

Emerging Technology in Clean Energy



“The nation that leads the world in creating new energy sources will be the nation that leads the 21st century global economy”

- President Barack Obama, April 22, 2009



President Barack Obama signed more than $70 billion in renewable energy and energy efficiency measures into law as part of the American Recovery and Reinvestment Act

Current State of Solar Power



Barriers to Solar Energy

- Cost
- Efficiency

NREL identified 10 Non-technical barriers to Solar Energy:

- Lack of government policy supporting EE/RE (13)*
- Lack of information dissemination and consumer awareness about energy and EE/RE (12)
- High cost of solar and other EE/RE technologies compared with conventional energy (10)
- Difficulty overcoming established energy systems (10)*
- Inadequate financing options for EE/RE projects (10)
- Failure to account for all costs and benefits of energy choices (8)*
- Inadequate workforce skills and training (7)*
- Lack of adequate codes, standards, and interconnection and net-metering guidelines (5)
- Poor perception by public of renewable energy system aesthetics (4)
- Lack of stakeholder/community participation in energy choices and EE/RE projects (4)

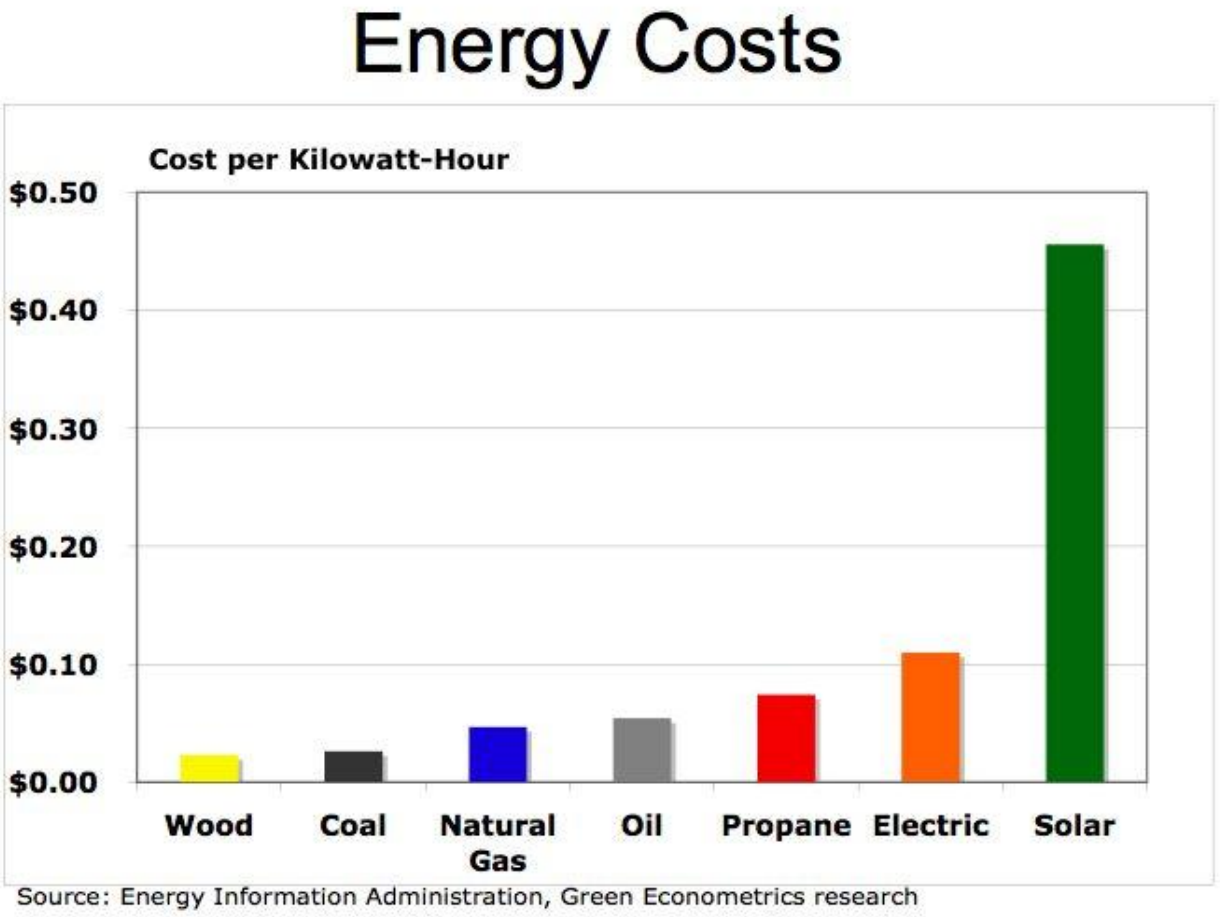
Source:
Nontechnical Barriers to Solar Energy Use: Review of Recent Literature
R. Margolis and J. Zuboy
National Renewable Energy Laboratory, 1617 Cole Boulevard, Golden, Colorado 80401-339

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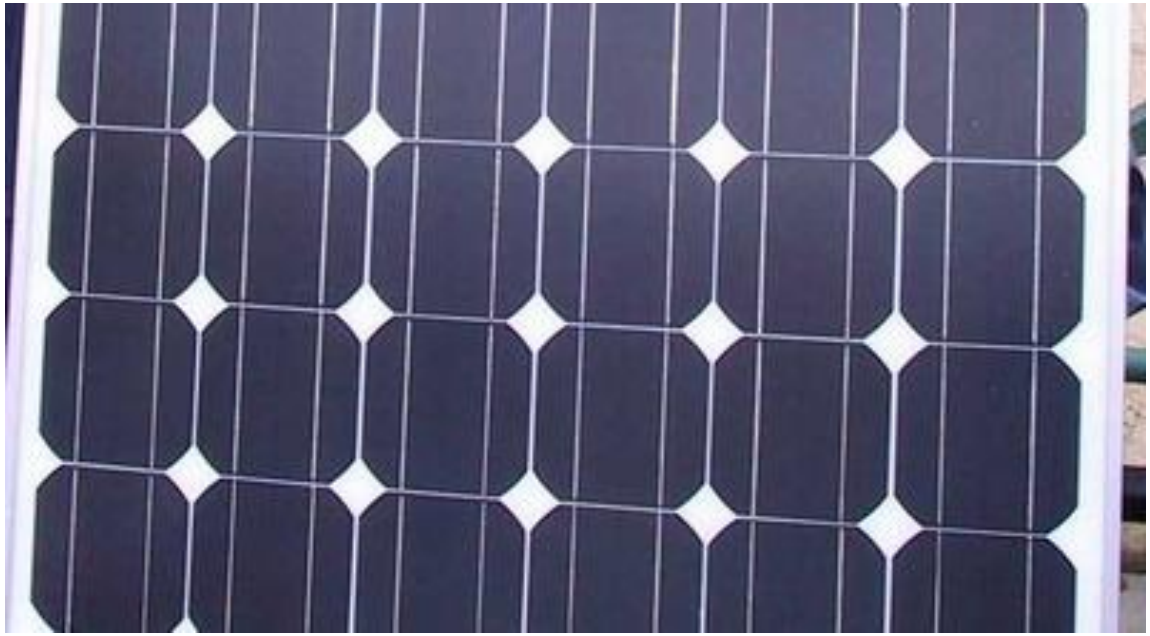
Solar Energy is nearly 4-10x the cost of hydrocarbon fuel!



Efficiency

1st Generation (crystalline silicon)

- 33% Efficiency
- Expensive: 5-7 year payback period
  - Refined Silicon is expensive and thus hard reduce cost



Efficiency

2nd Generation (Cdte Thin Film)

- low-cost, but low-efficiency thin-film

Current records for efficiency

- 18% (Cdte by Sheffield Hallam University)
- 19.9% (copper indium gallium selenide by NREL)
- 42.8 % (Multi-Junction Solar Cells by University of Delaware)



Current State of Solar Power

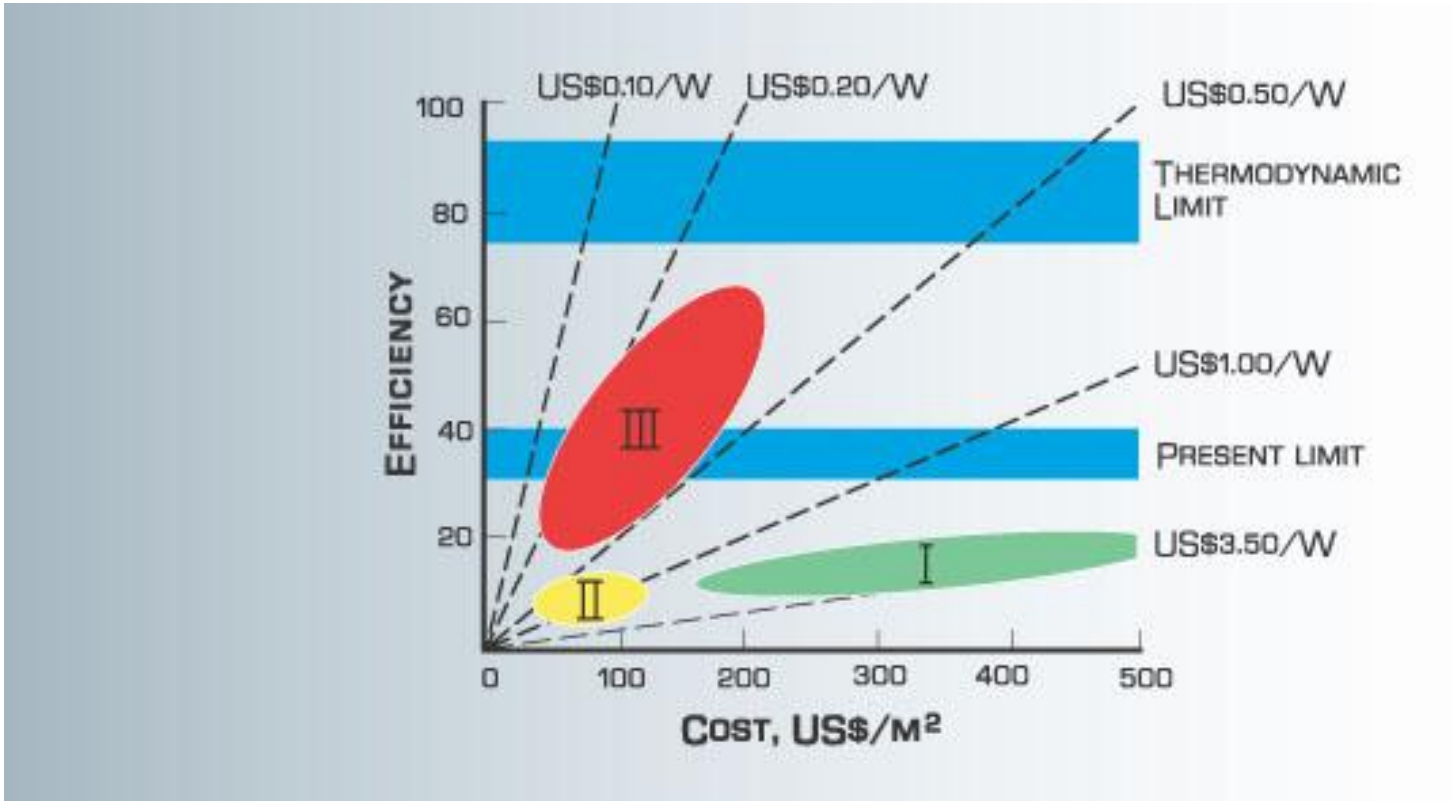
3rd Generation

advanced thin-film photovoltaic cell

Harnesses nanotechnology to provide greater efficiency and lower costs

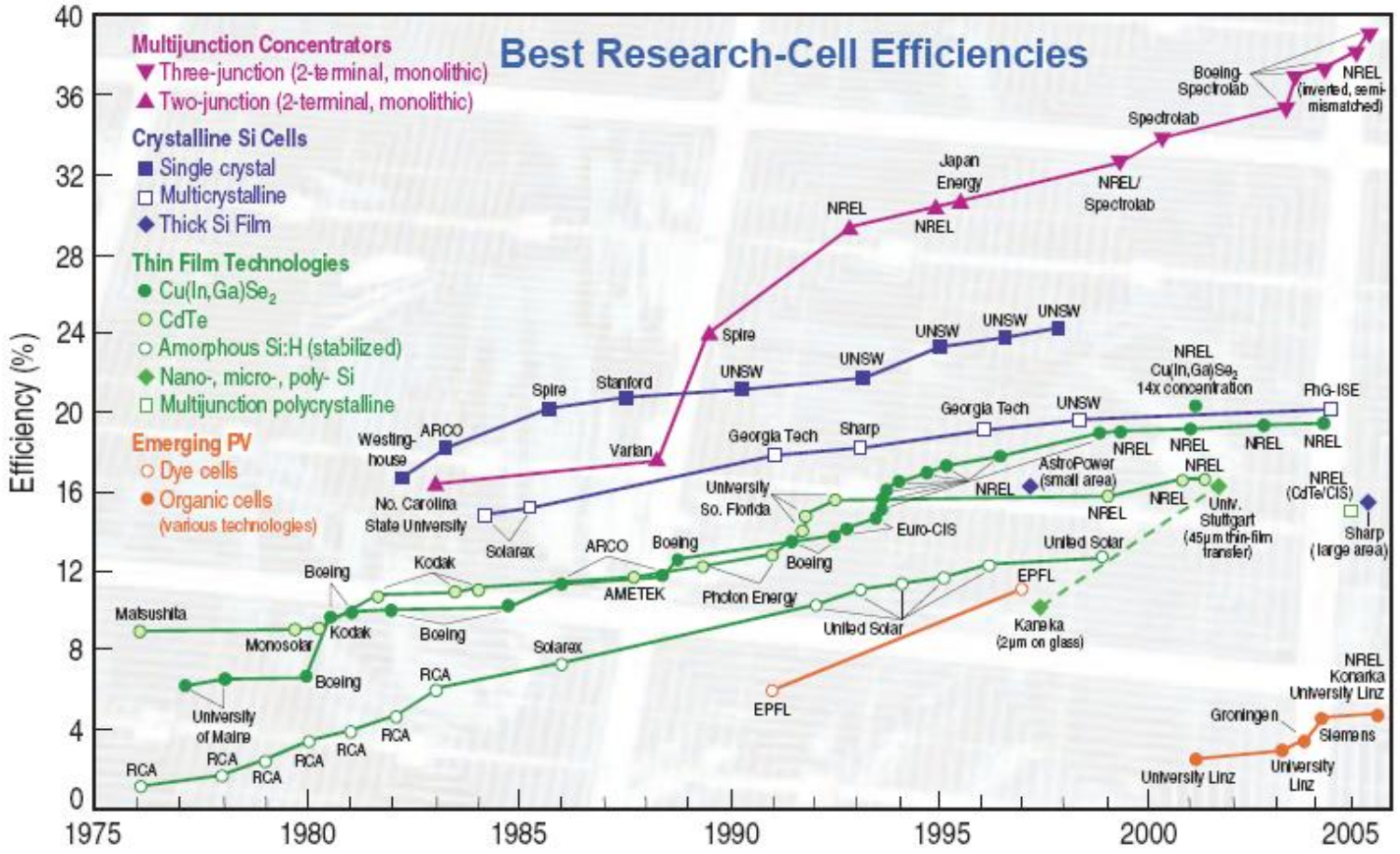
- Includes: polymer solar cells, nanocrystalline cells, and dye-sensitive solar cells

Cost vs. Efficiency of Solar Cells



Efficiency and cost projections for first-, second- and third generation photovoltaic technology (wafers, thin-films, and advanced thin-films, respectively)

Source: University of New South Wales



Source: US Dept of Energy 2006

How do we lower costs?

1. Increase Efficiency
2. Reduce Material Costs

Next generation technology

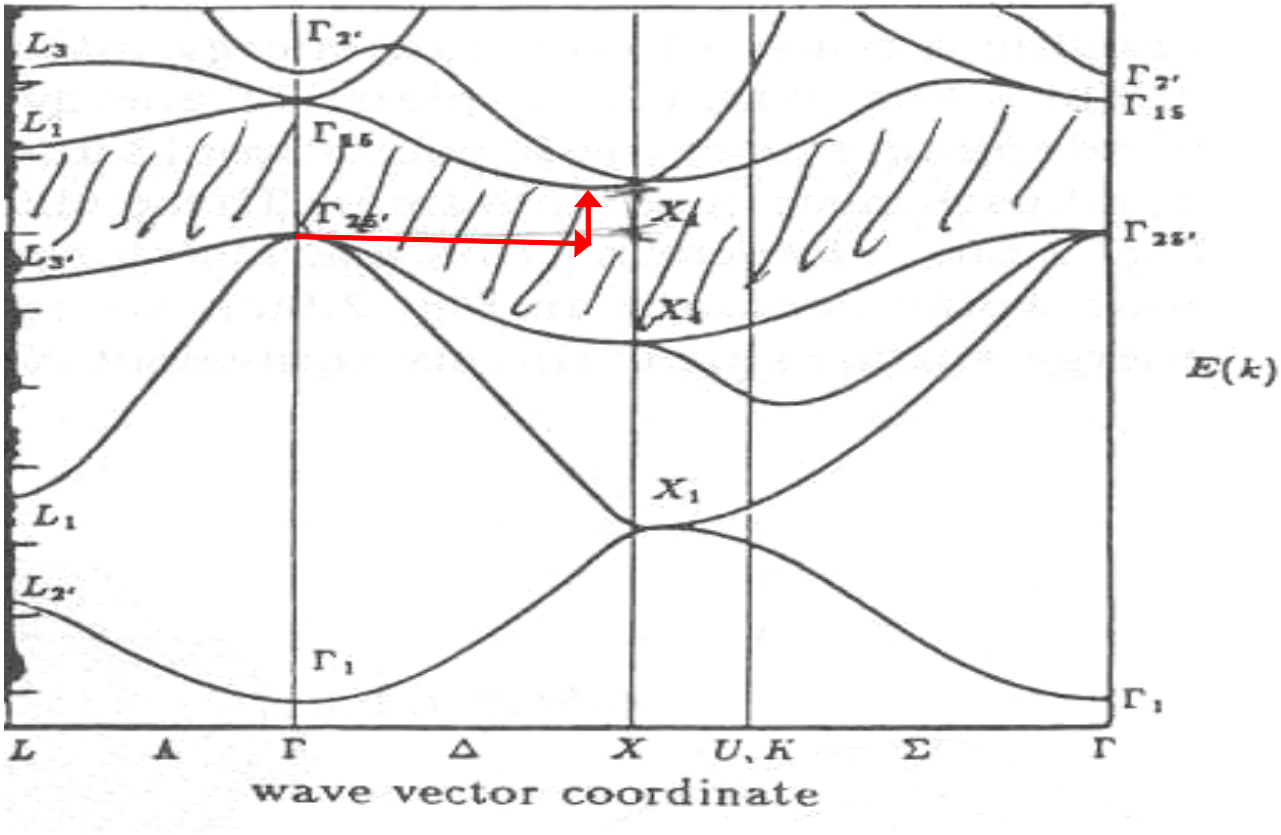
- **Silicon nanostructures**

  Bandgap engineering of silicon.

  Applications could be tandem solar cells and energy selective contacts for hot carrier solar cells.

  Fabrication of silicon nanostructures consisting of quantum well and quantum dot super lattices to achieve band gap control

The energy band structure for silicon



$$\hbar\omega = E_g + \hbar\Omega$$

Next generation technology (cont.)

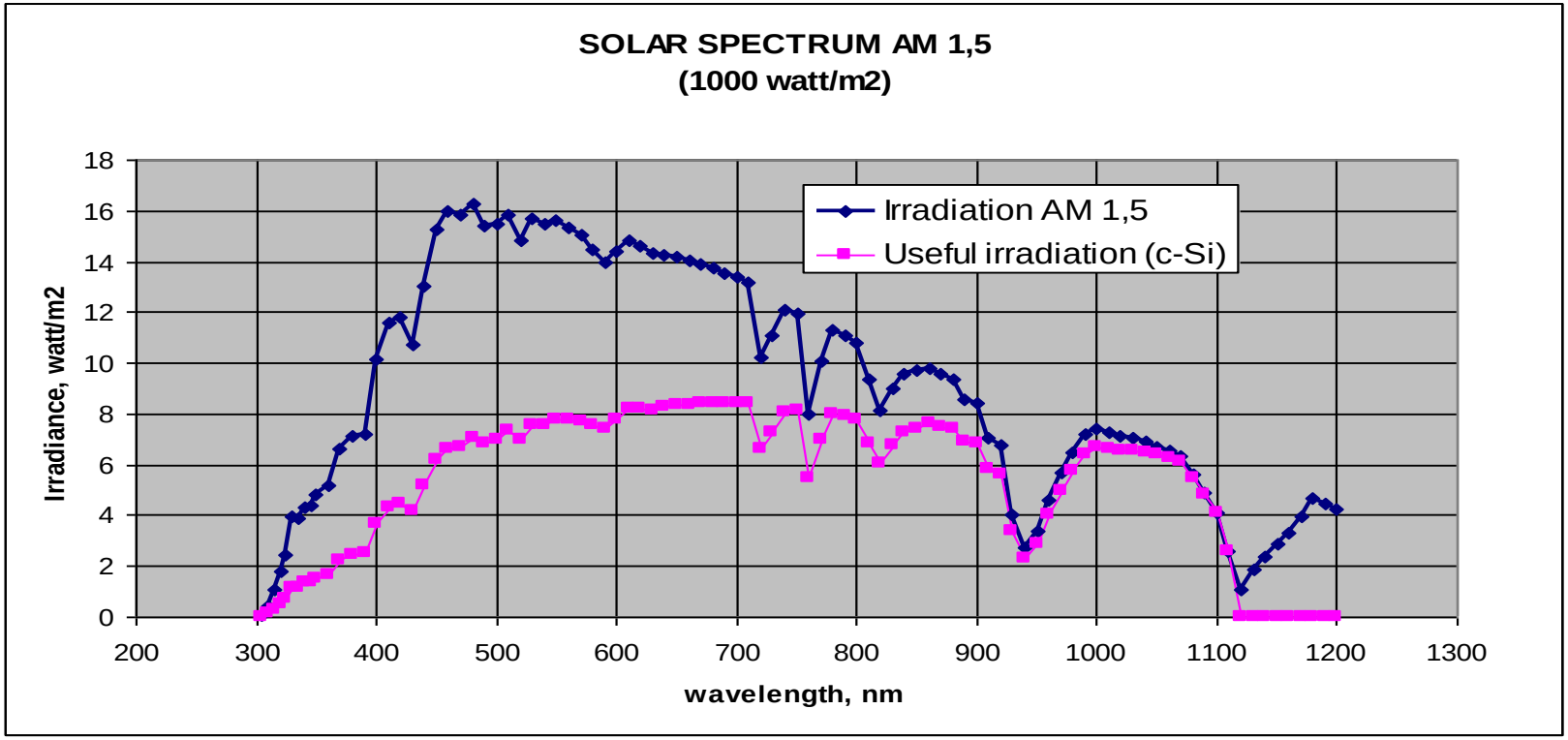
- **Up/Down converters**

  Luminescent materials that:

  EITHER absorb one high energy photon and emit more than one low energy photon just above the bad gap of the solar cell (down-conversion)

  OR that absorb more than one low energy photon below the band gap of the cell and emit one photon just above the band gap (up-conversion).

Understanding cell efficiency



Next generation technology (cont.)

- **Hot carrier Cells**

  This concept tackles the major PV loss mechanism of thermalisation of carriers.

  The purpose is to slow down the rate of photoexcited carrier cooling caused by phonon interaction in the lattice to allow time for the carriers to be collected whilst they are still hot, and hence increasing the voltage of a cell.

Next generation technology (cont.)

- **Thermoelectric solar cells**

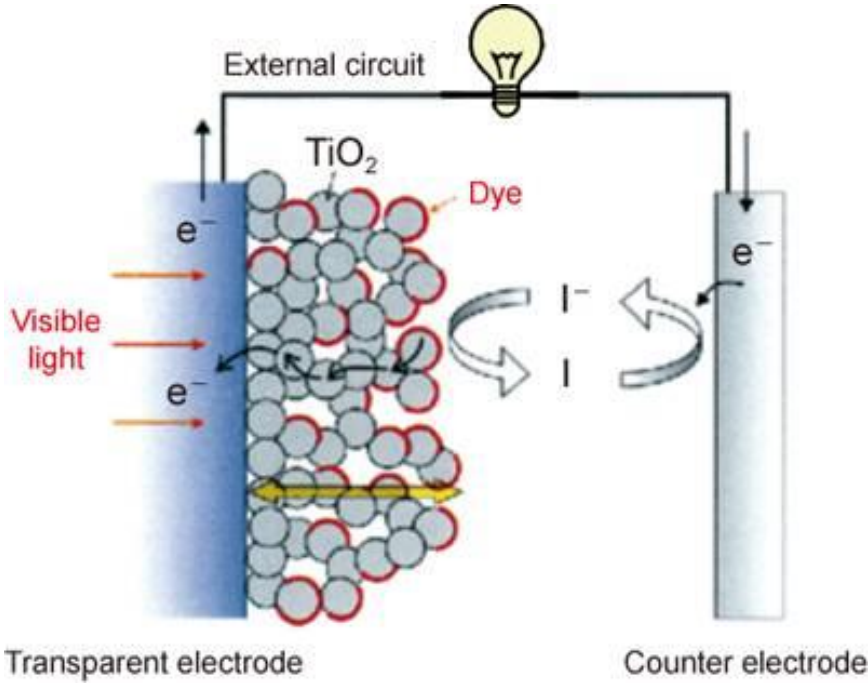
  Application of the concept of energy –selective electron transport used in hot carrier solar cells, to develop thermo electrics and thermo-ionics devices.

Grätzel cells

- Dye-sensitized solar cell
- Named after inventor Michael Gratzel

Concept

- Photosensitive dye absorbs UV light and is placed between two electrodes
- Dye in cell are excited and electrons are discharged



Source: http://www.ehow.com/how_4867315_build-solar-cell.html

Grätzel cells

- Advantages
  - Uses Titanium Dioxide - a cheap and widely available material.
    - Also used in toothpaste
  - Easy to manufacture
- Disadvantages
  - Lower efficiency and power than PV Cells
  - Efficiency 11-16%
  - Does not absorb full spectrum of light

Current Research

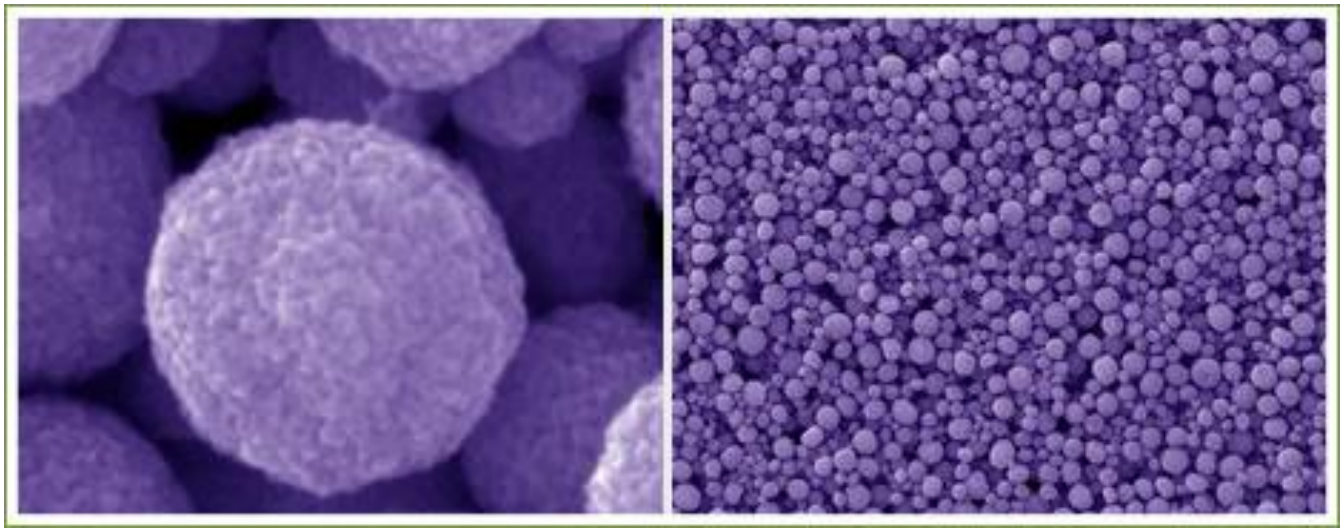
Dye-sensitized solar cell technology

“Popcorn Balls”

-Tiny spheres grouped into bigger porous spheres

- each sphere contains 1000 sq feet of light absorbing pigments

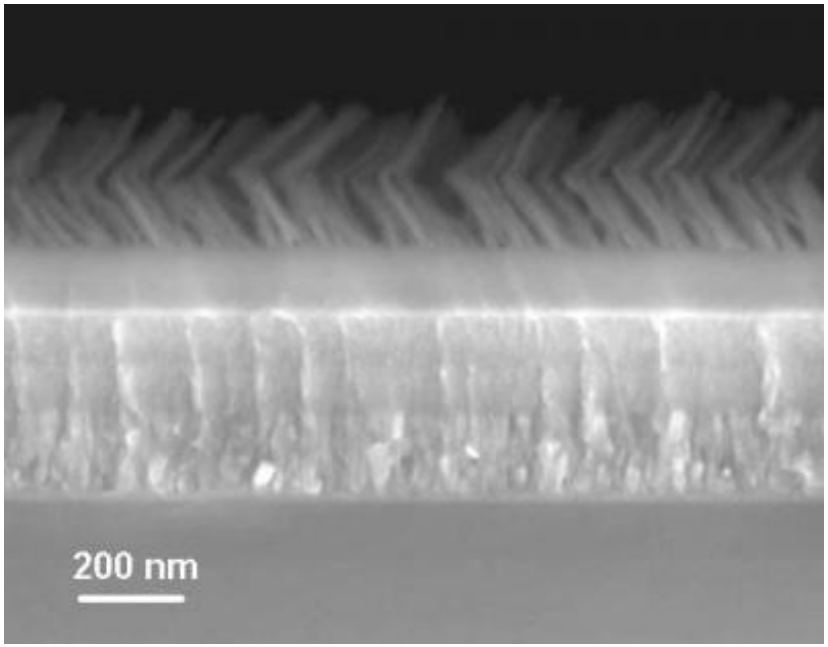
-boosts absorption on solar cells by 250%



Source: http://www.engr.washington.edu/facresearch/highlights/mse_popcornsolar.html

Coatings and Dyes

From Prof. Shawn-Yu Lin of Rensselaer Polytechnic Institute
"Realization of a Near Perfect Antireflection Coating for Silicon Solar Energy,"



- Special NanoCoating boosts efficacy of solar cells

-Overcomes two hurdles of solar cells:
    -Boosts energy absorption
    - absorb the entire spectrum of sunlight from any angle, regardless of the sun's position in the sky

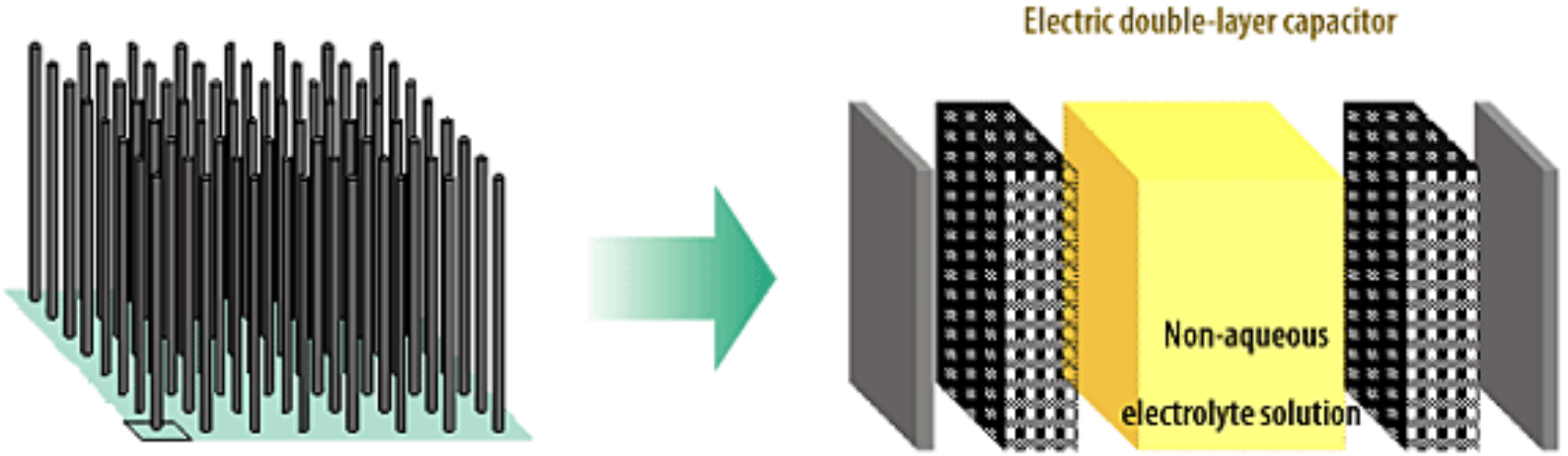
Solar Cell absorption:
Untreated Silicon Solar Cell**: 67.4%** of sunlight
With Antireflective Coating: **96.21%**

Mei-Ling Kuo, David J. Poxson, Yong Sung Kim, Frank W. Mont, Jong Kyu Kim, E. Fred Schubert, and Shawn-Yu Lin,
"Realization of a near-perfect antireflection coating for silicon solar energy utilization," Opt. Lett. **33**, 2527-2529 (2008)

Carbon Nanotube Capacitor

- CNT: high density, high purity and high orientation characteristics
  - Minimizes internal resistance
  - Electrical capacity per specific surface area is higher than that of active carbon

= higher output level, higher energy density, and longer operating life characteristics that are typically required of capacitors



http://www.nedo.go.jp/english/activities/portal/gaiyou/p06028/p06028.html

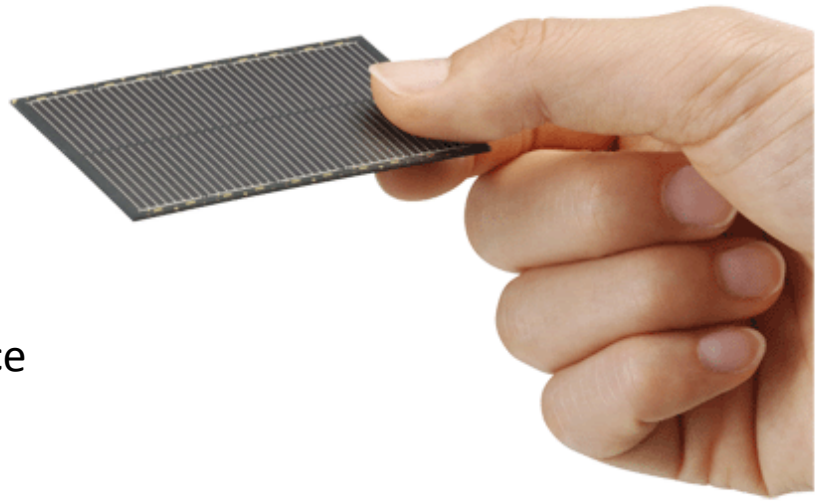
Carbon Nanotube Capacitor

- At the University of Texas:
  - With a 1 atom thick layer of carbon nanotube
  - 2630 m2/gram

Products in the market

- Industry's thinnest solar panel at 0.8 mm
-Solar cells use polycrystalline silicon,
and deliver a maximum power of 300 mW
-Enough to power mobile electronics

-Electrode pattern can be formed on the cell
-surface to meet the requirements of the device
- manufacturer, enabling the creation of
-modules with original designs



LROGC02 Solar Module for Mobile Devices

Source: Sharp Electronics

- http://www.physorg.com/news144940463.html
- http://www.physorg.com/news140787110.html


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BIOFUELS
CELLULOSIC ETHANOL
BIODIESEL
SECOND GENERATION FEEDSTOCK TECHNOLOGIES
HYDROGEN
DISTRIBUTED GENERATION
ADVANCED TECHNOLOGIES
SOLAR
POLY/MULTISILICON TECHNOLOGIES
CPV TECHNOLOGIES
SYSTEM INTEGRATION
OCEAN ENERGY
TIDAL ENERGY
WAVE ENERGY
OCEAN THERMAL ENERGY CONVERSION
WIND
NEW MATERIALS
BLADE MANUFACTURING AND DESIGN
ENERGY EFFICIENCY
POWER STORAGE
WIRELESS ELECTRICITY
WATER TREATMENT
INDUSTRIAL WATER PURIFICATION
MUNICIPAL WATER TREATMENT