

Nanotechnology and the Energy Challenge

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Brookhaven National Laboratory

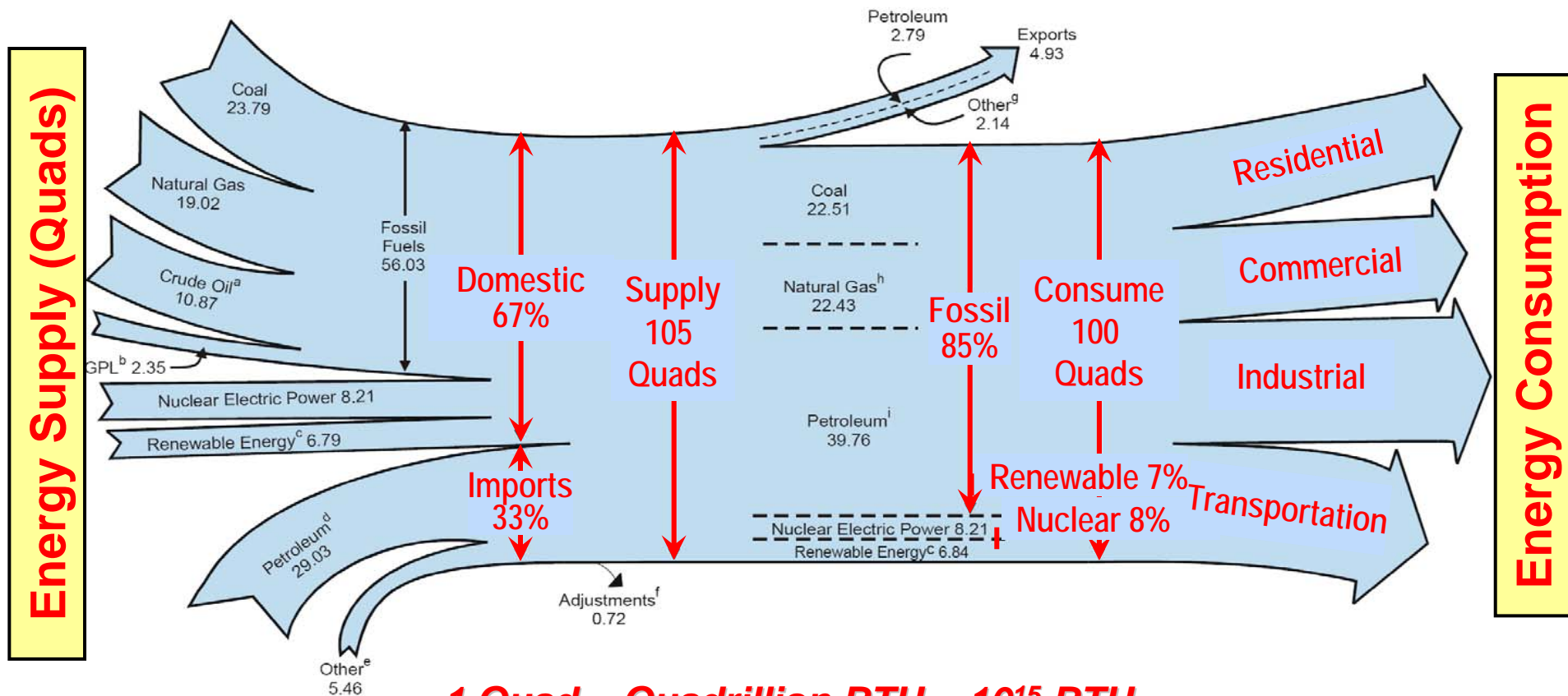


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U.S. Energy Flow, 2006 (Quads)

85% of primary energy is from fossil fuels
About 1/3 of U.S. primary energy is imported



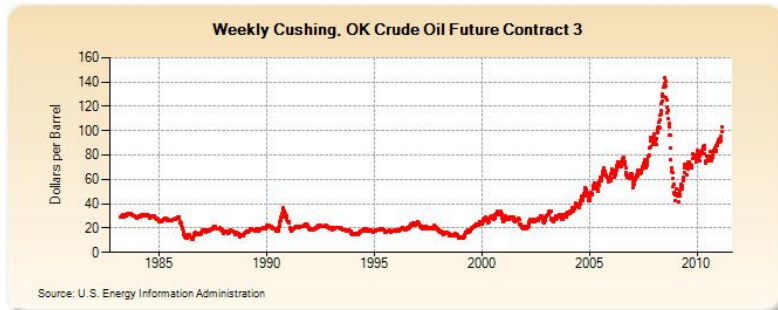
1 Quad = Quadrillion BTU = 10^{15} BTU



The Elements of the Energy Challenge

1. Amount of (most) energy sources, is limited, if not scarce.

Oil Price Increases



2. The sources of energy are not uniformly distributed.
3. Most (current) energy sources pollute environment.



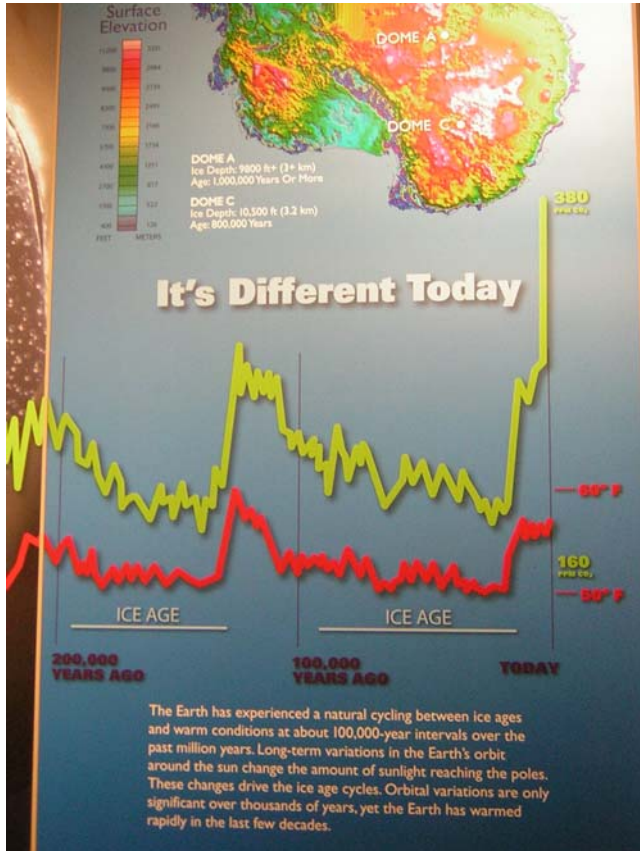
Political Tensions Rise



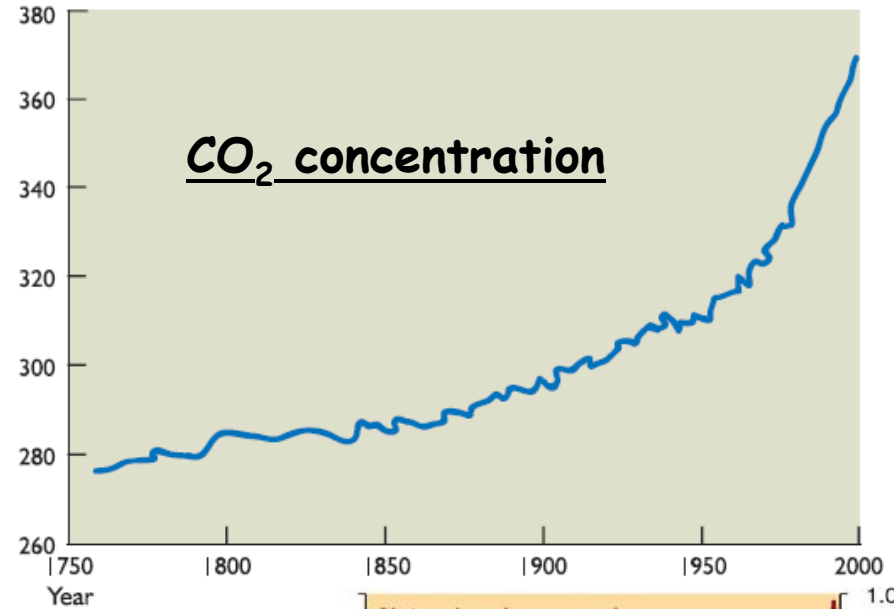
Climate Changes

Correlation between CO₂ and Temperature

In the past, changes in T led to changes in CO₂ concentration

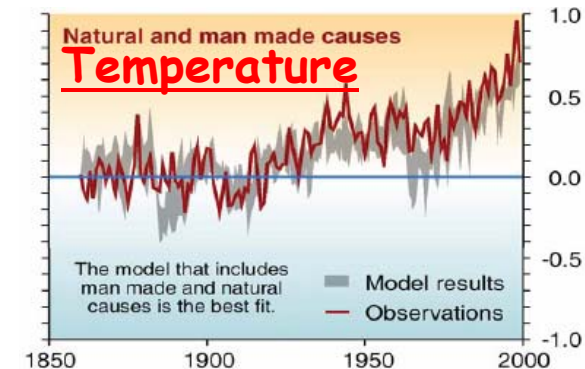


CO₂ Concentration, parts per million



Is current T increase caused by CO₂ increase?

Is CO₂ increase caused by human activities?



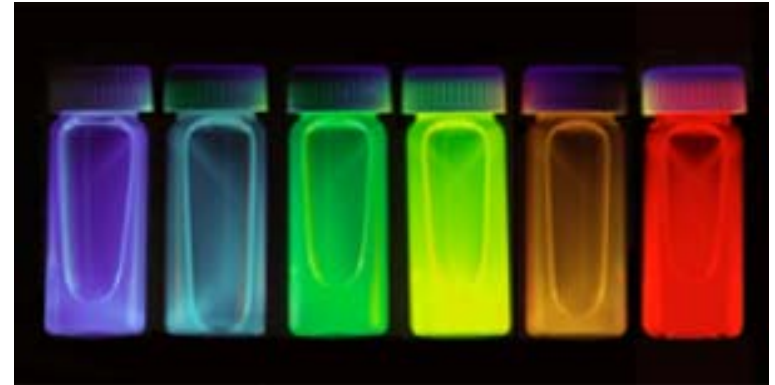
MOST PROBABLY, YES



The Science Behind Nanotechnology

At the Nanoscale:

Materials' properties change
(color, conductivity,
mechanical resistance, etc)



Relative number of atoms on surface
increases dramatically (catalysis)

Nanoparticles reach everywhere (medicine)



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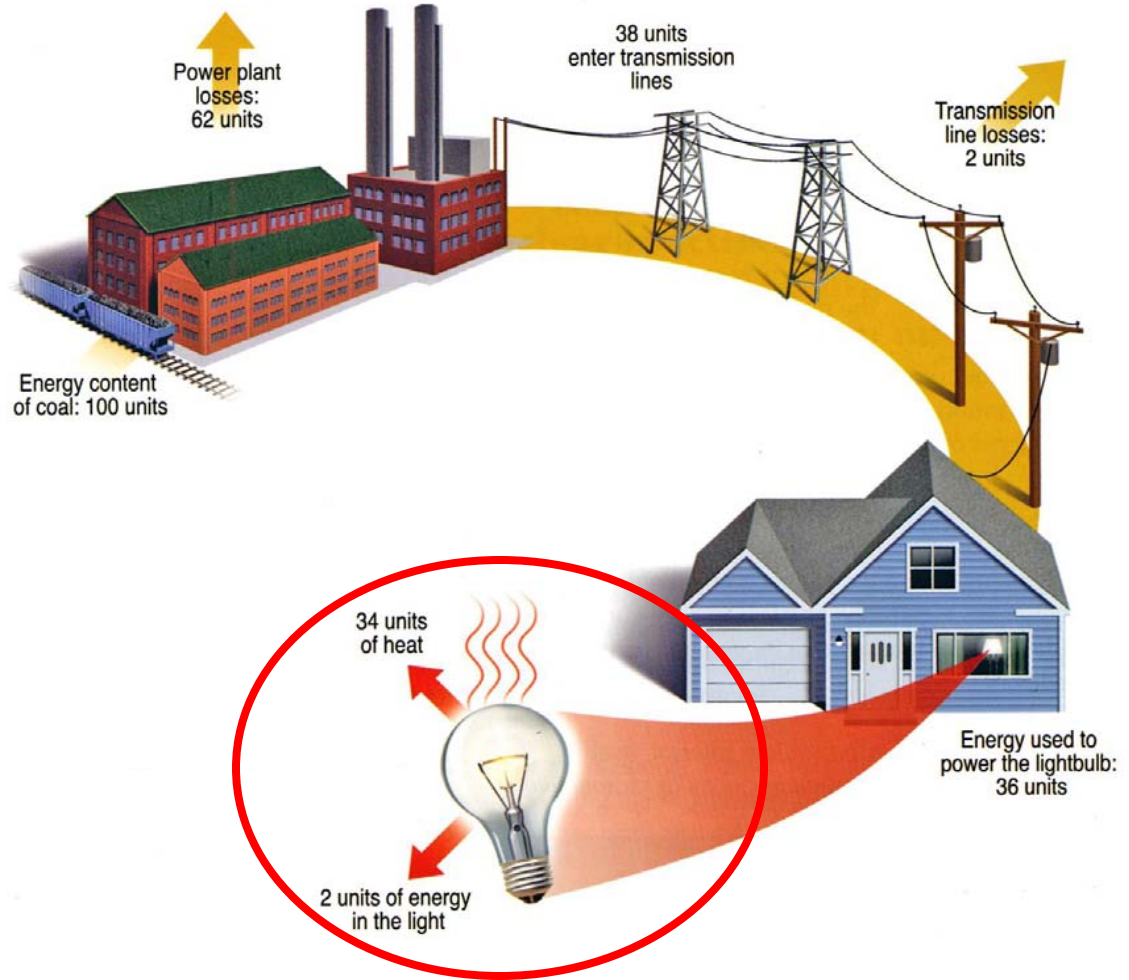
Improving Efficiency: Lighting



Quantum-dot-based LED
(10x better than incandescent)



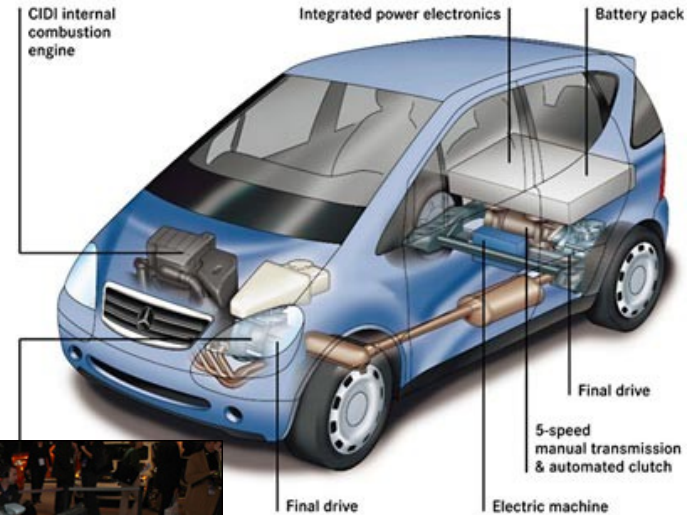
Three-way Fluorescent Light Bulb
(4x better than incandescent)



Transportation

Hybrid (today's) -- Prius

ICE + auxiliary electric motor
+ battery system to recover
energy lost in breaking



Plug-in Hybrid (2011) -- Volt

Electric motor +
high-capacity battery +
auxiliary ICE for long trips



All Electric -- Tesla

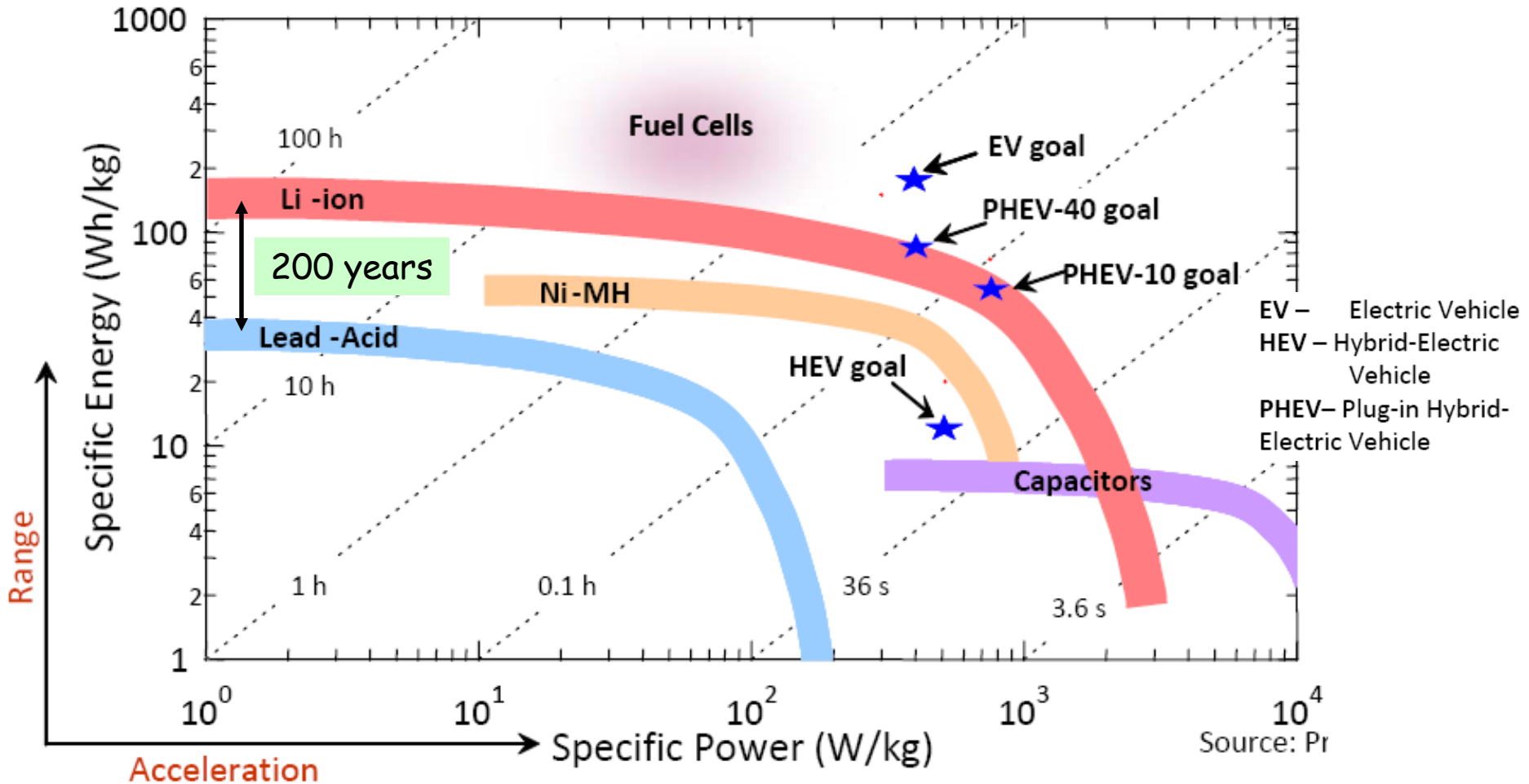
Electric motor +
very-high-capacity battery



Power Density and Energy Storage

IC Engine-2500 Wh/kg

An EV needs batteries with double energy density of today's



(V. Srinivasan, LBNL)



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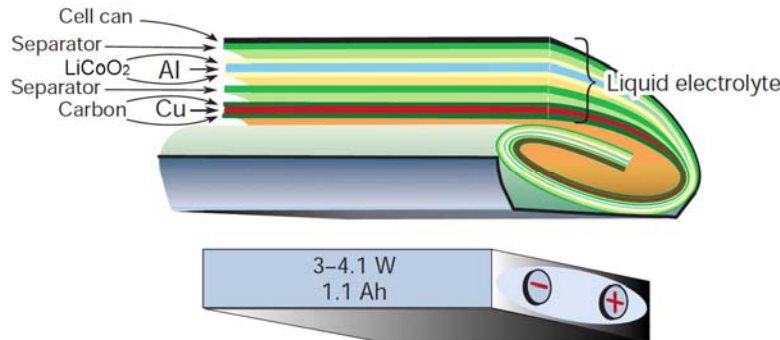
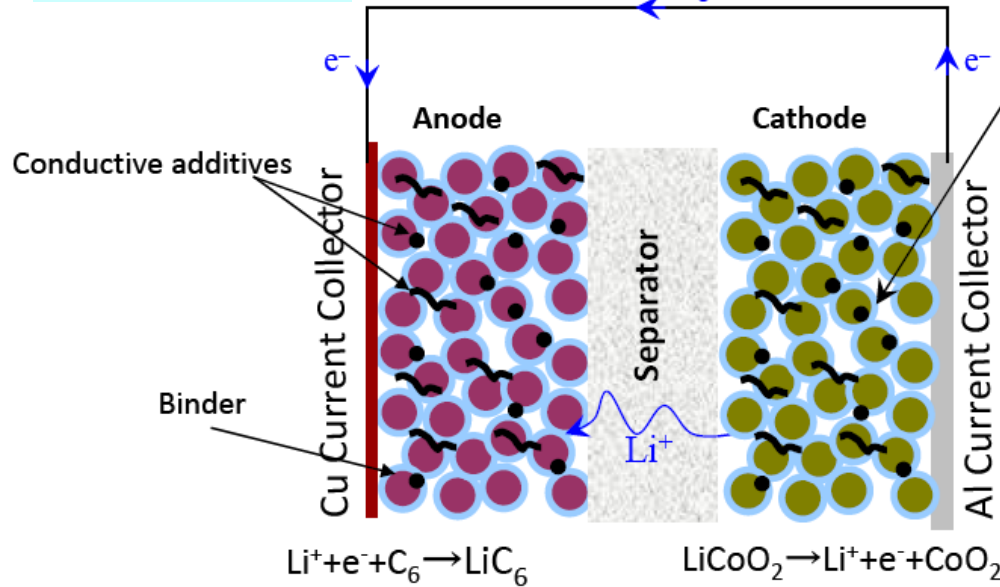
Li-ion Rechargeable Batteries

(in charging mode!)

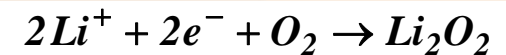
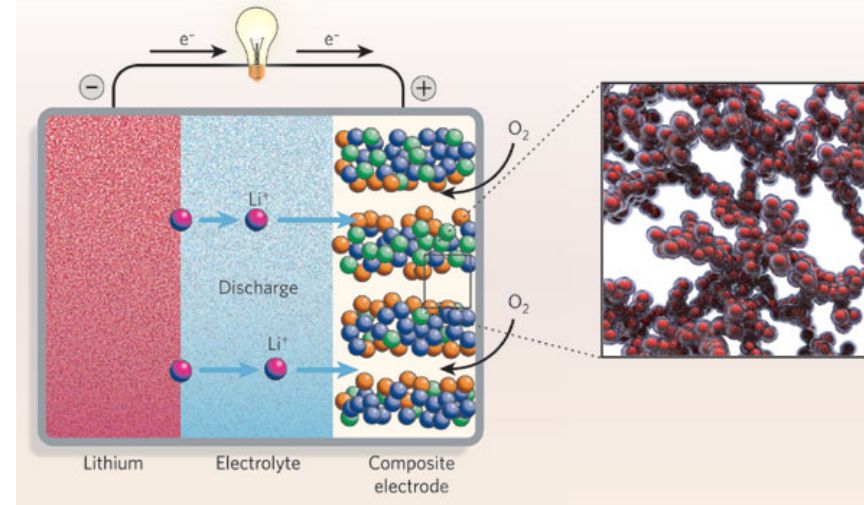
Lithium-ion battery

(V. Srinivasan, LBNL)

Electrolyte
LiPF₆ in Ethylene carbonate/diethyl carbonate



Li-air battery (under development)

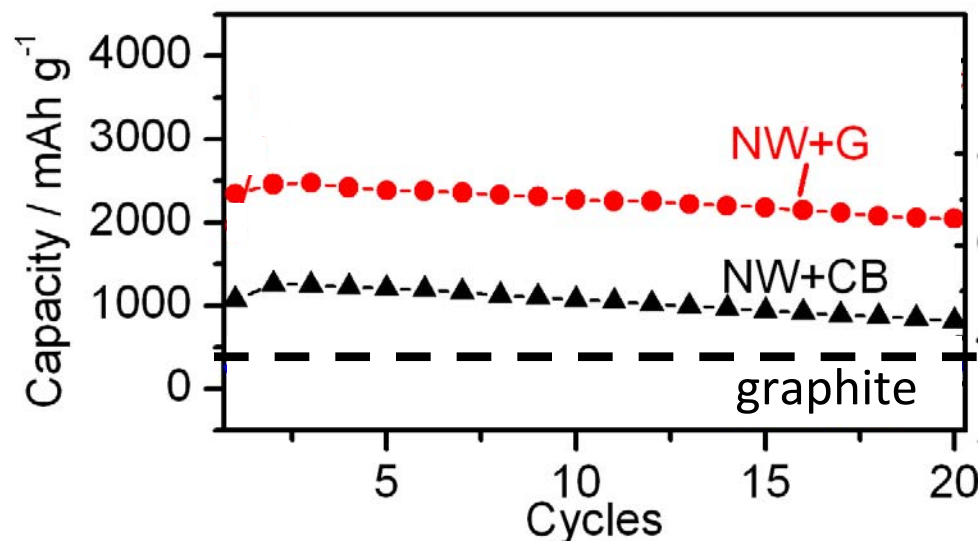
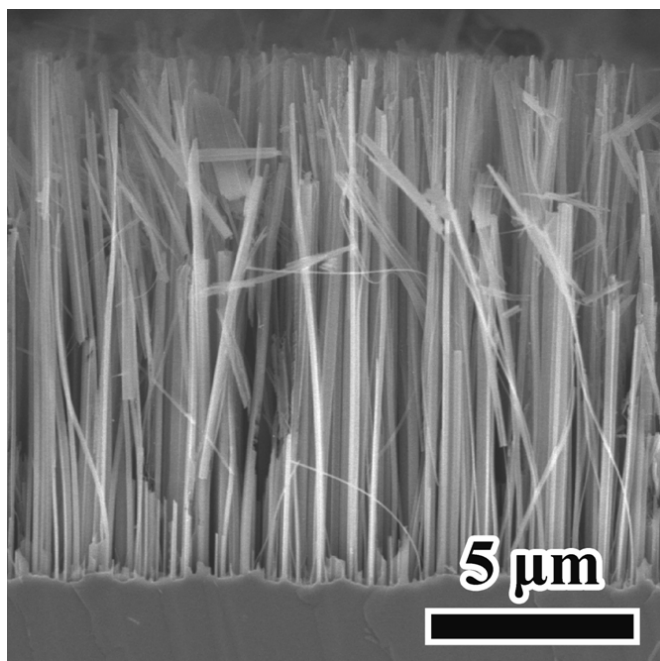


Rechargeable Li-ion Batteries

Oriented porous silicon nanowires at the anode

Good: Si has insertion capacity of up to ~ 4000 mA-h/g (>10 x higher than C)

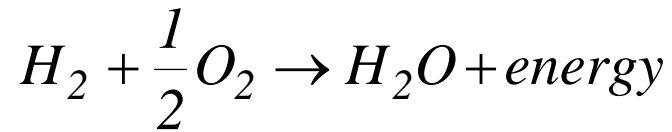
Challenge: How to accommodate >4 x volume increase upon alloying



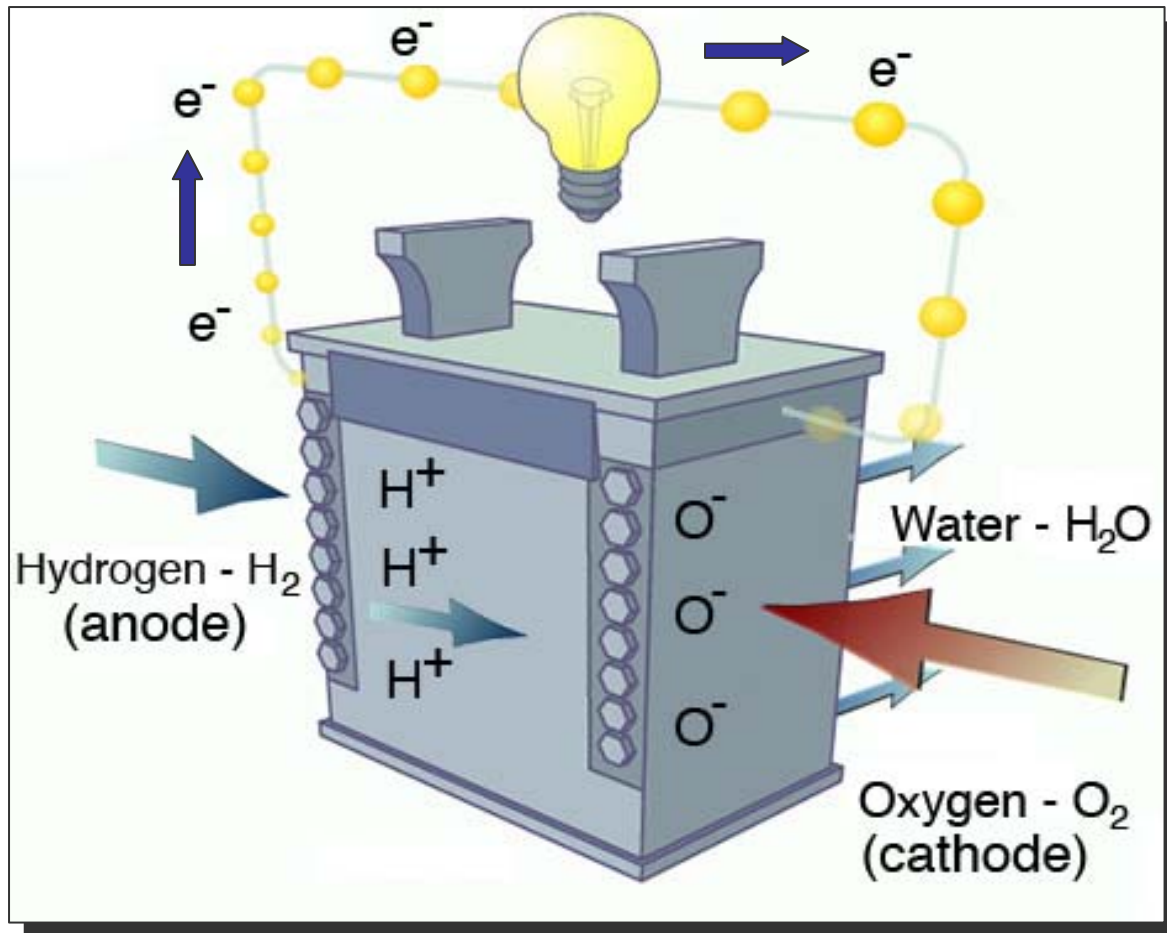
ACS Applied Materials & Interfaces 2 1548, 2010.
Journal of Physical Chemistry C (In press), 2010.



Fuel Cells

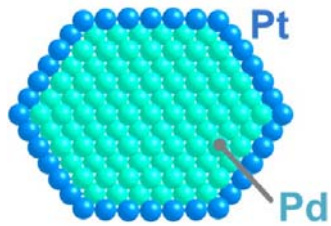


Uses hydrogen and oxygen as fuel.

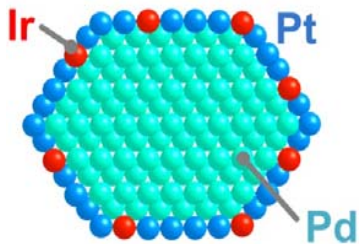


Nanocatalysts for Fuel Cells

Platinum as a nanocatalyst in fuel cells

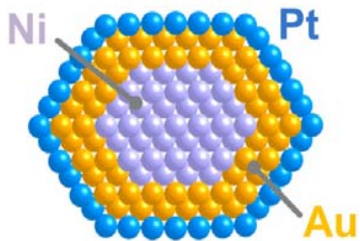


Pt monolayer on Pd nanoparticles



Mixed-metal Pt on Pd nanoparticles

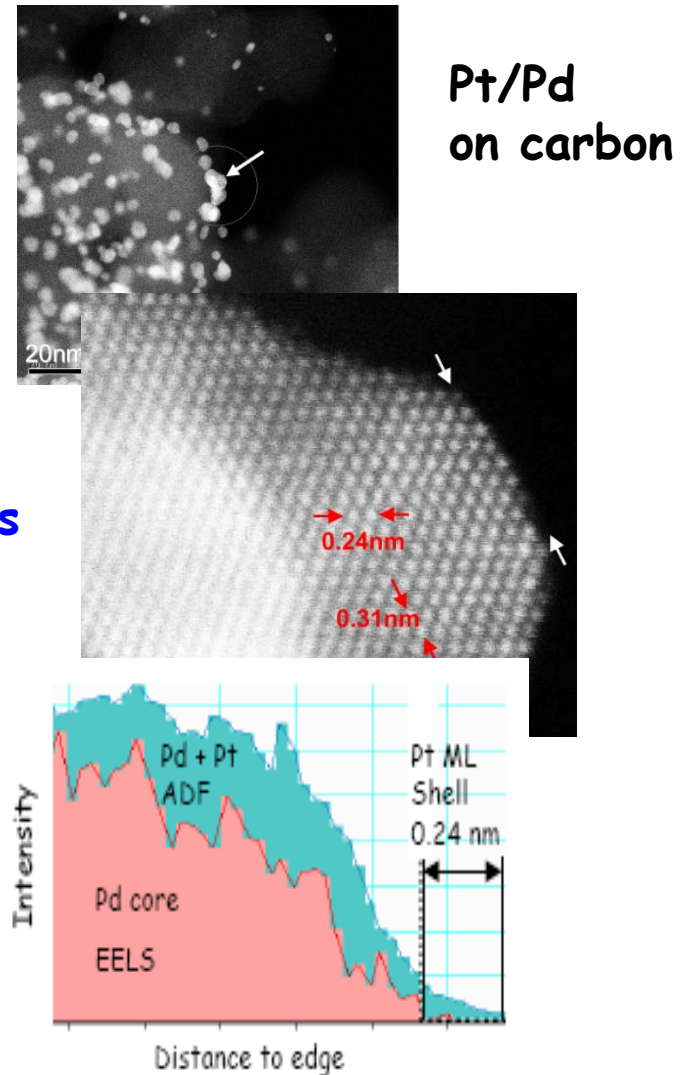
Enhanced activity



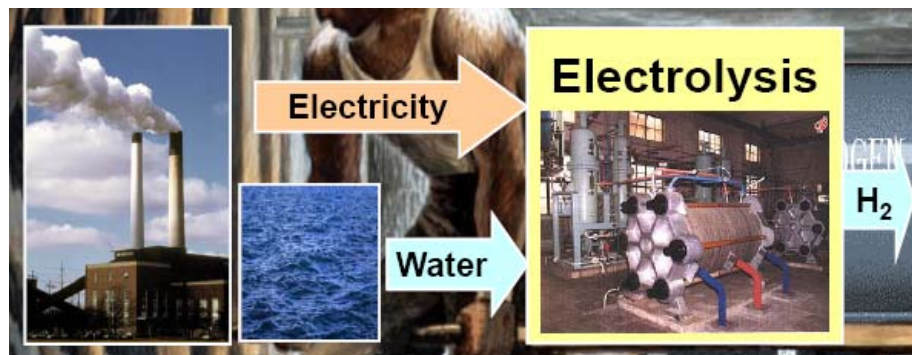
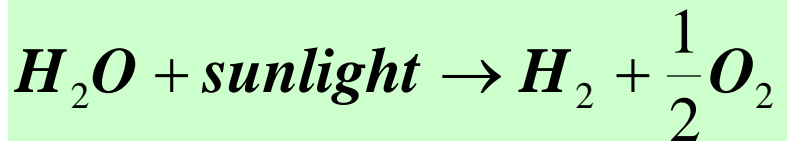
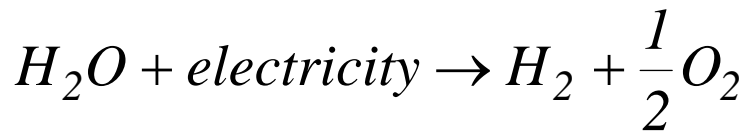
Pt on non-noble metal - noble metal core-shell

Further increase of the Pt mass activity up to 20-fold of Pt/C

[Electrochim. Acta **52**, 2257 (2007)]

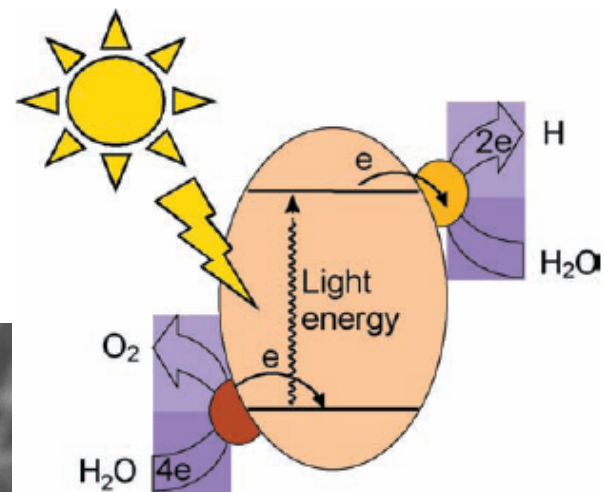
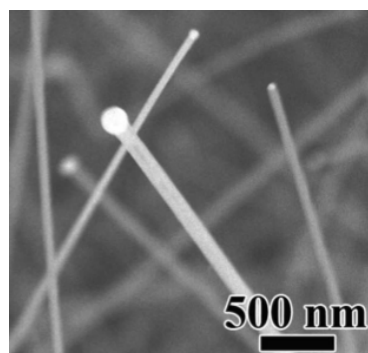
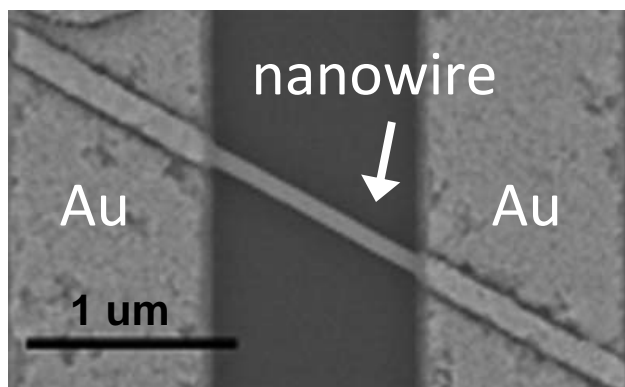


Hydrogen Production



Efficient catalysts needed

(GaN)(ZnO) Nanowires



Appl. Phys. Lett. **96**, 183112 (2010)

Appl. Phys. Lett. **97**, 083108 (2010)

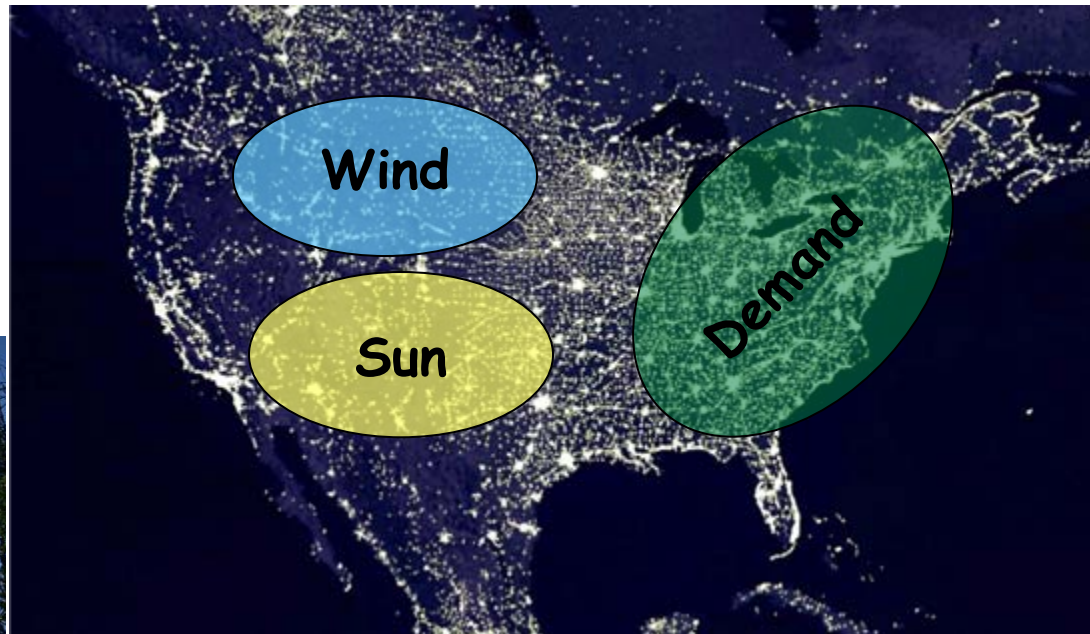
Renewable Energy and its Challenges

A world that works on renewable energy will essentially be an **Electric World**. Renewable sources such as solar and wind energy are very variable, both in time and space.

Main Challenges: Technical and Economic

Storage

Transmission



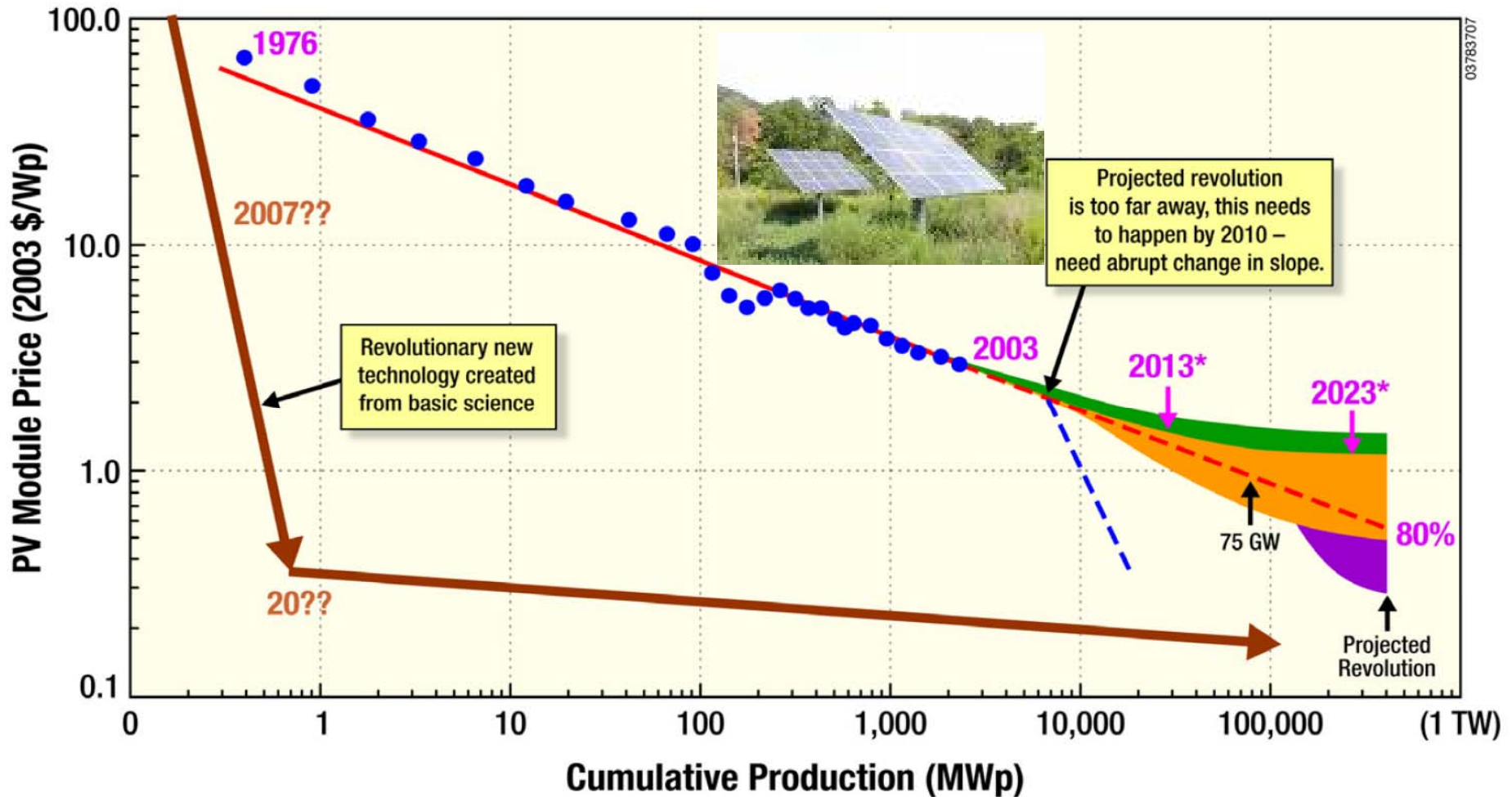
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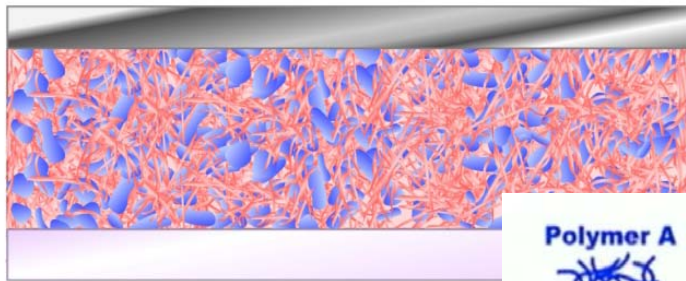
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Cost Evolution of Solar Panels



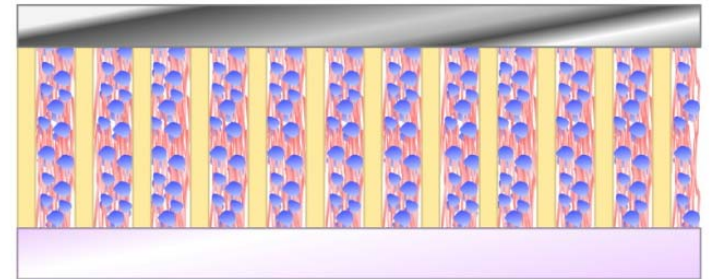
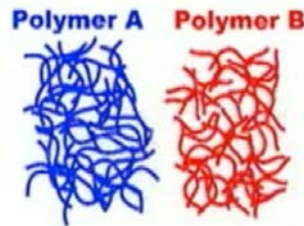
Nanostructured Organic Solar Cells

State of the art: 5% - 7%



Good

Easy to make
Large interfacial area
Short exciton transport distances
Random, non-equilibrium structure



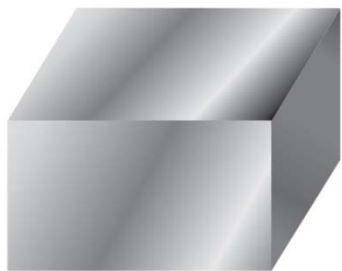
Better?

More control of phase separation
More ordered structure?
Large interfacial area
Short exciton transport distances
Harder to make?

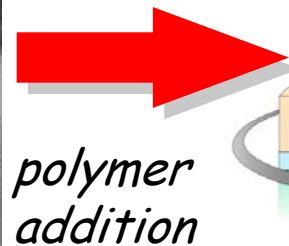
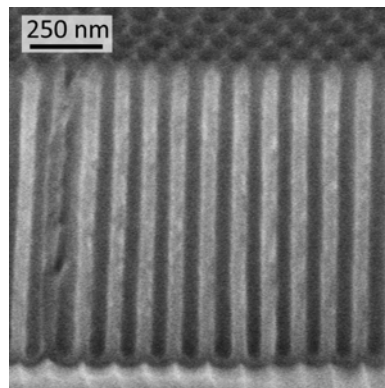


Nanostructured Organic Solar Cells

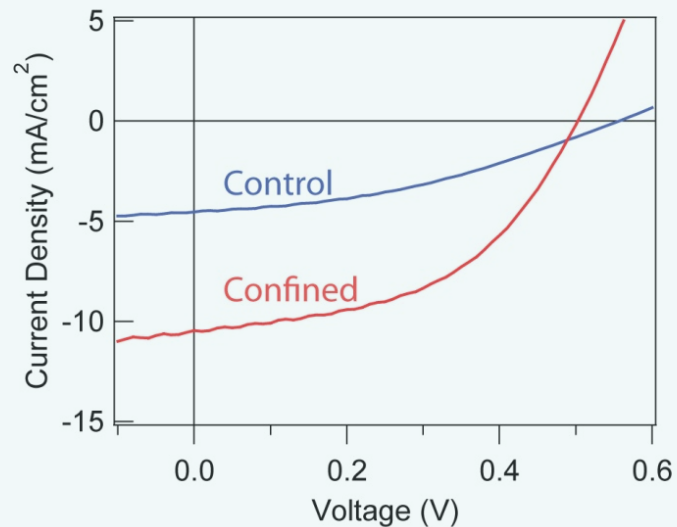
Aluminum



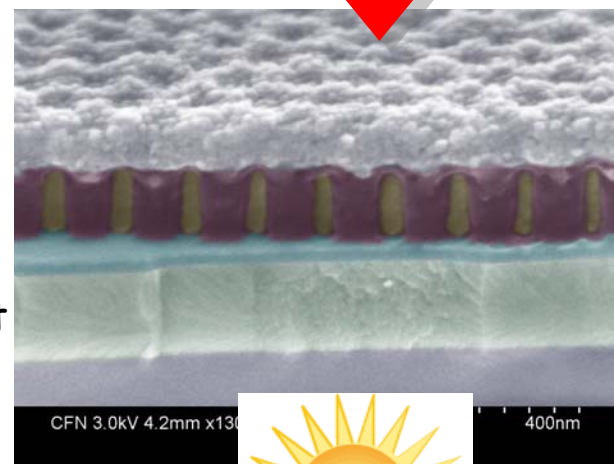
Aluminum Oxide Nanotrenches



Twice the Optical Response
Of Conventional Organic Cells



Top contact (Al)
 Al_2O_3 filled with organic blend
Transparent contact
Glass



Organic Solar Cell



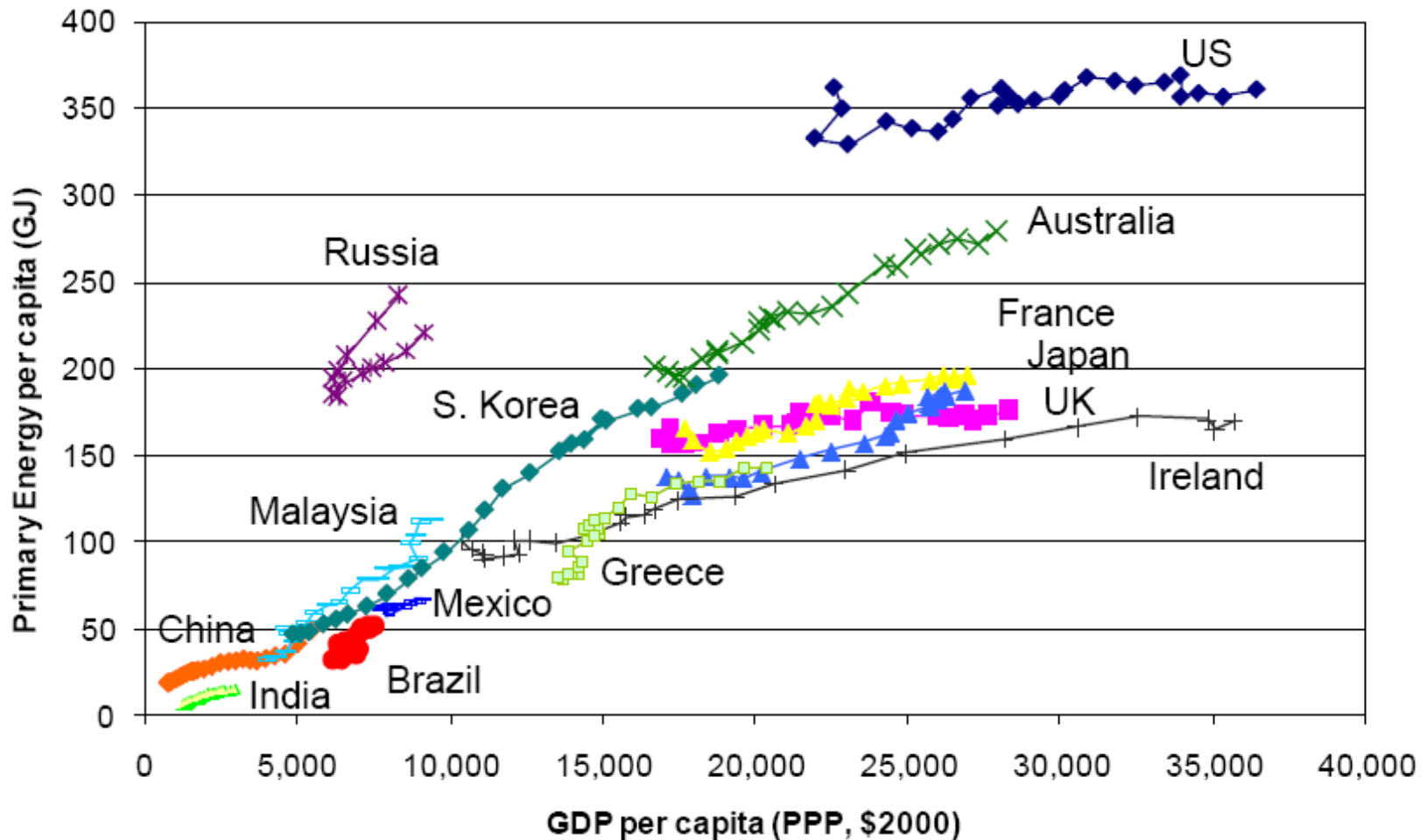
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Energy Usage and Economic Development



A Dilemma,... and its Solution?

Economic Growth or Sustainable Earth?

There is no silver bullet
for this dilemma.



(Nano)technology can do its part.
The rest depends on us:
economists, politicians, and
all CITIZENS