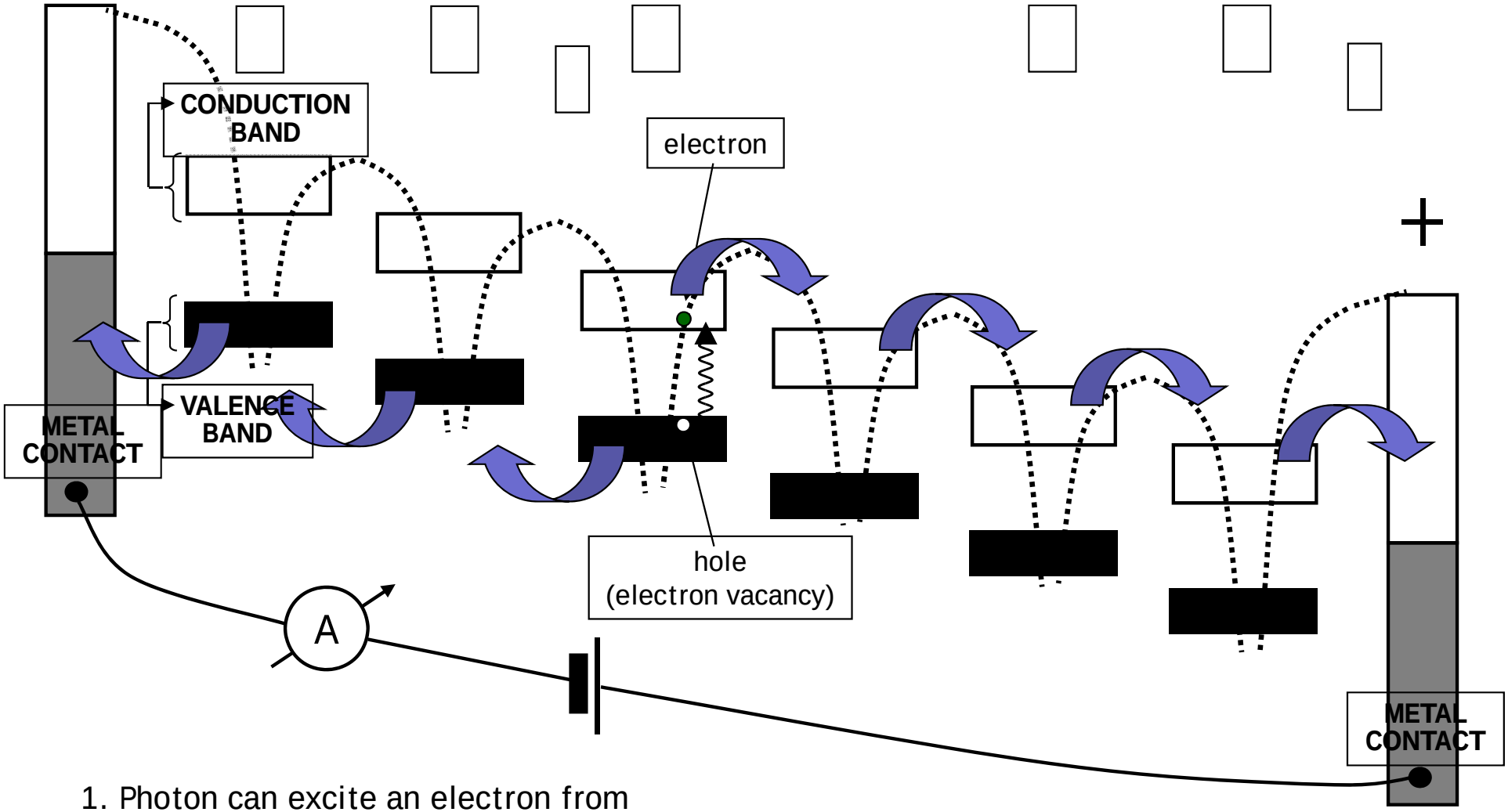
## Conduction in nanostructured materials




## Conduction in nanostructured materials (with Voltage applied)



# *Biased Semiconductor as a Photodetector of Light*




1. Photon can excite an electron from
   Valence Band (ground state) to Conduction Band (excited state)
2. The externally applied bias (that generates the electric field in the semiconductor)
   will separate the photo-generated electron and hole
3. The electron and a hole will reach the metal contacts, be collected by the bias
   battery, and be measures as a photocurrent.
4. If more photons are absorbed by the semiconductor, more current we will measured

PHOTODETECTORS

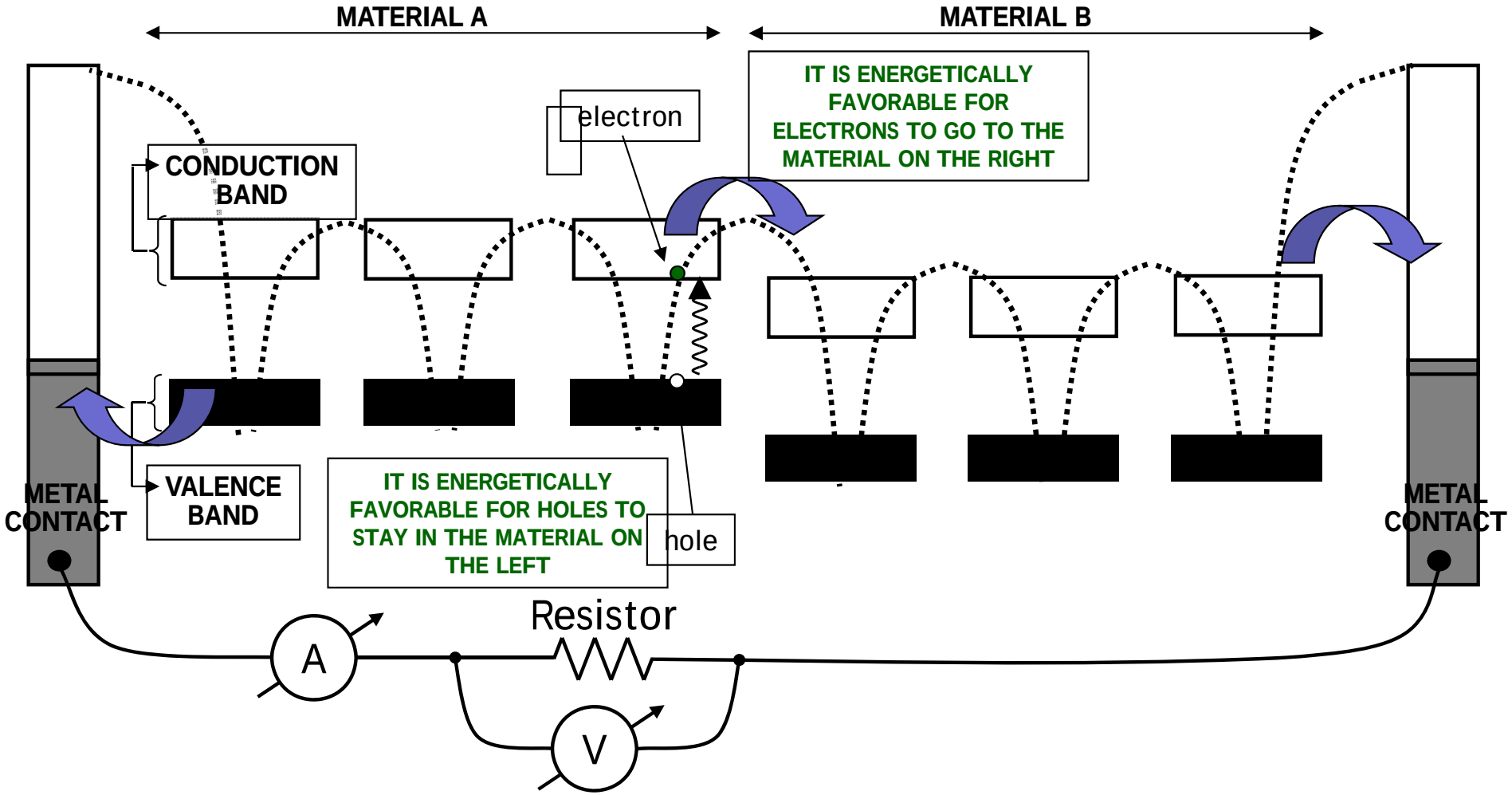
Apply bias (spend energy) to measure photocurrent
generated by light shining on the photodetector

SOLAR CELLS

Shine light on the solar cell and
generate voltage and current (power, energy)

(junction of two different semiconductors)

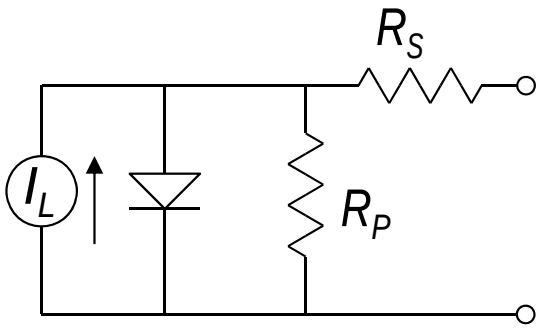
# Semiconductor Heterojunction Solar Cell

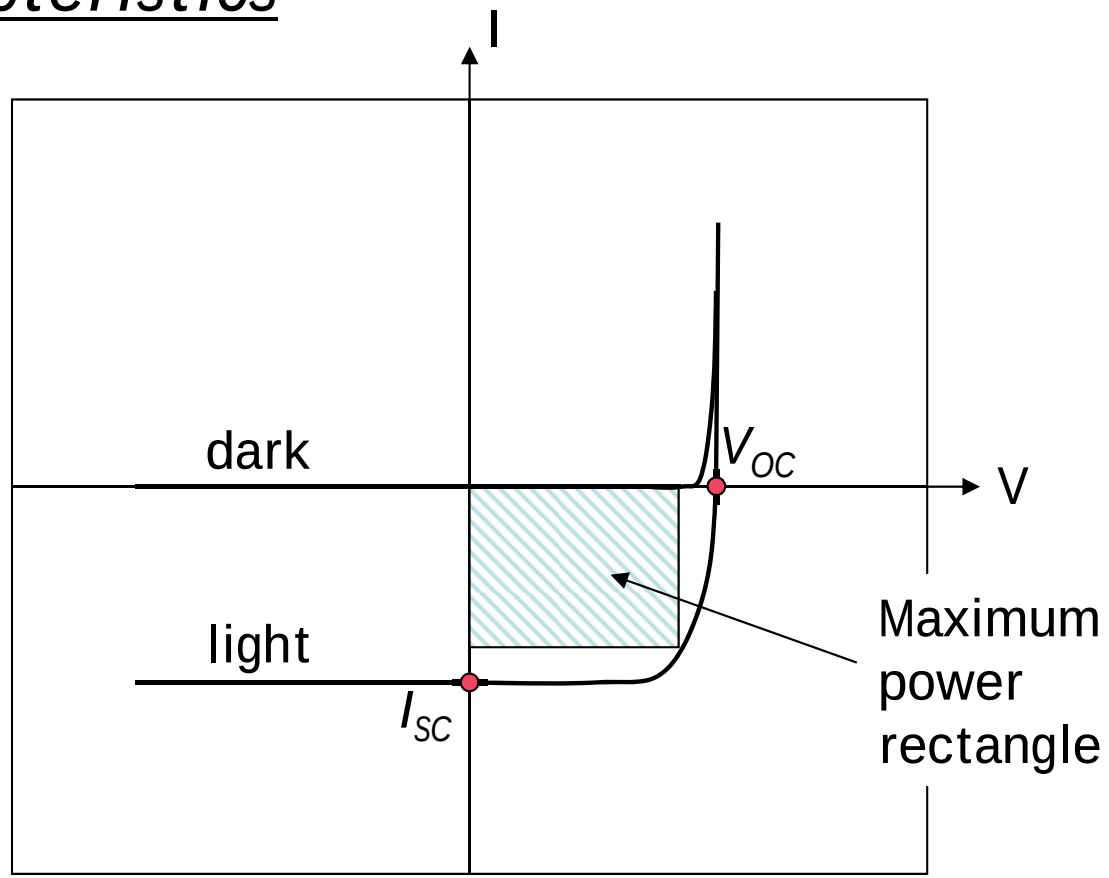



1. Photon can excite an electron from
   Valence Band (ground state) to Conduction Band (excited state)
2. At the heterojunction the electron and hole can separate, resulting in buld-up of electrons on the right and build-up of holes on the left → WE GENERATED PHOTOVOLTAGE
3. If solar cell is connected to a resistor, the photo-voltage will drive current through the resistor

# *Solar Cell Characteristics*

Circuit model



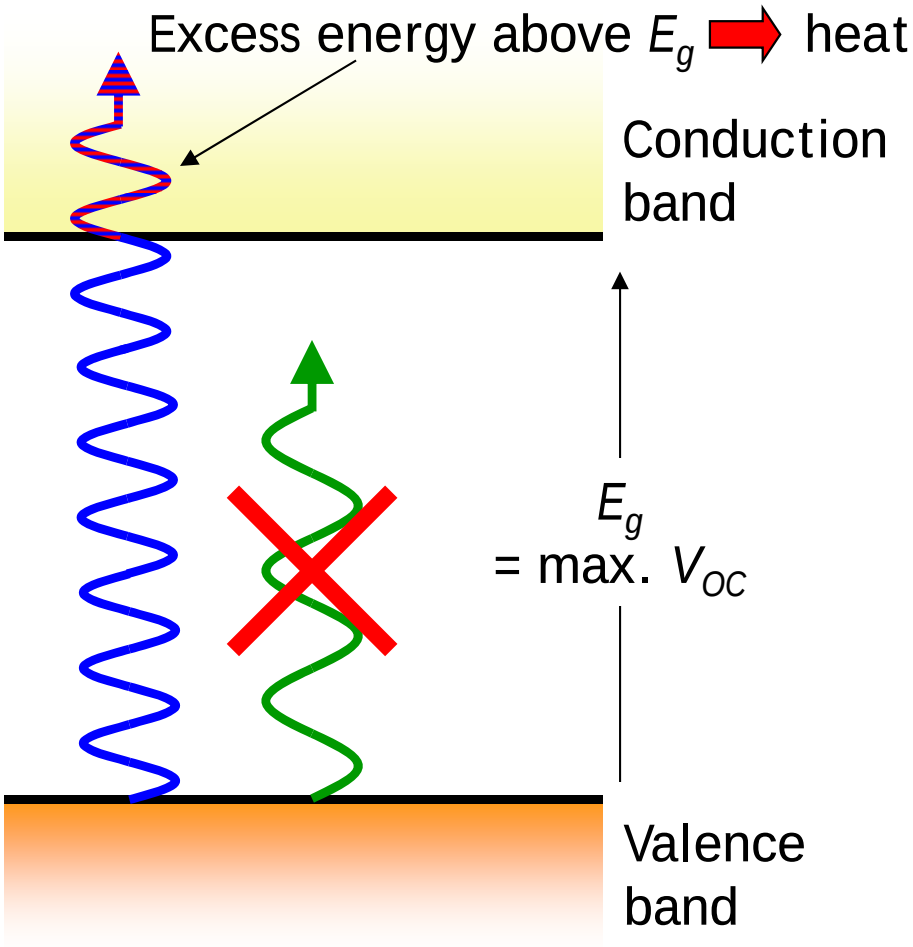



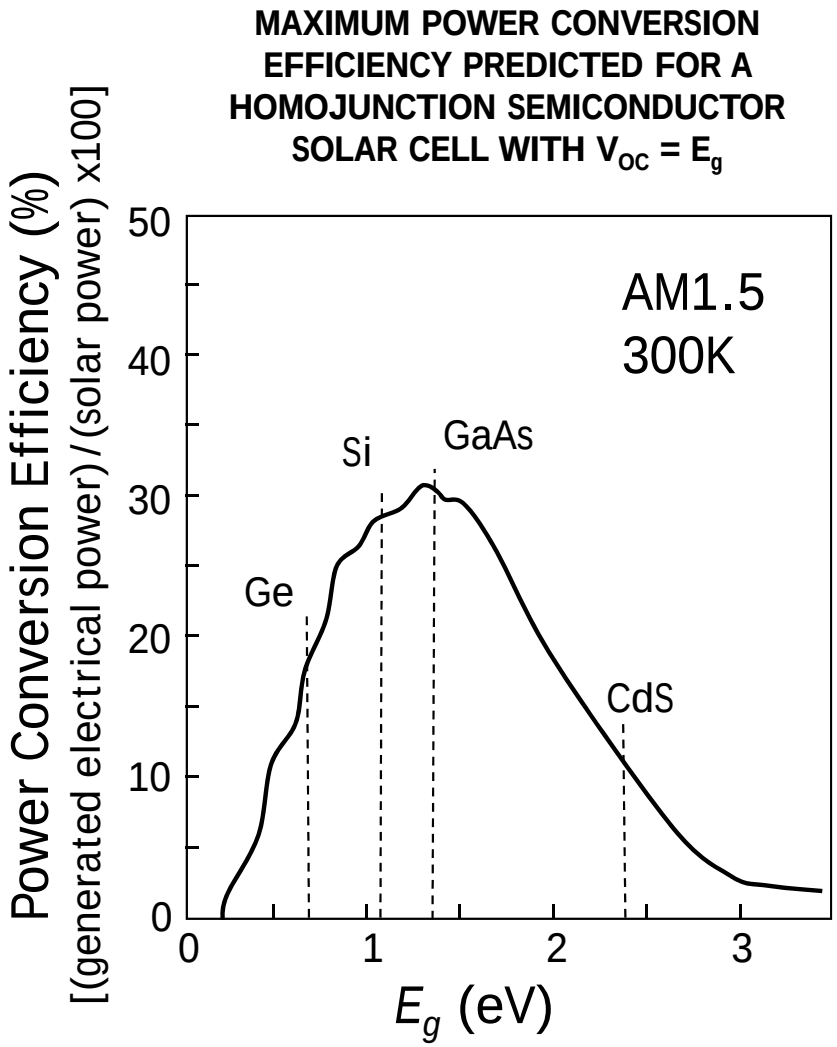

Critical parameters: $V_{OC}$, open circuit voltage

$I_{SC}$, short circuit current

FF, fill factor = $\dfrac{\text{area max. power rectangle}}{V_{OC} \cdot I_{SC}}$

# *Fundamental Efficiency Limits of Solar Energy Conversion in Photovoltaics*

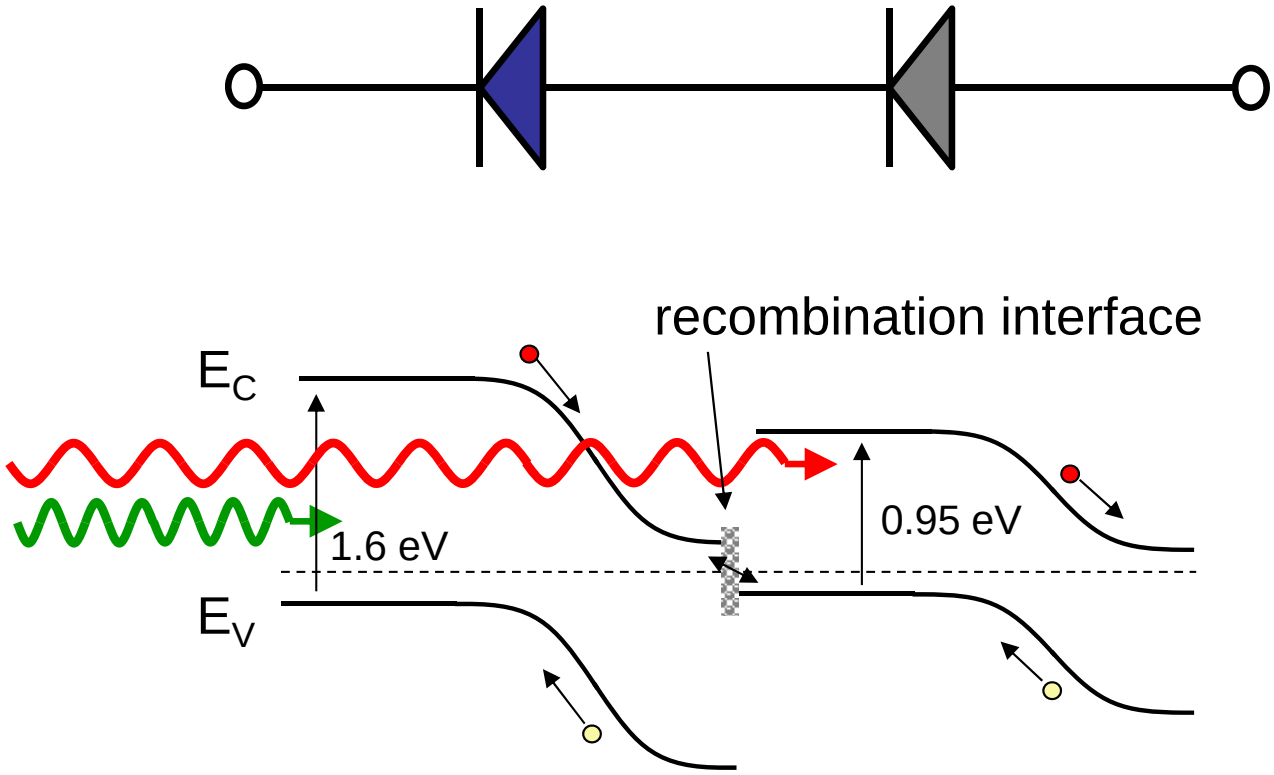



As band gap increases, the maximum open circuit voltage increases, but the fraction of the solar spectrum absorbed decreases.

# *Multiple Junction Cells*

Connect solar cells in series.
Usually wide gap cells in series with narrow gap cells.




Voltage of cells adds.
But need same current through each cell. Must carefully tune absorption.

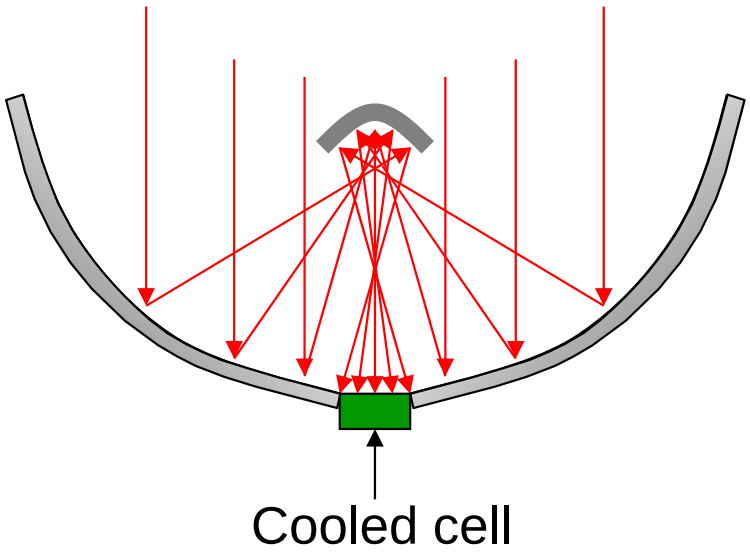
Advantage: highest performance cells made this way.

*from M. Baldo*

# A SHORT TERM GOAL: SOLAR CONCENTRATORS

Efficiency of devices increases with light intensity:

- Short circuit current increases linearly with incident power
- Open circuit voltage increases




**FIXED LENS OR MIRROR COLLECTOR**

- Concentration factor limited to $n^2$. ($G \sim 2$) ($n$: refractive index)

Image is in the public domain

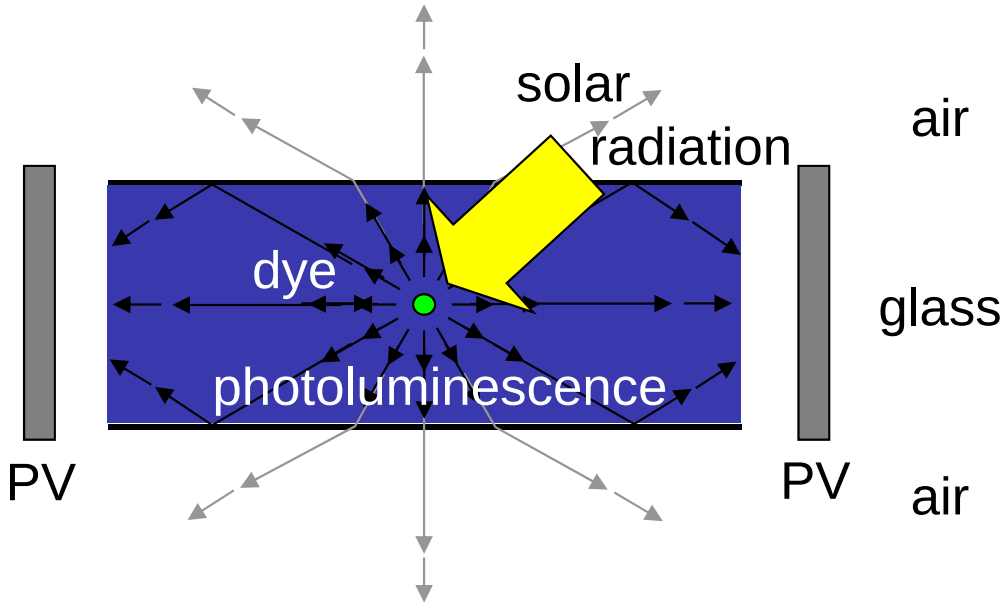
**TRACKING COLLECTORS**

- Mechanical – adds cost and maintenance
- PV needs cooling
- Must be widely spaced to avoid shadowing

## *A different approach:*

### *use Organics only for Optical Function of solar cells …*

Simple construction: dye in or on waveguide




Structure collects and concentrates light onto PV cells.

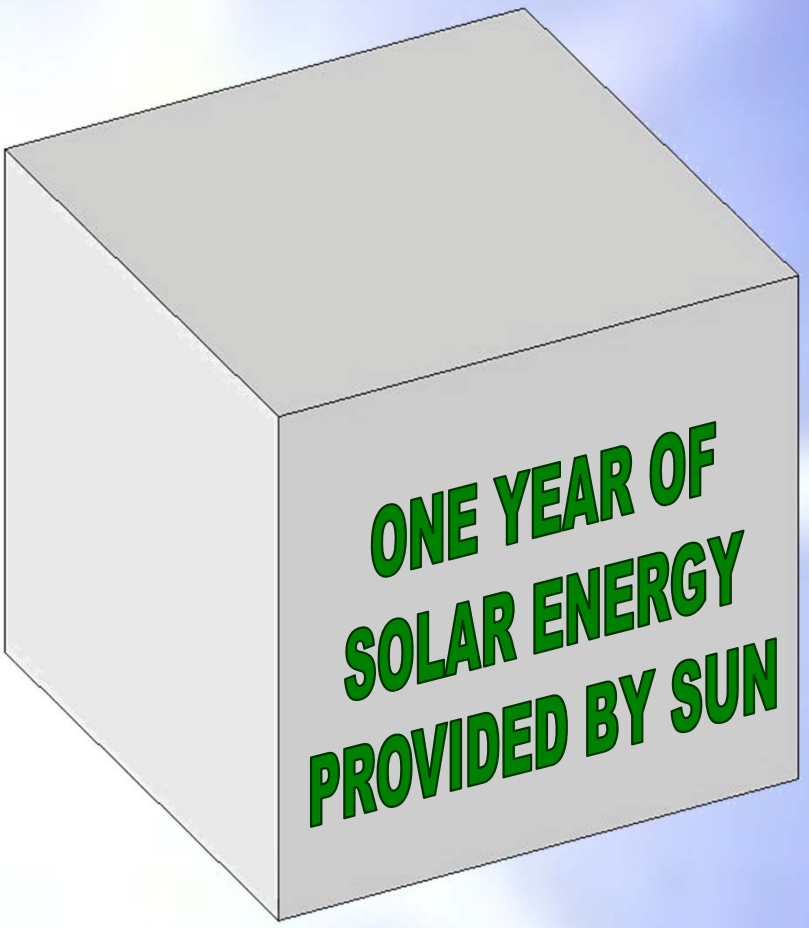
This is not a new idea…

'LUMINESCENT SOLAR CONCENTRATOR'

*W. H. Weber and J. Lambe, Applied Optics 15, 2299 (1976)*

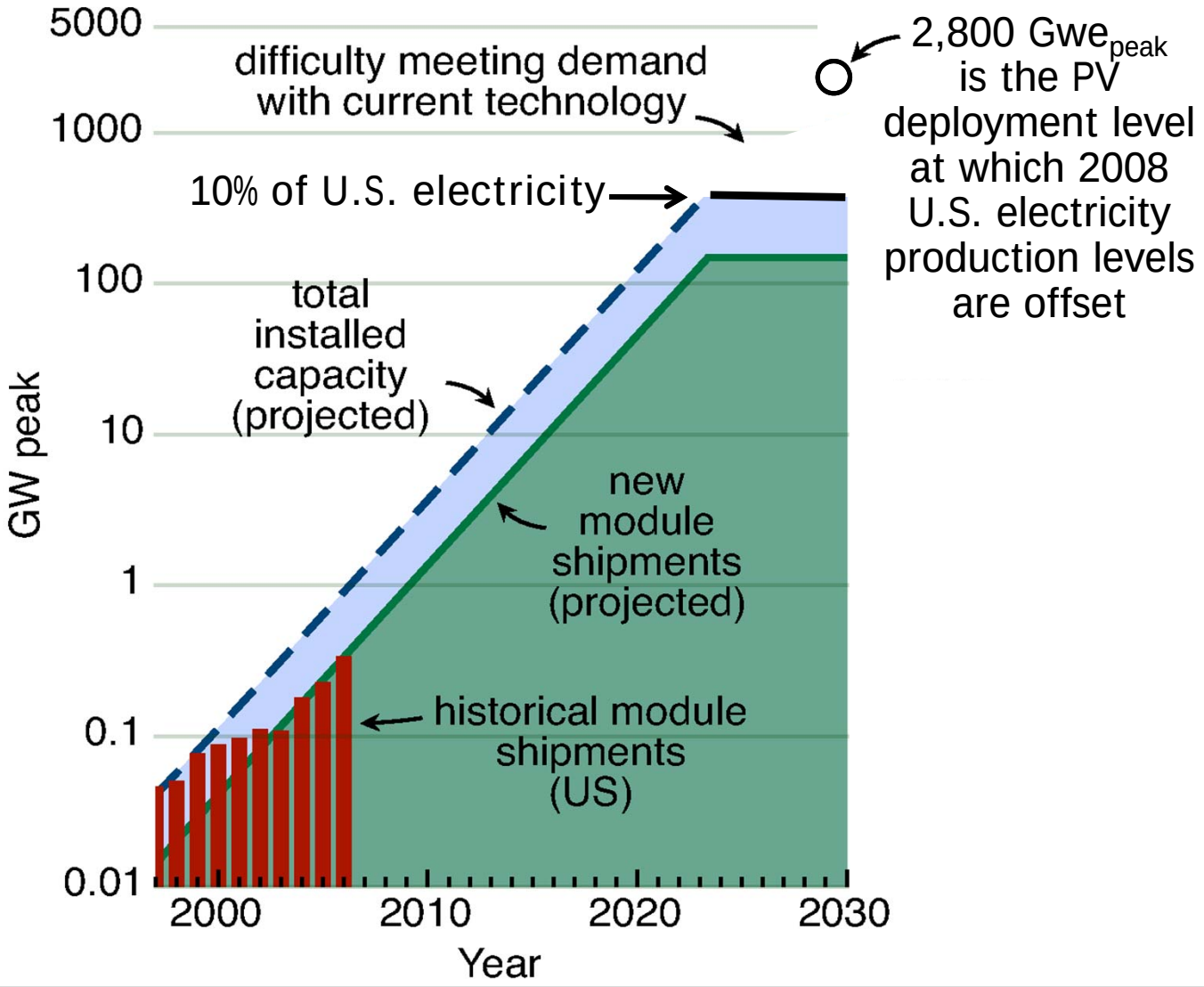
x 10,000 =

ONE YEAR OF EARTH'S FOSSIL ENERGY CONSUMPTION



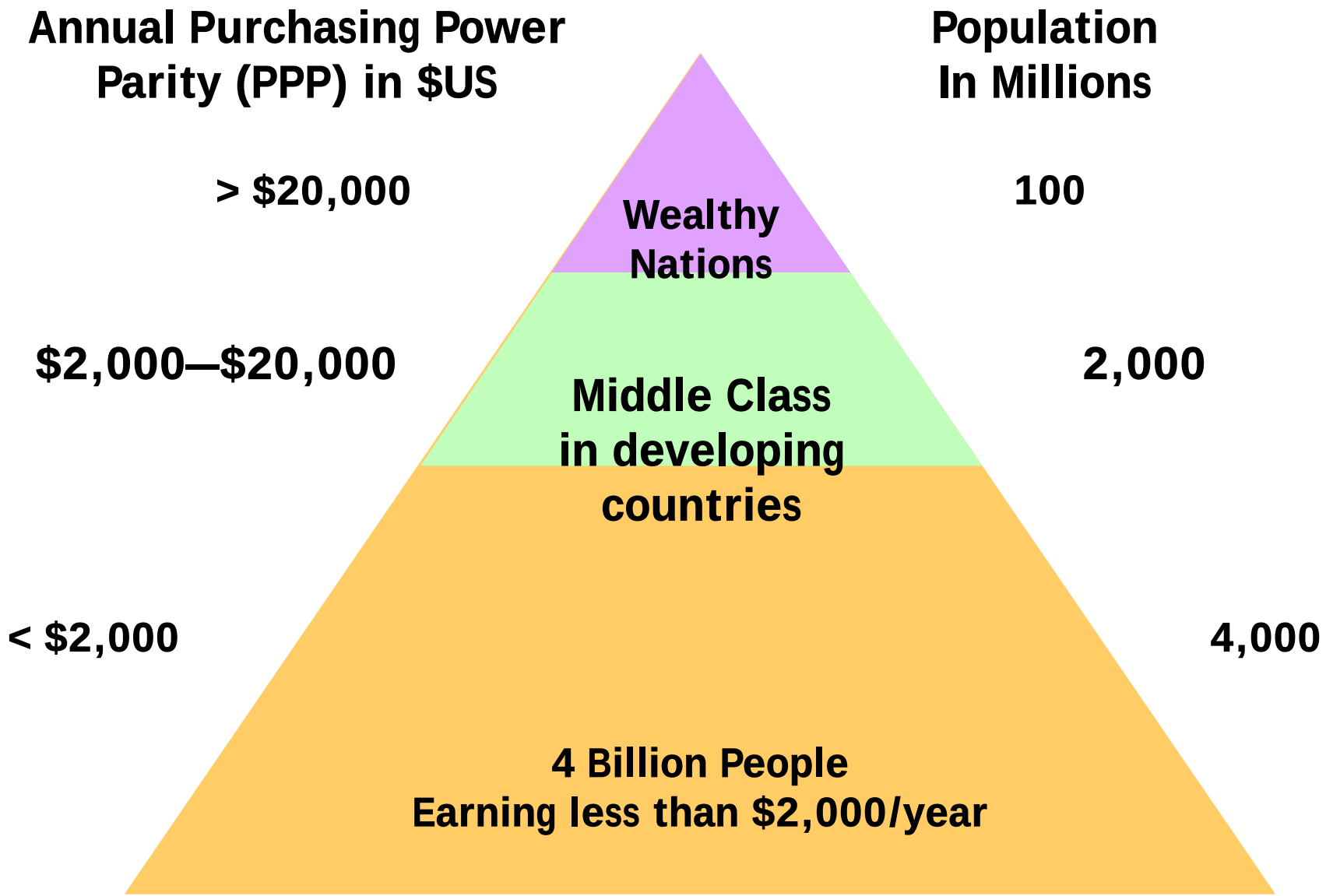

SOLAR ENERGY = RENEWABLE

# Deployment of Solar Photovoltaics in U.S.




**BY 2022 WE COULD DEPLOY PVs TO OFFSET 10% OF U.S. ELECTRICITY DEMAND FOR LARGER DEPLOYMENTS – STORAGE TECHNOLOGY IS NEEDED**

# “The Bottom of the Pyramid”




Source: Prahalad & Hammond, Harvard Business Review, Vol. 80, Issue 9 (Sep. 2002), pp48-58

# *Solar Cookers*

# 6.007 Electromagnetic Energy: From Motors to Lasers

Spring 2011