First in a Series
OSTP presents
Hot Topics in Science and Technology

Nanotechnology:
Energizing Our Future

Wednesday, August 10th

10 am – noon

EEOB 476

Web Coverage
http://www.sc.doe.gov/bes/presentations/archives_10AUG05.html

A panel of distinguished speakers will describe for a general audience how nanotechnology could revolutionize our homes, vehicles, and energy sources.

10:00	**Introductory Remarks** Richard Russell, Deputy Director of Technology, OSTP
10:10	**Energy Needs: The Big Picture** Patricia Dehmer, Director, Basic Energy Sciences, Office of Science, DOE
10:30	**Nanotechnology 101** Paul Alivisatos, Lawrence Berkeley National Laboratory
10:50	**Nanotechnology for the Hydrogen Economy** George Crabtree, Argonne National Laboratory
11:10	**Nanotechnology for Solar Energy** Prof. Nathan Lewis, California Institute of Technology
11:30	**Nanotechnology for Solid-State Lighting** Harriet Kung, Director, Materials Sciences Division, Basic Energy Sciences, Office of Science, DOE
11:50	**Wrap-up**

Hors d'oeuvres will be served before and after the event
in the Indian Treaty Room.

BASIC ENERGY SCIENCES –
Serving the Present, Shaping the Future
http://www.science.doe.gov/bes

Some Energy Facts …

… and their implications for R&D needed to assure a secure energy future

OSTP Series
Hot Topics in Science and Technology
Nanotechnology: Energizing Our Future

Patricia M. Dehmer
Director, Office of Basic Energy Sciences
Office of Science, U.S. Department of Energy
10 August 2005

Contents

1. Energy consumption today and through the 21st century
2. Energy flow diagrams for the U.S.
3. Energy reserves
4. Renewable energy today with speculations on the future
5. Energy and the environment
6. A summary “boxology” of energy R&D areas
7. Why nanoscience and nanotechnology?

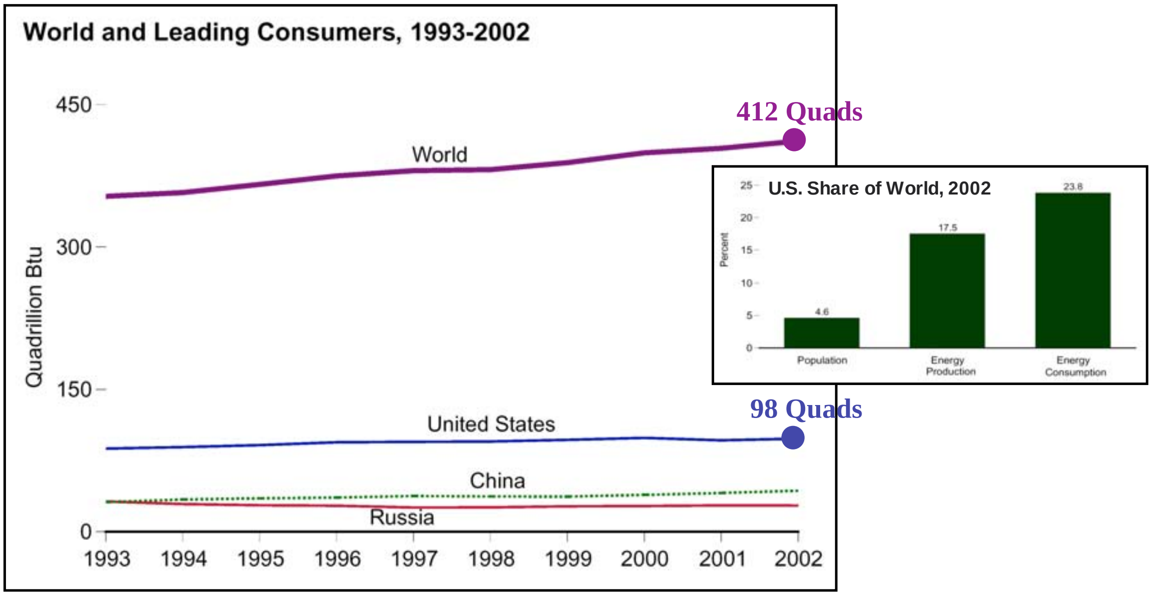
Results 1 - 100 of about 17,400,000

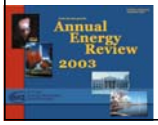
Energy Information Administration
Energy Information Administration (US Dept. of **Energy**) **Energy** Statistics, Data, and Analysis.
www.eia.doe.gov/ - 41k - Cached - Similar pages

References are given in the corner

Notes are provided in the blue boxes.

U.S. and World Energy Consumption Today

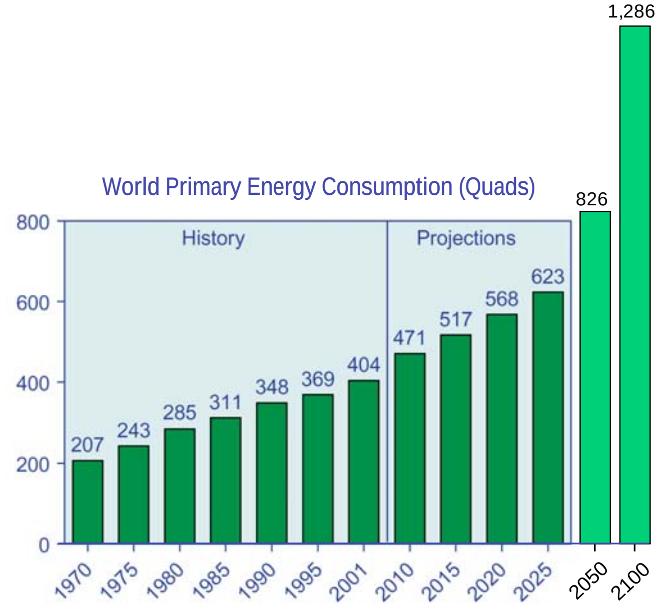




<u>Some equivalent ways of referring to the energy used by the U.S. in 1 year (approx. 100 Quads)</u>

100.0 quadrillion British Thermal Units (Quads)	U.S. & British unit of energy
105.5 exa Joules (EJ)	Metric unit of energy
3.346 terawatt-years (TW-yr)	Metric unit of power (energy/sec)x(#seconds in a year)

Projected World Energy Consumption in the Coming Century

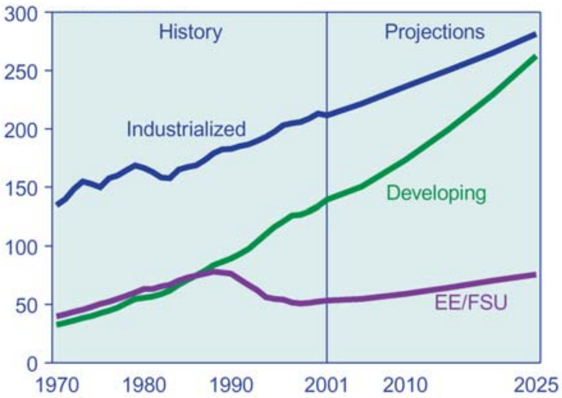


Projections to 2025 are from the Energy Information Administration, International Energy Outlook, 2004.

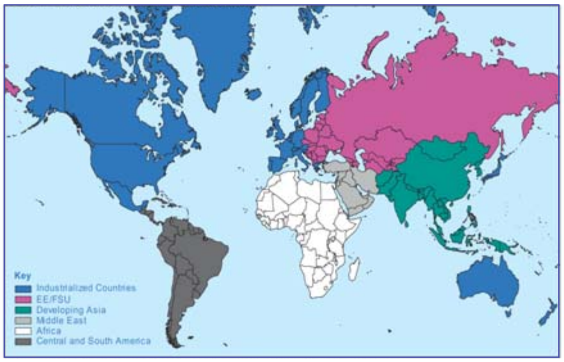
Projections for 2050 and 2100 are based on a scenario from the Intergovernmental Panel on Climate Change (IPCC), an organization jointly established in 1988 by the World Meteorological Organization and the United Nations Environment Programme. The IPCC provides comprehensive assessments of information relevant to human-induced climate change. The scenario chosen is based on "moderate" assumptions (Scenario B2) for population and economic growth and hence is neither overly conservative nor overly aggressive.

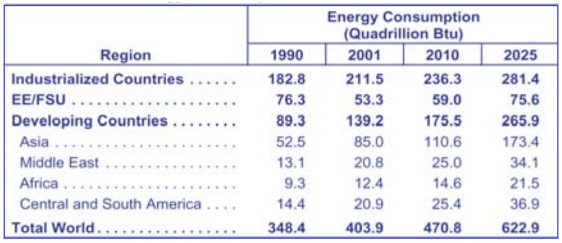
Projected World Energy Consumption by Region

World Energy Consumption by Region (Quads)



World Regions



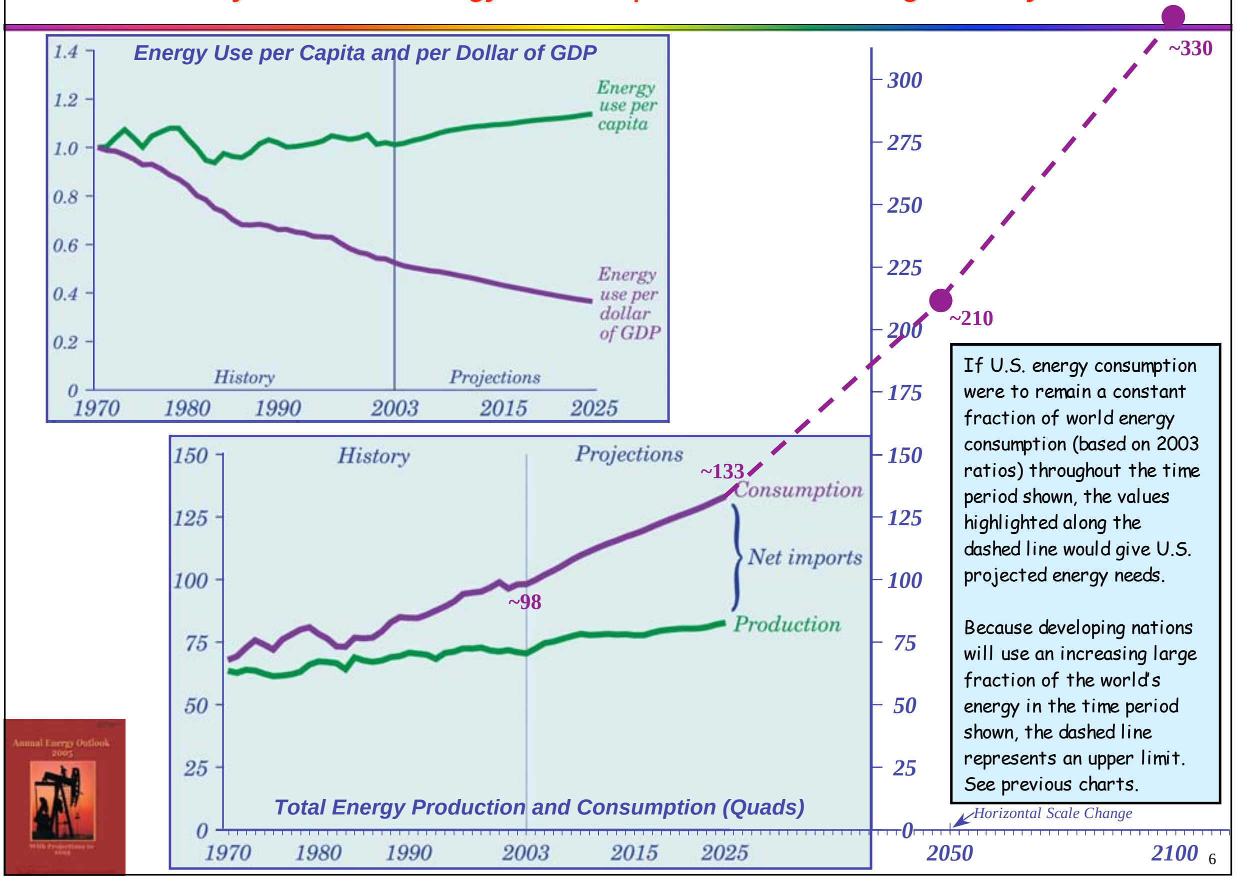


Region	Energy Consumption (Quadrillion Btu)			
	1990	2001	2010	2025
Industrialized Countries	**182.8**	**211.5**	**236.3**	**281.4**
EE/FSU	**76.3**	**53.3**	**59.0**	**75.6**
Developing Countries	**89.3**	**139.2**	**175.5**	**265.9**
Asia	52.5	85.0	110.6	173.4
Middle East	13.1	20.8	25.0	34.1
Africa	9.3	12.4	14.6	21.5
Central and South America	14.4	20.9	25.4	36.9
Total World	**348.4**	**403.9**	**470.8**	**622.9**

International Energy Outlook 2004

Overall, world energy consumption is predicted to increase faster than that of the U.S. and other industrialized countries, because between 2000 and 2025 energy demand in the developing countries nearly doubles.

Projected U.S. Energy Consumption in the Coming Century



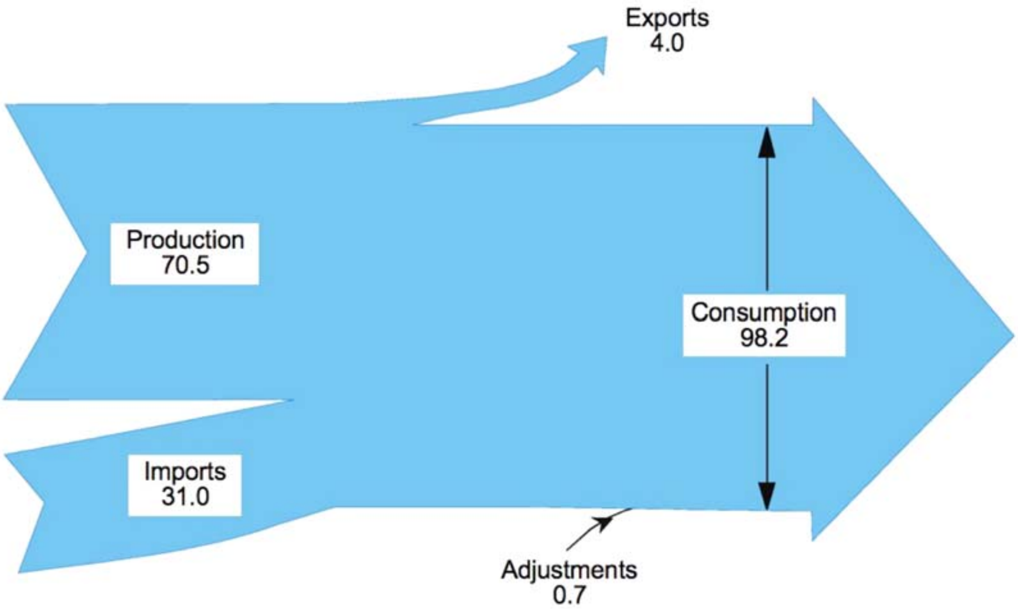
If U.S. energy consumption were to remain a constant fraction of world energy consumption (based on 2003 ratios) throughout the time period shown, the values highlighted along the dashed line would give U.S. projected energy needs.

Because developing nations will use an increasing large fraction of the world's energy in the time period shown, the dashed line represents an upper limit. See previous charts.

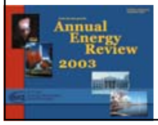
Annual Energy Outlook 2005

U.S. Energy Flow, 2003 (Quads)

Energy Sources

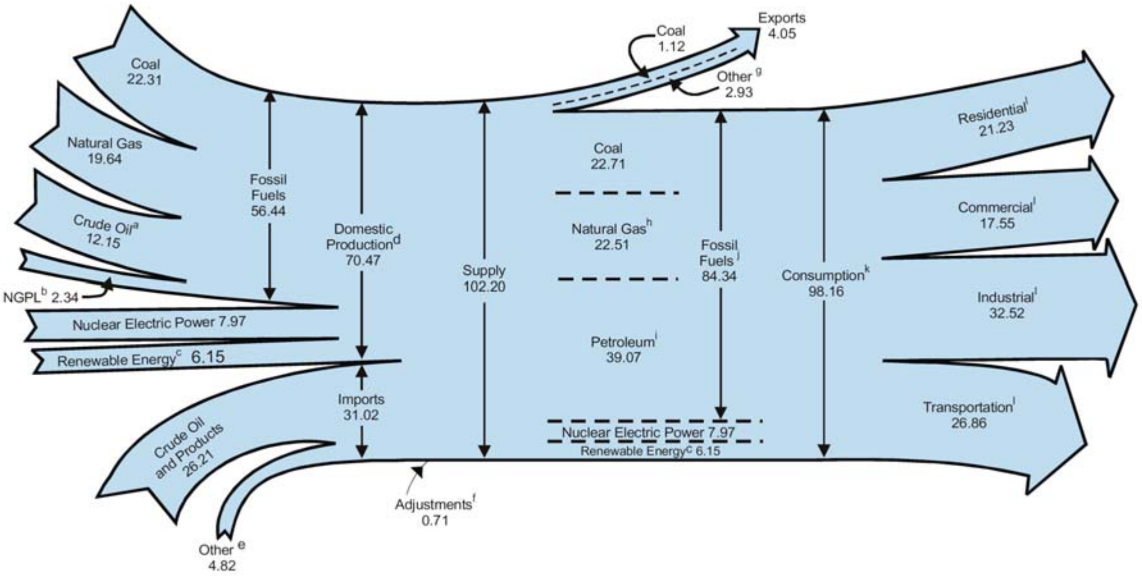


Energy Consumption Sectors

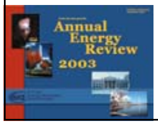


About 30% of primary energy is imported.

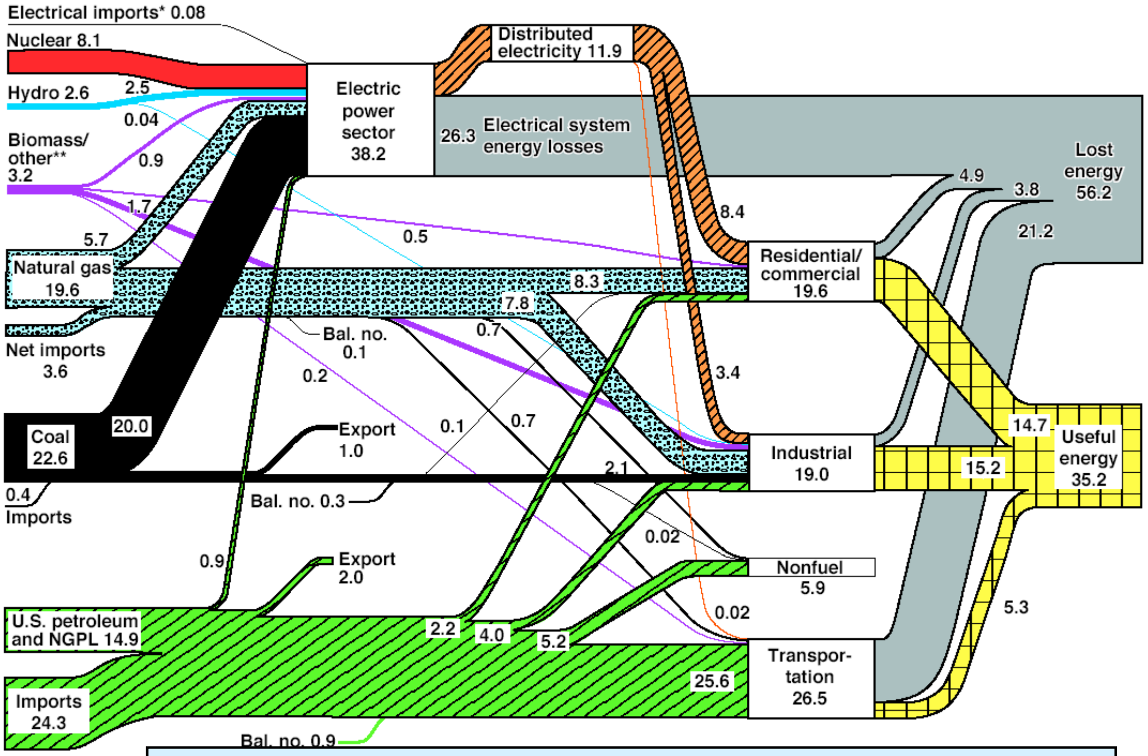
U.S. Energy Flow, 2003 (Quads)



- 85% of primary energy is from fossil fuels; 8% is from nuclear; 6% is from renewables.
- Most imported energy is petroleum, which is used for transportation.
- The end-use sectors (residential, commercial, industrial, transportation) all use comparable amounts of energy.



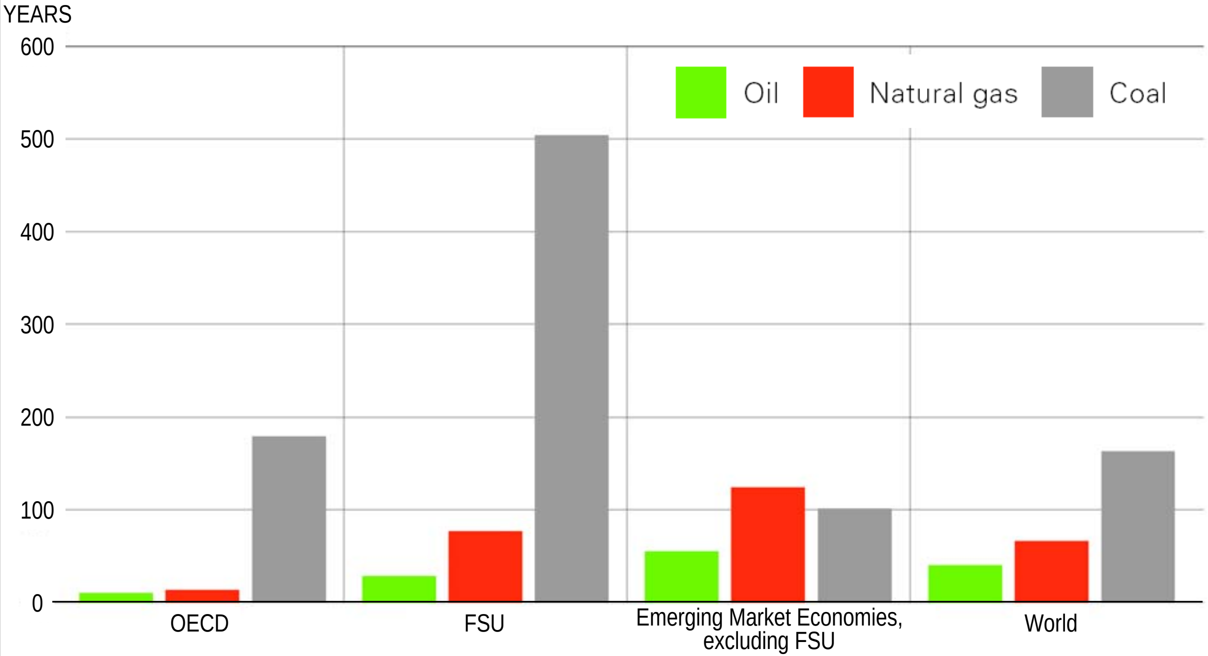
U.S. Energy Flow, 2002 (Quads)



June 2004
Lawrence Livermore National Laboratory
http://eed.llnl.gov/flow

- 39% of primary energy goes toward electricity generation; 69% of that is lost energy.
- 80% of energy used in transportation sector is lost energy.
- Overall, 58% of primary energy is lost energy.

Fossil Fuel Reserves-to-Production (R/P) Ratios at End 2004

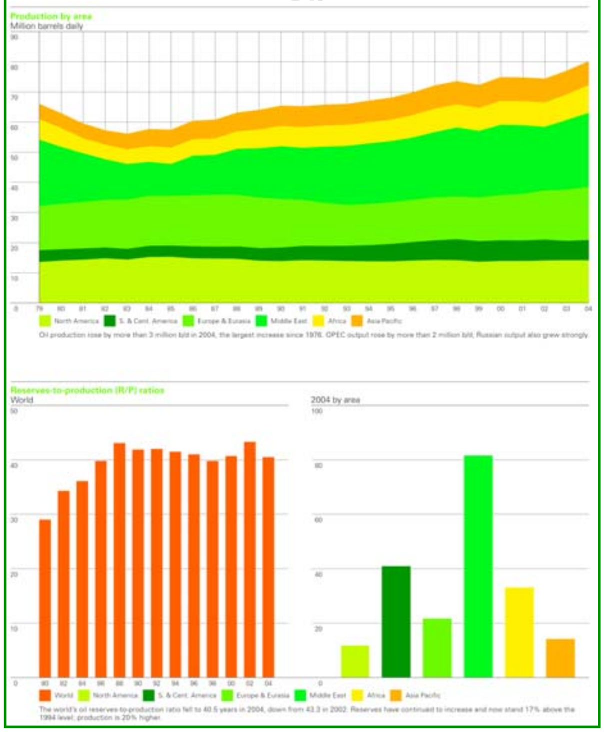


- The world's R/P ratio for coal is almost five times that for oil and almost three times that for gas. Coal's dominance in R/P ratio is particularly pronounced in the OECD and the FSU.
- R/P ratios for oil and gas have been approximately constant or slightly increasing during the past 20 years. Both reserves and production have increased during this period. See next chart.

BP Statistical Review of World Energy 2005

Reserves-to-Production (R/P) Ratios at End 2004

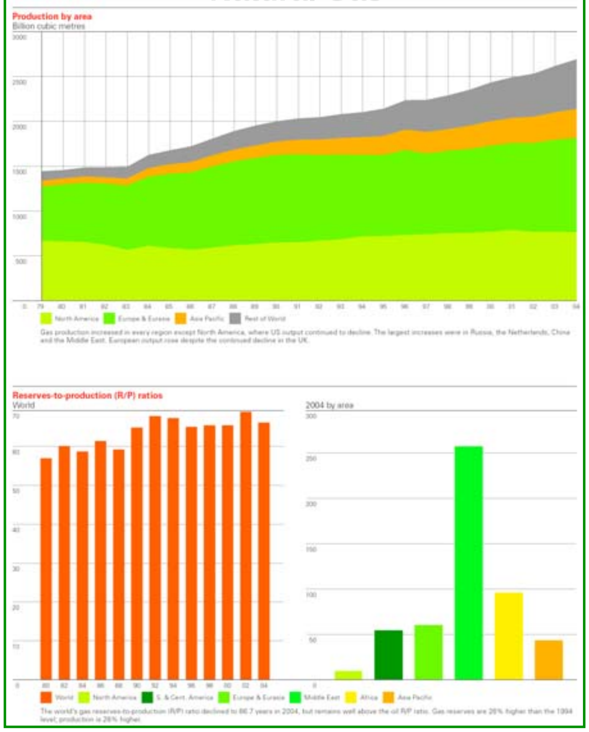
Oil



Oil production rose by more than 3 million b/d in 2004, the largest increase since 1976. OPEC output rose by more than 2 million b/d; Russian output also grew strongly.

The world's oil reserves-to-production ratio fell to 40.5 years in 2004, down from 43.3 in 2002. Reserves have continued to increase and now stand 17% above the 1994 level; production is 20% higher.

Natural Gas



Gas production increased in every region except North America, where US output continued to decline. The largest increases were in Russia, the Netherlands, China and the Middle East. European output rose despite the continued decline in the UK.

The world's gas reserves-to-production (R/P) ratio declined to 66.7 years in 2004, but remains well above the oil R/P ratio. Gas reserves are 26% higher than the 1994 level; production is 26% higher.

BP Statistical Review of World Energy 2005

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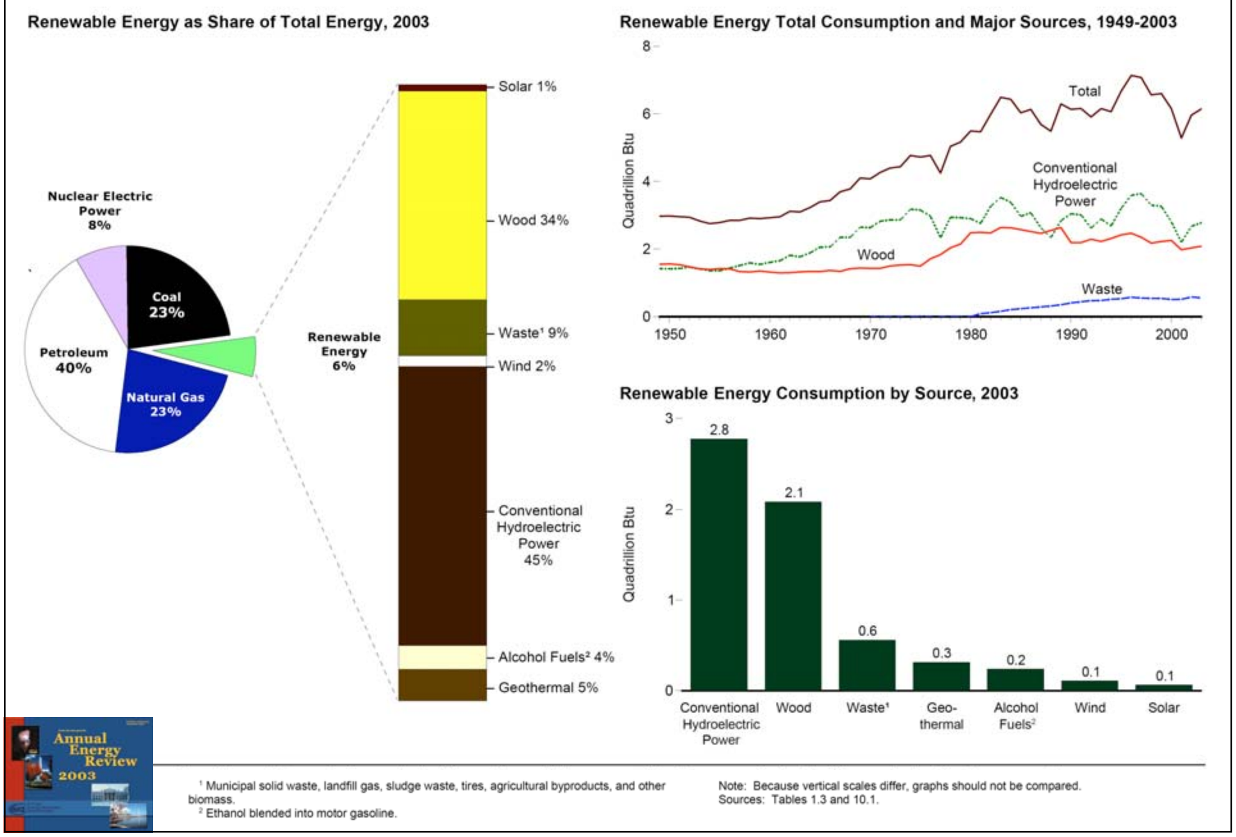
36 Estimates of the Time of the Peak of World Oil Production (There are More)

Published	By	Peak Year/Range	Published	By	Peak Year/Range
1972	ESSO	About 2000	1999	Parker	2040
1972	UN	By 2000	2000	Bartlett	2004 or 2019
1974	Hubbert	1991-2000	2000	Duncan	2006
1976	UKDOE	About 2000	2000	EIA	2021-2167; 2037 most likely
1977	Hubbert	1996	2000	IEA (WEO)	Beyond 2020
1977	Ehrlich, et al.	2000	2001	Deffeyes	2003-2008
1979	Shell	Plateau by 2004	2001	Goodstein	2007
1981	World Bank	Plateau around 2000	2002	Smith	2010-2016
1985	Bookout	2020	2002	Campbell	2010
1989	Campbell	1989	2002	Cavallo	2025-2028
1994	Ivanhoe	OPEC Plateau 2000-2050	2003	Greene, et al.	2020-2050
1995	Petroconsultants	2005	2003	Laherrère	2010-2020
1997	Ivanhoe	2010	2003	Lynch	No visible peak
1997	Edwards	2020	2003	Shell	After 2025
1998	IEA (WEO)	2014	2003	Simmons	2007-2009
1998	Campbell/Laherrère	2004	2004	Bakhitari	2006-2007
1999	Campbell	2010	2004	CERA	After 2020
1999	Odell	2060	2004	PFC Energy	2015-2020

EIA's short answer to "When will oil production peak?" is "Not soon, but within the present century." The most probable scenarios put the peak at about mid century.

Energy Information Administration

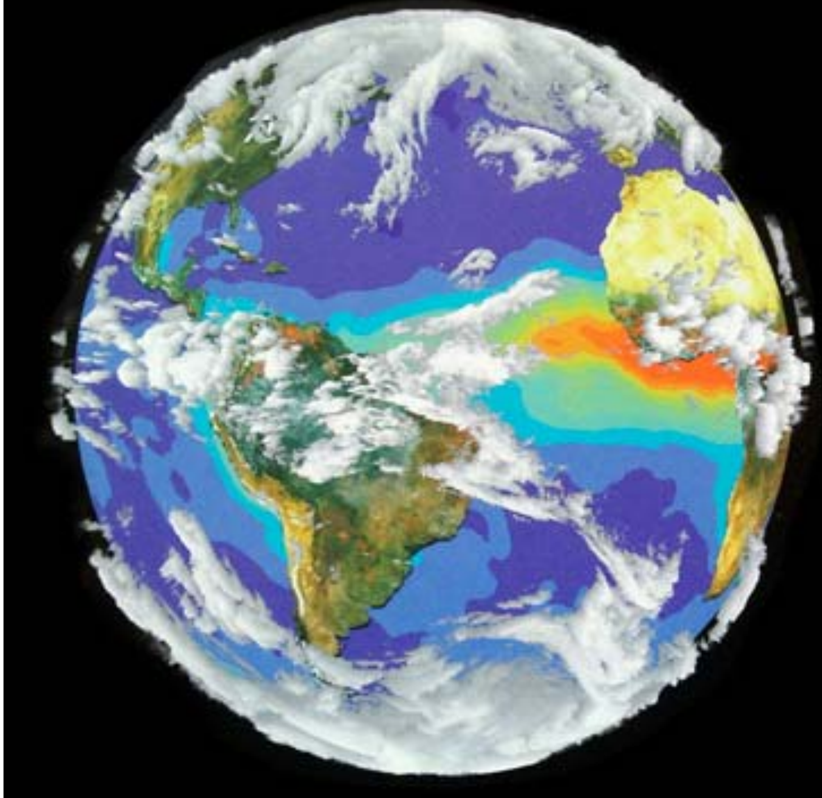
Renewable Energy Consumption by Major Sources



[1] Municipal solid waste, landfill gas, sludge waste, tires, agricultural byproducts, and other biomass.

[2] Ethanol blended into motor gasoline.

Note: Because vertical scales differ, graphs should not be compared.
Sources: Tables 1.3 and 10.1.



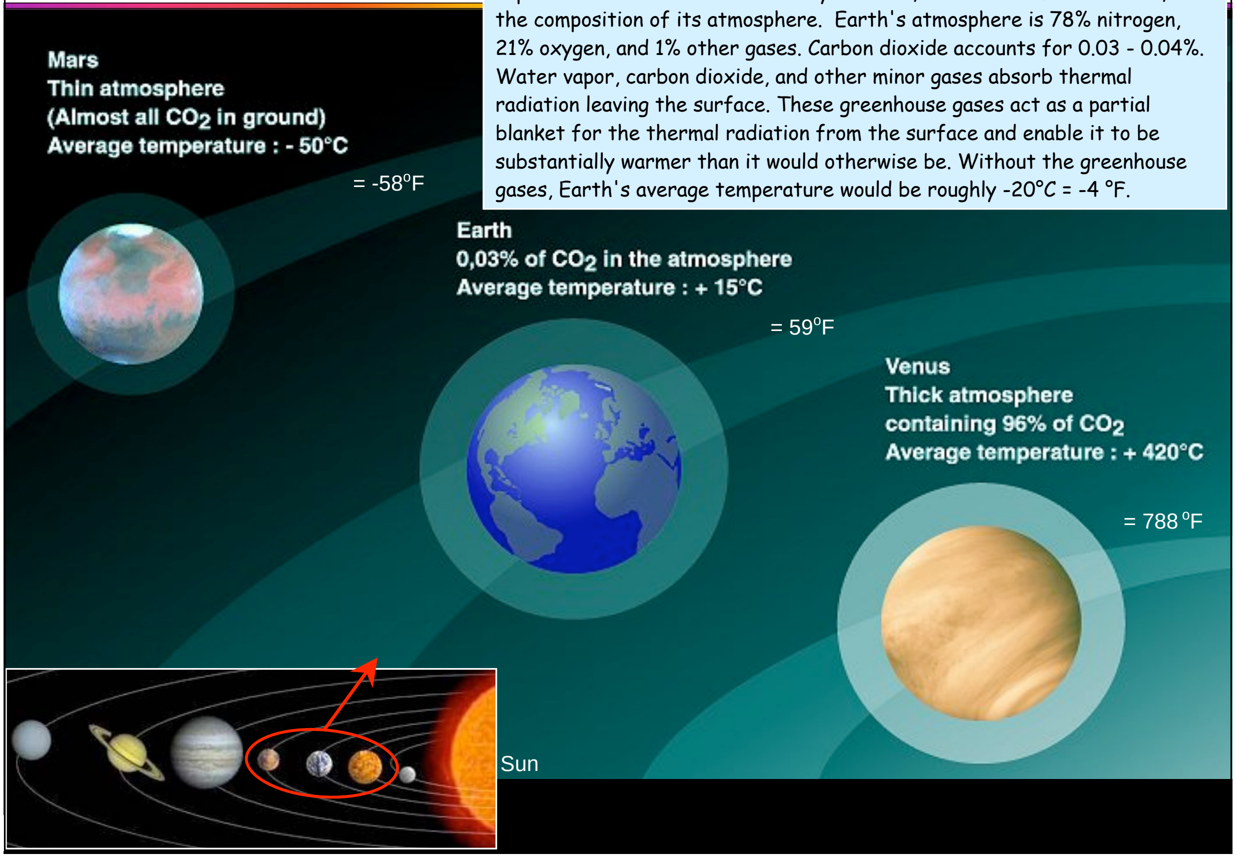
How do the Earth's land, water, air, and life interact to affect the environment?

This Earth image is a compilation of data from several different satellites that remotely sense vegetation, clouds, fires, and aerosols.

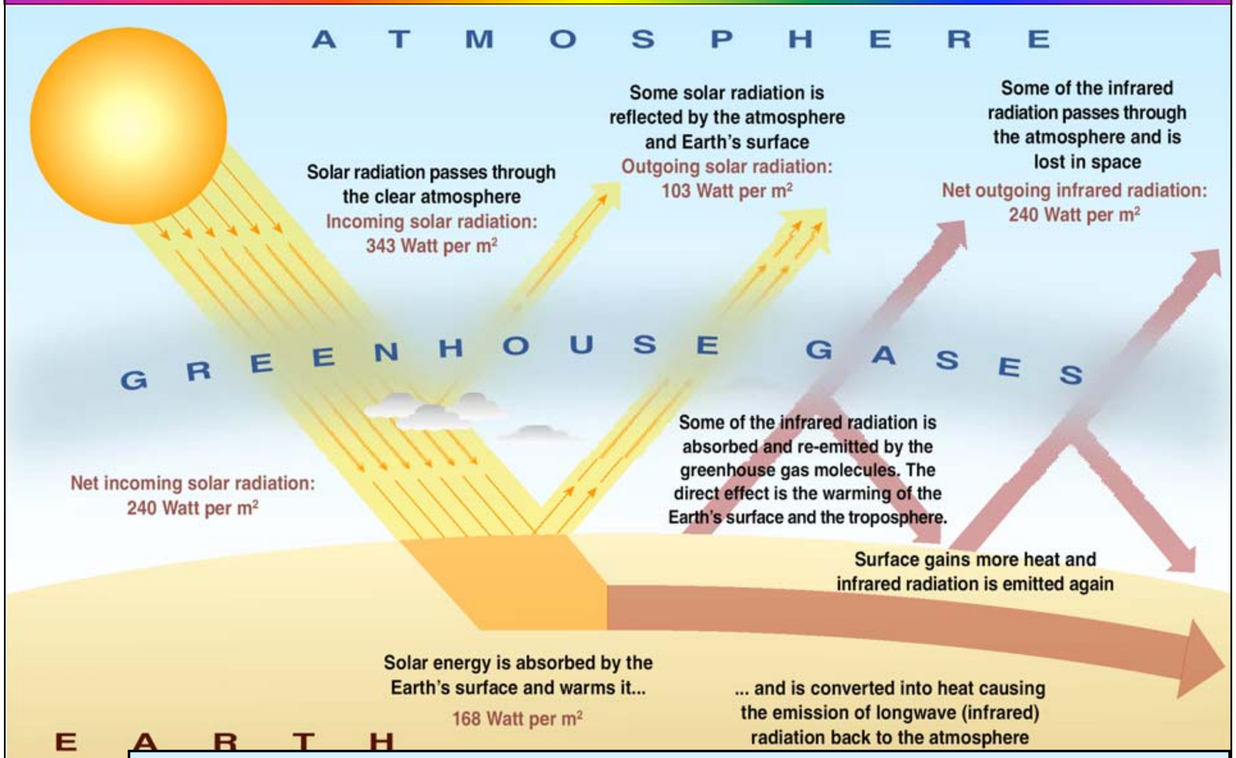
Image Source: NASA, Earth Science Enterprise, *Understanding Our Changing Planet*
URL: http://departments.weber.edu/sciencecenter/nasa/lithographs/lit26.jpg

Planets, Atmospheres, and Climate

A planet's climate is determined by its mass, its distance from the sun, and the composition of its atmosphere. Earth's atmosphere is 78% nitrogen, 21% oxygen, and 1% other gases. Carbon dioxide accounts for 0.03 - 0.04%. Water vapor, carbon dioxide, and other minor gases absorb thermal radiation leaving the surface. These greenhouse gases act as a partial blanket for the thermal radiation from the surface and enable it to be substantially warmer than it would otherwise be. Without the greenhouse gases, Earth's average temperature would be roughly -20°C = -4 °F.

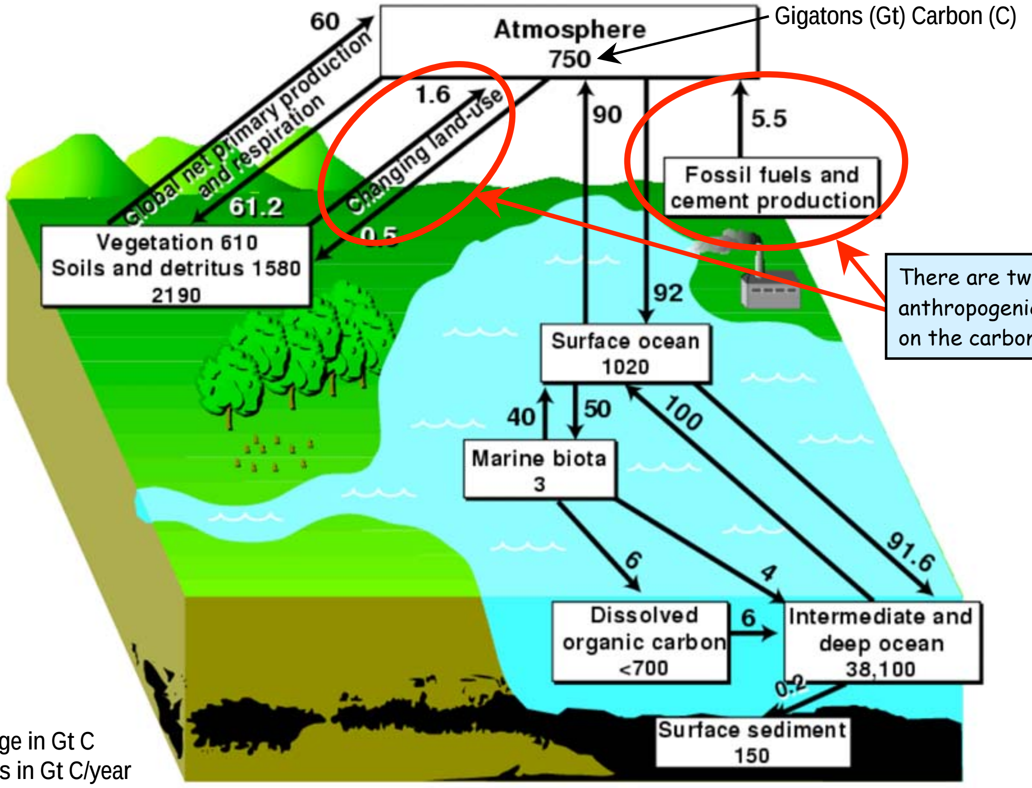


The Greenhouse Effect



Human actions – burning fossil fuels and land clearing – are increasing the concentrations of greenhouse gases. This is known as the enhanced greenhouse effect. Naturally occurring greenhouse gases include water vapor, carbon dioxide, methane, nitrous oxide, and ozone. Greenhouse gases that are not naturally occurring include hydro-fluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6), which are generated in a variety of industrial processes.

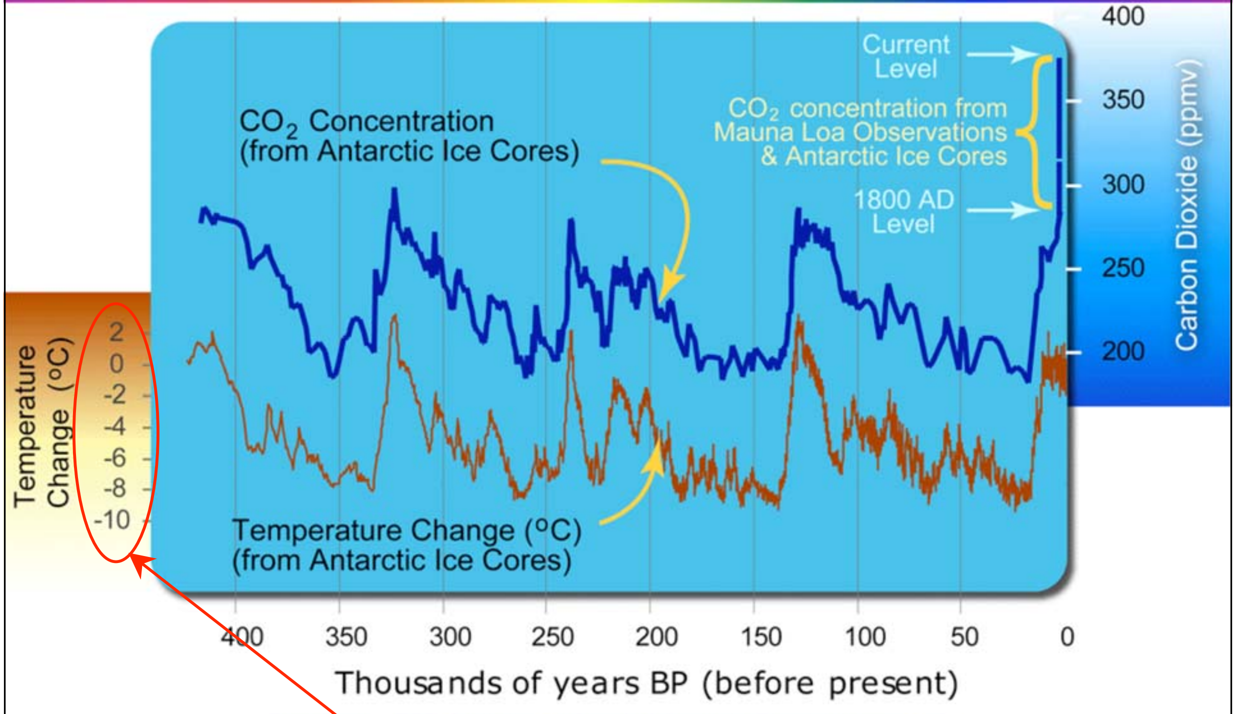
The Earth's Carbon Cycle



There are two primary anthropogenic effects on the carbon cycle.

Storage in Gt C
Fluxes in Gt C/year
1 Gton = 10^9 tons

CO$_2$ Concentrations and Temperature Change

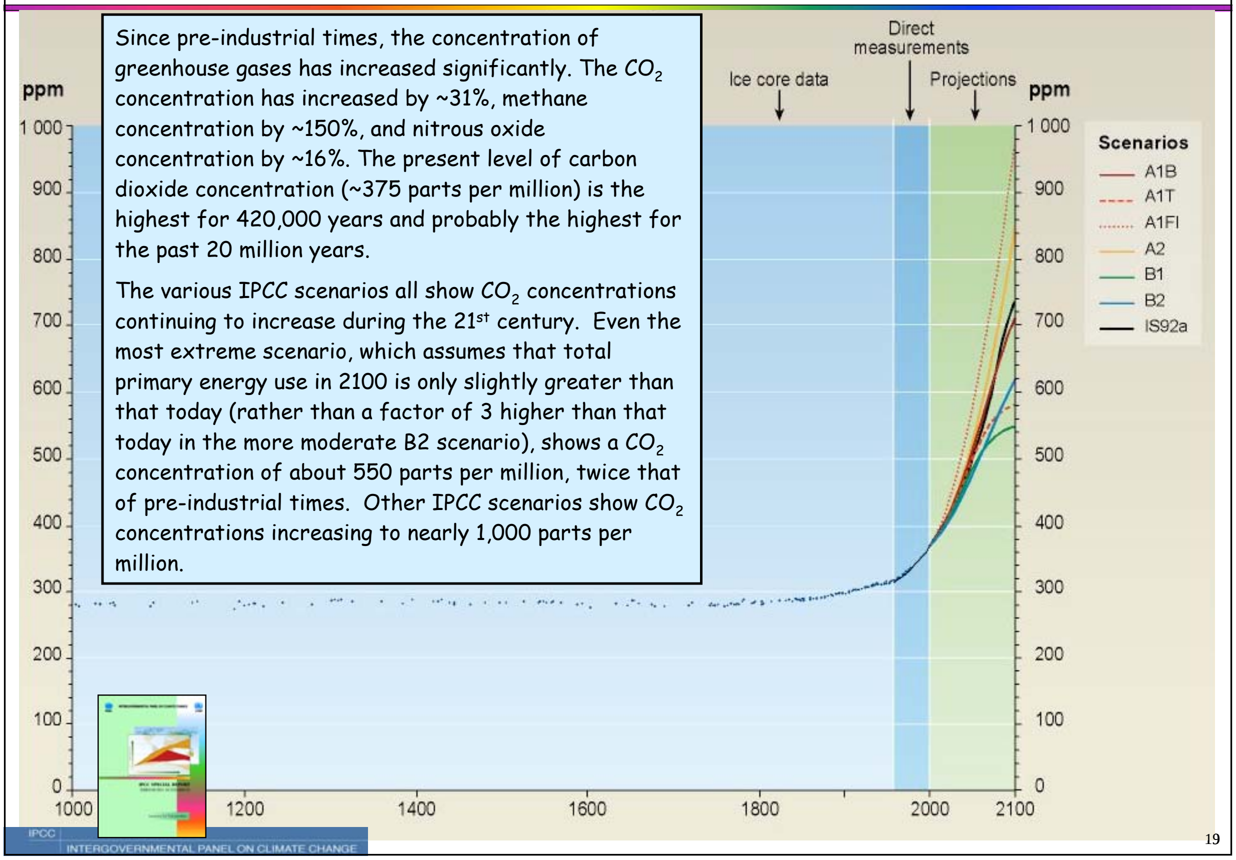


Data Source CO2: ftp://cdiac.ornl.gov/pub/trends/co2/vostok.icecore.co2
Data Source Temp: http://cdiac.esd.ornl.gov/ftp/trends/temp/vostok/vostok.1999.temp.dat

Note that total temperature change across several ice ages was only about 12°C or about 22°F.

The Woods Hole Research Center

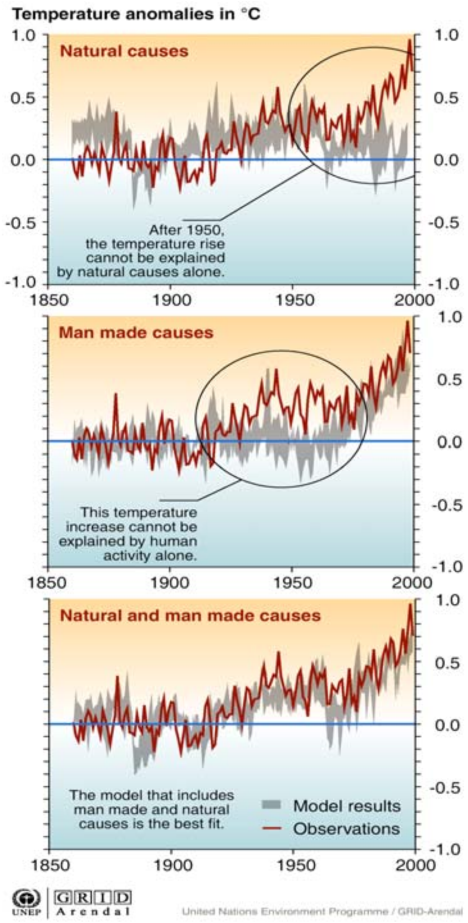
Past and Future CO_2 Atmospheric Concentrations for Various IPCC Scenarios



Since pre-industrial times, the concentration of greenhouse gases has increased significantly. The CO_2 concentration has increased by ~31%, methane concentration by ~150%, and nitrous oxide concentration by ~16%. The present level of carbon dioxide concentration (~375 parts per million) is the highest for 420,000 years and probably the highest for the past 20 million years.

The various IPCC scenarios all show CO_2 concentrations continuing to increase during the 21st century. Even the most extreme scenario, which assumes that total primary energy use in 2100 is only slightly greater than that today (rather than a factor of 3 higher than that today in the more moderate B2 scenario), shows a CO_2 concentration of about 550 parts per million, twice that of pre-industrial times. Other IPCC scenarios show CO_2 concentrations increasing to nearly 1,000 parts per million.

Climate Models, CO_2 Concentrations, and Temperature Change for Past Data



- Recorded global temperature change can be compared with computer models that predict temperature change under different "forcing" scenarios, (with "forcings" signifying external influences on the solar radiative budget of the planet - greenhouse gases, aerosols, increased solar radiation, and other agents). The charts compare observed temperature anomalies from the historic mean (red line) with the results of computer models that attempt to predict temperature based on the interactions of other environmental influences (gray line).

- The top two charts illustrate that models using natural and anthropogenic influences alone [Natural causes & Man-made causes] fail to match the observed record of temperature anomalies since 1866. But the combination of natural and anthropogenic models [Natural and man-made causes] produces a close match to the measured data. This is seen as a clear "thumbprint" of human impacts on climate change.

- Based on results such as these, the Intergovernmental Panel on Climate Change (IPCC) 2001 report stated that "concentrations of atmospheric greenhouse gases and their radiative forcing have continued to increase as a result of human activities."

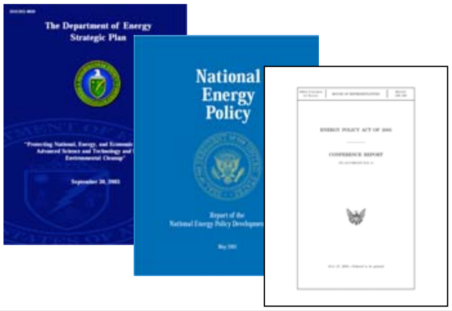
Research for a Secure Energy Future

Supply, Distribution, Consumption, and Carbon Management,

Decision Science and Complex Systems Science

- Carbon Energy Sources
  - Coal
  - Petroleum
  - Natural Gas
  - Oil shale, tar sands, hydrates,...
- Carbon Management
  - CO_2 Sequestration
    - Geologic
    - Terrestrial
    - Oceanic
  - Carbon Recycle
  - Global Climate Change Science
- No-net-carbon Energy Sources
  - Nuclear Fission
  - Nuclear Fusion
  - Renewables
    - Hydropower
    - Biomass
    - Geothermal
    - Wind
    - Solar
    - Ocean
- Distribution/Storage
  - Electric Grid
  - Electric Storage
  - Hydrogen
- Energy Consumption
  - Transportation
  - Buildings
  - Industry

Energy Conservation, Energy Efficiency, and Environmental Stewardship


The Department of Energy Strategic Plan

September 30, 2003

National Energy Policy

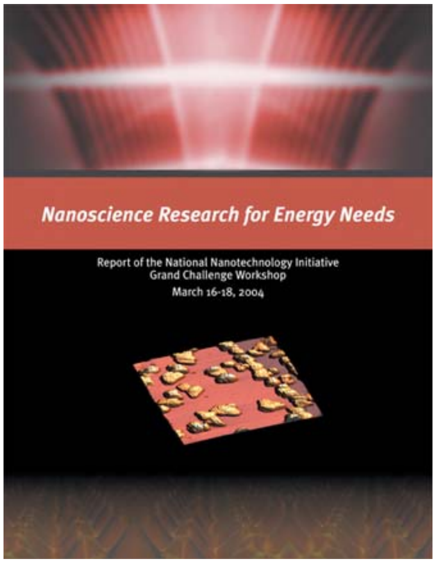
Report of the National Energy Policy Development

ENERGY POLICY ACT OF 2005

CONFERENCE REPORT

Nanoscience Research for Energy Needs

> "All the elementary steps of energy conversion (charge transfer, molecular rearrangement, chemical reactions, etc.) take place on the nanoscale. Thus, the development of new nanoscale materials, as well as the methods to characterize, manipulate and assemble them, creates an entirely new paradigm for developing new and revolutionary energy technologies."


Nanoscience Research for Energy Needs

Report of the National Nanotechnology Initiative
Grand Challenge Workshop
March 16-18, 2004

- The workshop identified nine key areas of energy technology in which nanoscience is expected to have a substantial impact:
  - Scalable methods to split water with sunlight for hydrogen production
  - Reversible hydrogen storage materials operating at ambient temperatures
  - Harvesting of solar energy with 20 percent power efficiency and 100 times lower cost
  - Solid-state lighting at 50 percent of the present power consumption
  - Highly selective catalysts for clean and energy-efficient manufacturing
  - Super-strong light-weight materials to improve efficiency of cars, airplanes, etc.
  - Power transmission lines capable of 1 gigawatt transmission
  - Low-cost fuel cells, batteries, thermoelectrics, and ultra-capacitors built from nanostructured materials
  - Materials synthesis and energy harvesting based on the efficient and selective mechanisms of biology
- The strategy for achieving these targets lies in growing R&D efforts in six areas:
  - Catalysis by nanoscale materials
  - Using interfaces to manipulate energy carriers
  - Linking structure and function at the nanoscale
  - Assembly and architecture of nanoscale structures
  - Theory, modeling, and simulation for energy nanoscience
  - Scalable synthesis methods

A Series of Workshops to Understand Basic Research Needs for Energy

Basic Research Needs to Assure a Secure Energy Future
Basic Energy Sciences Advisory Committee Workshop
October 21-25, 2002
The foundation workshop that set the model for the focused workshops that follow.

Basic Research Needs for the Hydrogen Economy
Basic Energy Sciences Workshop
May 13-15, 2003
Led to BES solicitation in FY 2005 that awarded $21M in new funding as part of the President's Hydrogen Fuel Initiative.

Basic Research Needs for Solar Energy Utilization
Basic Energy Sciences Workshop
April 18-21, 2005
Heavily attended workshop (>200) with very enthusiastic participation in breakout sessions. Report published in July 2005.

- Each focused workshop seeks to define the basic research needed to overcome both short-term technology showstoppers and long-term scientific grand challenges.
- Future workshops will examine basic research needs for advanced nuclear reactors including advanced fuel cycles, solid-state lighting, superconductivity, and more.

ADDITIONAL REFERENCE MATERIALS

Prefixes and Names for Large and Small Numbers

Metric Prefix	Metric Symbol	Common Name (American and modern British "short scale")	Decimal Equivalent	Expo-nential
		google[1]		10^{100}
yotta	Y	septillion	1,000,000,000,000,000,000,000,000	10^{24}
zetta	Z	sextillion	1,000,000,000,000,000,000,000	10^{21}
exa	E	quintillion	1,000,000,000,000,000,000	10^{18}
peta	P	quadrillion	1,000,000,000,000,000	10^{15}
tera	T	trillion	1,000,000,000,000	10^{12}
giga	G	billion	1,000,000,000	10^{9}
mega	M	million	1,000,000	10^{6}
kilo	k	thousand	1,000	10^{3}
hecto	h	hundred	100	10^{2}
deca	da	ten	10	10^{1}
no prefix		one	1	10^{0}
deci	d	tenth	0.1	10^{-1}
centi	c	hundredth	0.01	10^{-2}
milli	m	thousandth	0.001	10^{-3}
micro	µ	millionth	0.000001	10^{-6}
nano	n	billionth	0.000000001	10^{-9}
pico	p	trillionth	0.000000000001	10^{-12}
femto	f	quadrillionth	0.000000000000001	10^{-15}
atto	a	quintillionth	0.000000000000000001	10^{-18}
zepto	z	sextillionth	0.000000000000000000001	10^{-21}
yocto	y	septillionth	0.000000000000000000000001	10^{-24}

[1] Invented more for fun than for use, the googol lies outside the regular naming systems.

Some Useful Conversion Factors

Approximate conversion factors

Crude oil*

From	To tonnes (metric)	kilolitres	barrels	US gallons	tonnes/ year
	Multiply by				
Tonnes (metric)	1	1.165	7.33	307.86	–
Kilolitres	0.8581	1	6.2898	264.17	–
Barrels	0.1364	0.159	1	42	–
US gallons	0.00325	0.0038	0.0238	1	–
Barrels/day	–	–	–	–	49.8

*Based on worldwide average gravity.

Products

	To convert barrels to tonnes	tonnes to barrels	kilolitres to tonnes	tonnes to kilolitres
	Multiply by			
LPG	0.086	11.6	0.542	1.844
Gasoline	0.118	8.5	0.740	1.351
Kerosene	0.128	7.8	0.806	1.240
Gas oil/diesel	0.133	7.5	0.839	1.192
Fuel oil	0.149	6.7	0.939	1.065

Natural gas and LNG

From	To billion cubic metres NG	billion cubic feet NG	million tonnes oil equivalent	million tonnes LNG	trillion British thermal units	million barrels oil equivalent
	Multiply by					
1 billion cubic metres NG	1	35.3	0.90	0.73	36	6.29
1 billion cubic feet NG	0.028	1	0.026	0.021	1.03	0.18
1 million tonnes oil equivalent	1.111	39.2	1	0.805	40.4	7.33
1 million tonnes LNG	1.38	48.7	1.23	1	52.0	8.68
1 trillion British thermal units	0.028	0.98	0.025	0.02	1	0.17
1 million barrels oil equivalent	0.16	5.61	0.14	0.12	5.8	1

Units

1 metric tonne = 2204.62 lb
= 1.1023 short tons
1 kilolitre = 6.2898 barrels
1 kilolitre = 1 cubic metre
1 kilocalorie (kcal) = 4.187 kJ = 3.968 Btu
1 kilojoule (kJ) = 0.239 kcal = 0.948 Btu
1 British thermal unit (Btu) = 0.252 kcal
= 1.055 kJ
1 quadrillion British thermal units (Btus)
= 1 Quad = 1.055 exa Joules (EJ)
= 0.03346 terawatt-year (TW-year)

1 kilowatt-hour (kWh) = 860 kcal
= 3600 kJ = 3412 Btu

Calorific equivalents

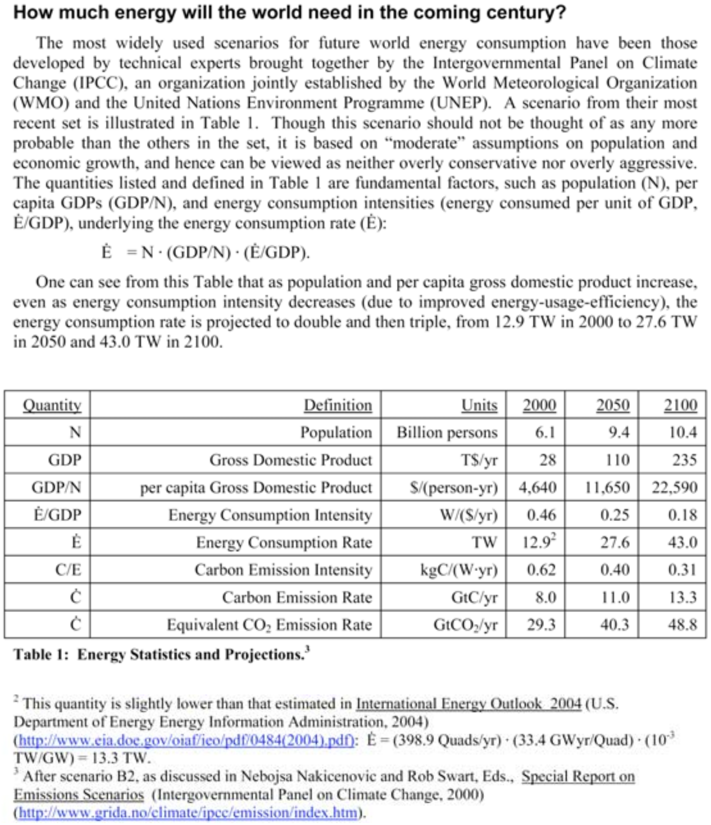
One tonne of oil equivalent equals approximately:

Heat units	10 million kilocalories 42 gigajoules 40 million Btu
Solid fuels	1.5 tonnes of hard coal 3 tonnes of lignite
Gaseous fuels	see natural gas and LNG table
Electricity	12 megawatt-hours

One million tonnes of oil produces about 4500 gigawatt-hours (= 4.5 terawatt-hours) of electricity in a modern power station.

BP Statistical Review of World Energy 2005

Projected World Energy Consumption in the Coming Century



How much energy will the world need in the coming century?

The most widely used scenarios for future world energy consumption have been those developed by technical experts brought together by the Intergovernmental Panel on Climate Change (IPCC), an organization jointly established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP). A scenario from their most recent set is illustrated in Table 1. Though this scenario should not be thought of as any more probable than the others in the set, it is based on "moderate" assumptions on population and economic growth, and hence can be viewed as neither overly conservative nor overly aggressive. The quantities listed and defined in Table 1 are fundamental factors, such as population (N), per capita GDPs (GDP/N), and energy consumption intensities (energy consumed per unit of GDP, $\dot{E}$/GDP), underlying the energy consumption rate ($\dot{E}$):

$$\dot{E} = N \cdot (GDP/N) \cdot (\dot{E}/GDP).$$

One can see from this Table that as population and per capita gross domestic product increase, even as energy consumption intensity decreases (due to improved energy-usage-efficiency), the energy consumption rate is projected to double and then triple, from 12.9 TW in 2000 to 27.6 TW in 2050 and 43.0 TW in 2100.

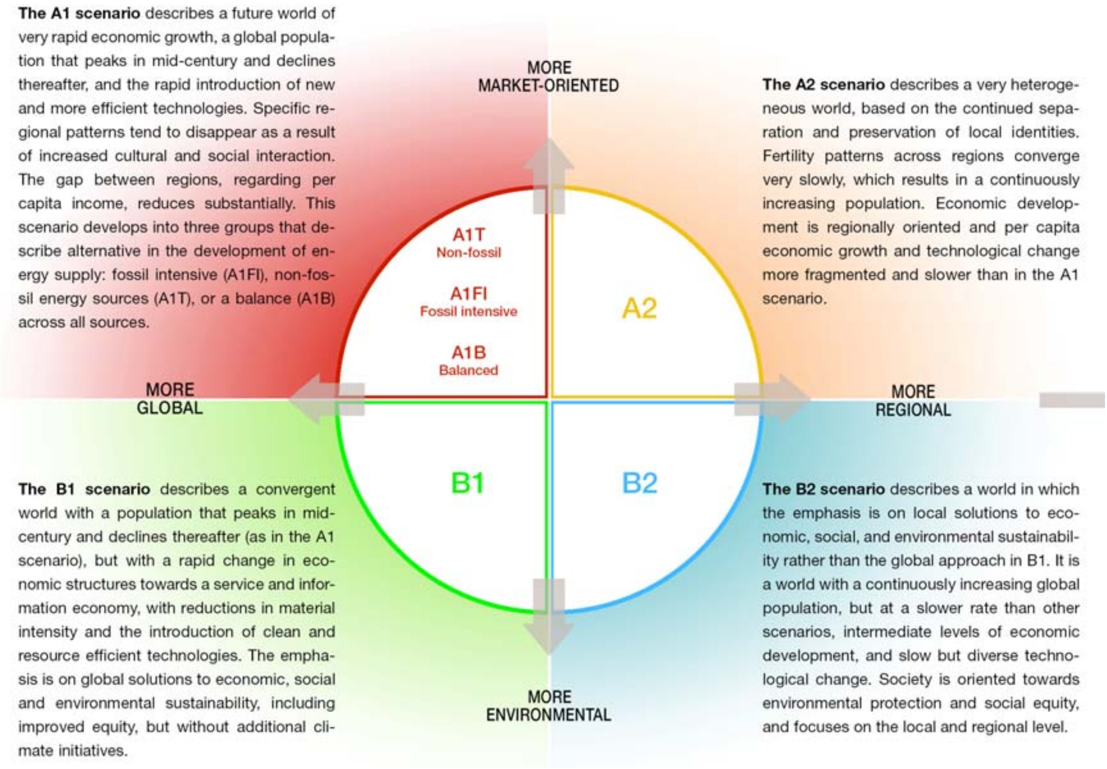
Quantity	Definition	Units	2000	2050	2100
N	Population	Billion persons	6.1	9.4	10.4
GDP	Gross Domestic Product	T\$/yr	28	110	235
GDP/N	per capita Gross Domestic Product	\$/(person-yr)	4,640	11,650	22,590
$\dot{E}$/GDP	Energy Consumption Intensity	W/(\$/yr)	0.46	0.25	0.18
$\dot{E}$	Energy Consumption Rate	TW	12.9[2]	27.6	43.0
C/E	Carbon Emission Intensity	kgC/(W·yr)	0.62	0.40	0.31
$\dot{C}$	Carbon Emission Rate	GtC/yr	8.0	11.0	13.3
$\dot{C}$	Equivalent CO_2 Emission Rate	$GtCO_2$/yr	29.3	40.3	48.8

Table 1: Energy Statistics and Projections.[3]

[2] This quantity is slightly lower than that estimated in International Energy Outlook 2004 (U.S. Department of Energy Energy Information Administration, 2004) (http://www.eia.doe.gov/oiaf/ieo/pdf/0484(2004).pdf): $\dot{E}$ = (398.9 Quads/yr) · (33.4 GWyr/Quad) · (10^{-3} TW/GW) = 13.3 TW.

[3] After scenario B2, as discussed in Nebojsa Nakicenovic and Rob Swart, Eds., Special Report on Emissions Scenarios (Intergovernmental Panel on Climate Change, 2000) (http://www.grida.no/climate/ipcc/emission/index.htm).

IPCC Socioeconomic Scenarios for Climate Modeling



The A1 scenario describes a future world of very rapid economic growth, a global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. Specific regional patterns tend to disappear as a result of increased cultural and social interaction. The gap between regions, regarding per capita income, reduces substantially. This scenario develops into three groups that describe alternative in the development of energy supply: fossil intensive (A1FI), non-fossil energy sources (A1T), or a balance (A1B) across all sources.

The A2 scenario describes a very heterogeneous world, based on the continued separation and preservation of local identities. Fertility patterns across regions converge very slowly, which results in a continuously increasing population. Economic development is regionally oriented and per capita economic growth and technological change more fragmented and slower than in the A1 scenario.

The B1 scenario describes a convergent world with a population that peaks in mid-century and declines thereafter (as in the A1 scenario), but with a rapid change in economic structures towards a service and information economy, with reductions in material intensity and the introduction of clean and resource efficient technologies. The emphasis is on global solutions to economic, social and environmental sustainability, including improved equity, but without additional climate initiatives.

The B2 scenario describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability rather than the global approach in B1. It is a world with a continuously increasing global population, but at a slower rate than other scenarios, intermediate levels of economic development, and slow but diverse technological change. Society is oriented towards environmental protection and social equity, and focuses on the local and regional level.

About the Speaker

Biography

Patricia M. Dehmer

Patricia Dehmer is the Director of the Office of Basic Energy Sciences in the Department of Energy's Office of Science. She holds a B.S. in Chemistry from the University of Illinois and a Ph.D. in Chemical Physics from the University of Chicago. After spending more than 20 years as a research scientist and group leader at Argonne National Laboratory, she joined the Department of Energy in 1995. In her current position, she oversees a budget of more than $1 billion for research in materials sciences, chemistry, geosciences, and biosciences and for the construction and operation of third- and fourth-generation light sources, high-flux neutron sources, and specialized facilities for microcharacterization, nanoscale materials synthesis, combustion research, and ion beam studies. During the ten years that Dr. Dehmer has led the Office of Basic Energy Sciences, she has initiated more than $3 billion in construction of scientific user facilities and instrumentation for them, and she has led strategic planning for research related to energy needs and for discovery science and articulation of the grand challenges that link the formerly disparate disciplines of chemistry, condensed matter and materials physics, biology, and computational sciences. Several of the recent studies that her office led (*Basic Research Needs to Assure a Secure Energy Future, Basic Research Needs for the Hydrogen Economy, Basic Research Needs for Solar Energy Utilization*, and a number of studies on nanoscale science) serve as the basis for today's OSTP briefing.

Dr. Dehmer has held many elected positions in the American Physical Society (APS), the American Association for the Advancement of Science, and the Gordon Research Conferences. She has served as the Chair of the APS Nominating Committee, a member of the APS Council and its Executive Committee, and as Chair of the APS Divisions of Atomic, Molecular, and Optical Physics and Laser Science. She has published 125 papers and given hundreds of scientific and science policy talks.

Nanoscience and technology
in six easy pieces

- The missing length scale
- One at a time
- It takes care of itself –defect tolerance
- High performance at large scales
- The energy connection
- Inspiration from nature- the hybrid system

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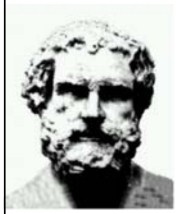
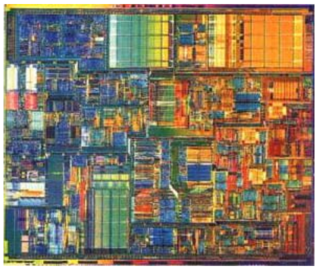
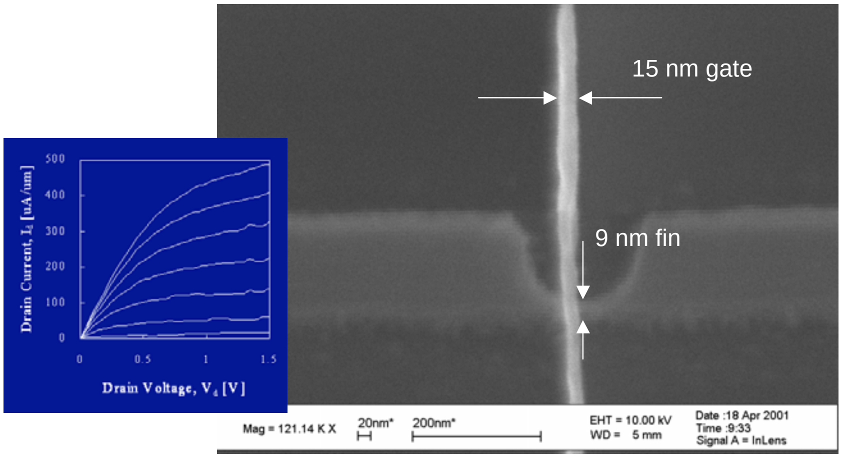
From Democritos to Gordon Moore



Democritos
(400 BC)



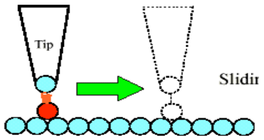
Gordon Moore



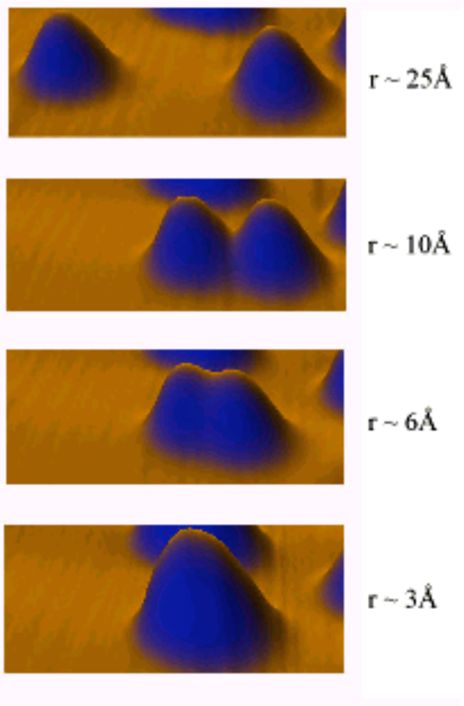
Bokor, King, Hu
UCB Device Group

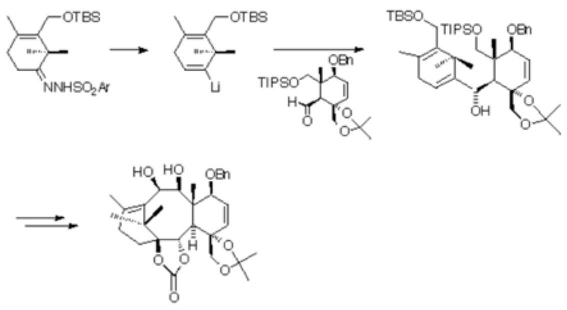
Nano-silicon FinFET with 15 nm gate and 9 nm fin. This is a fully functional MOS transistor with excellent electrical performance.

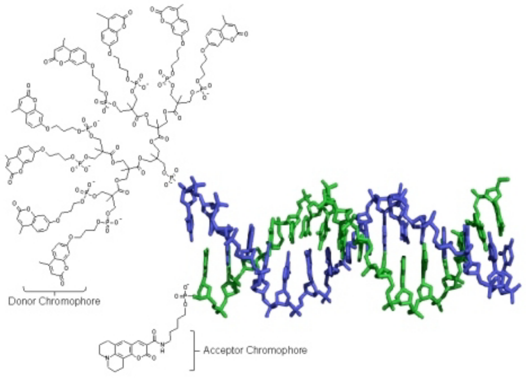
Atom Manipulation: then and now



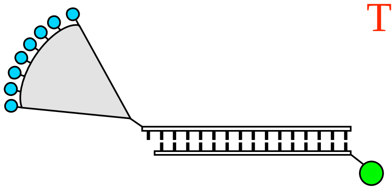
Building a Ni Dimer on Au(111)

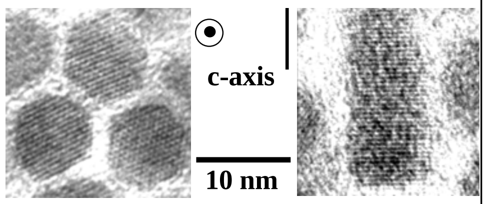




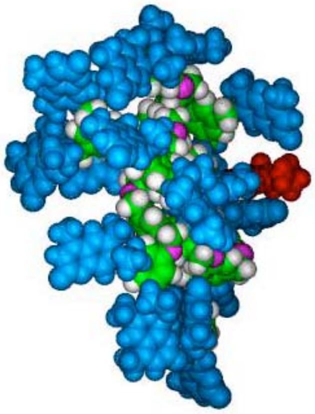


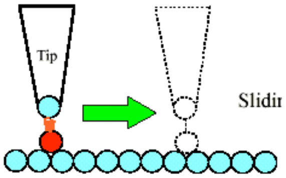
The Building Blocks



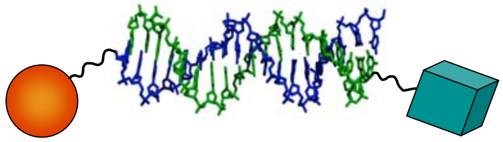


- •Dendrimer
- •Nanocrystal
- •Nanorods
- •Scanning Probe Tip.

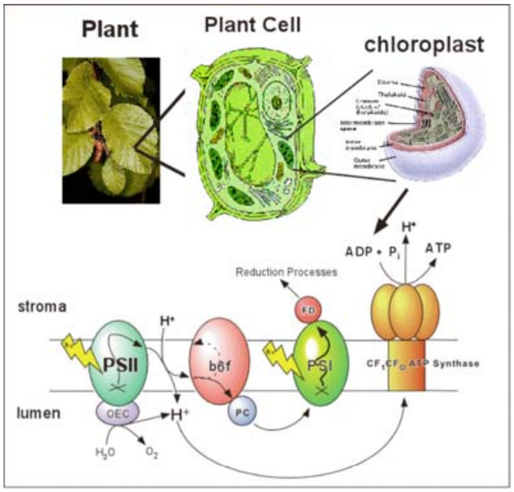


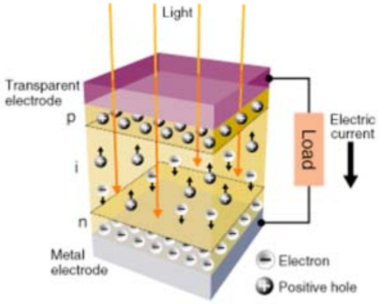


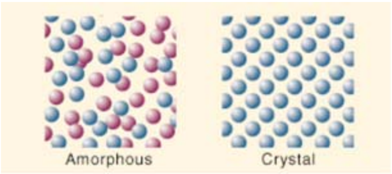
- •Patterned Surface
- •Cell Membrane
- •DNA
- •...

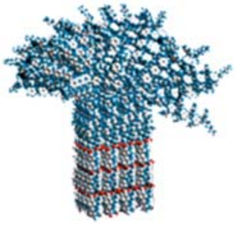


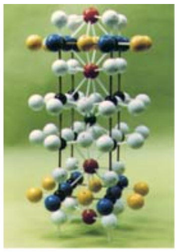
Heirarchical assembly of a complete system



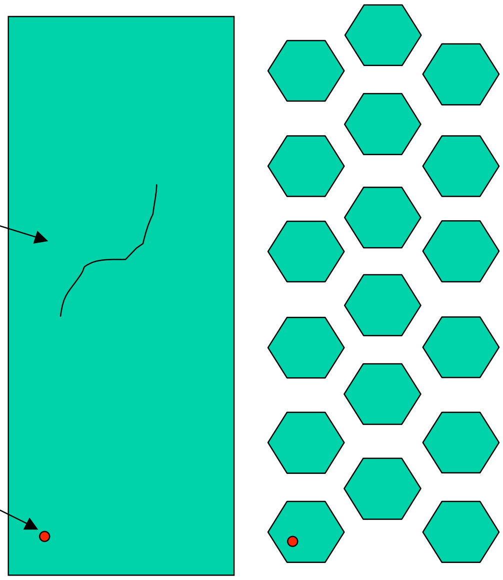








A comparison of defects in extended solids and nanocrystals



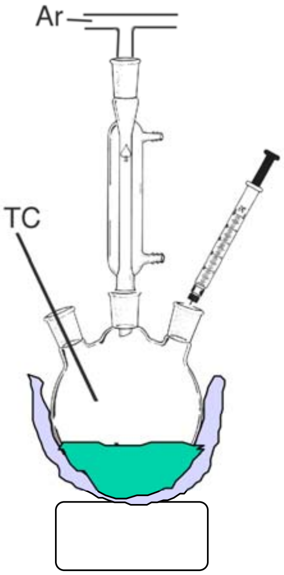
Non-equilibrium grain boundary

Equilibrium vacancy

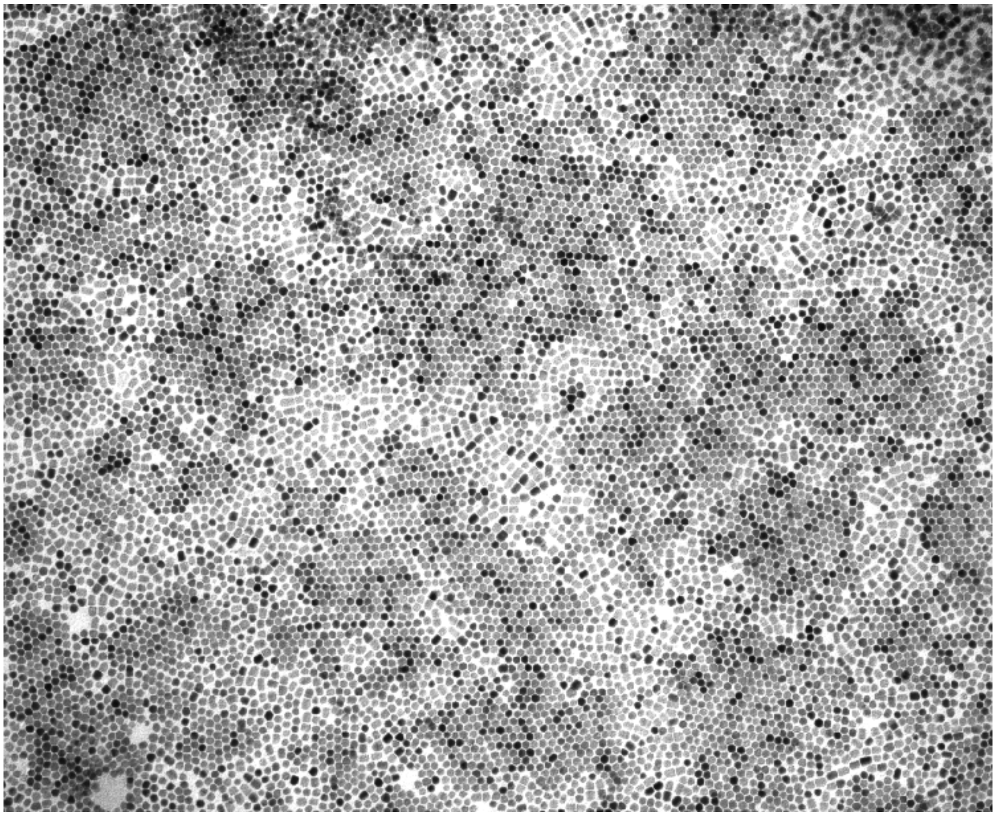
- 1 defect can affect an entire bulk solid
- On average, nanocrystals contain no equilibrium defects
- Easier to anneal out non-equilibrium defects in nanocrystals

Fabrication methods are key

Molecular Beam Epitaxy
of Quantum Structures



A wide field view of 7nm diameter surfactant capped CdSe nanocrystals



Some SCALING LAWS for nanoscale properties

Energy level spacing (band gap) E_g+~A/r^2

Density of states, oscillator strength (~V)

Charging energy (~1/r)

Melting temperature (~1/r)

Magnetic relaxation time (~N)

Timescale for structural metastability (~N)

Control of size and shape will be an important variable in the design of new materials

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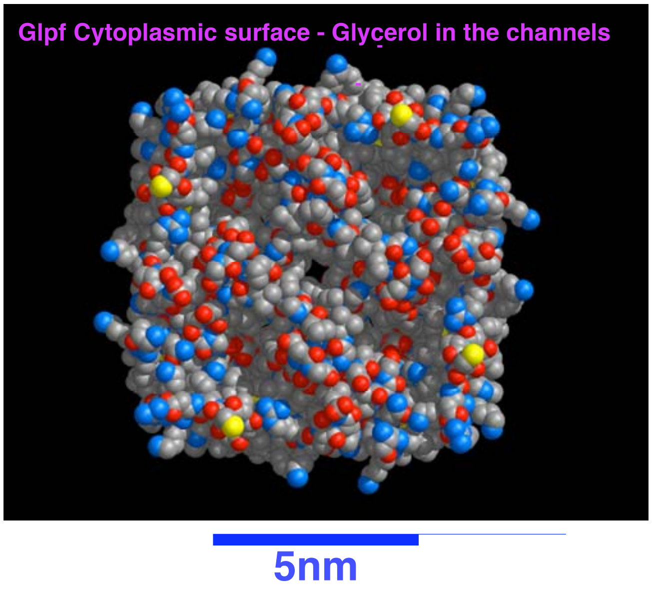
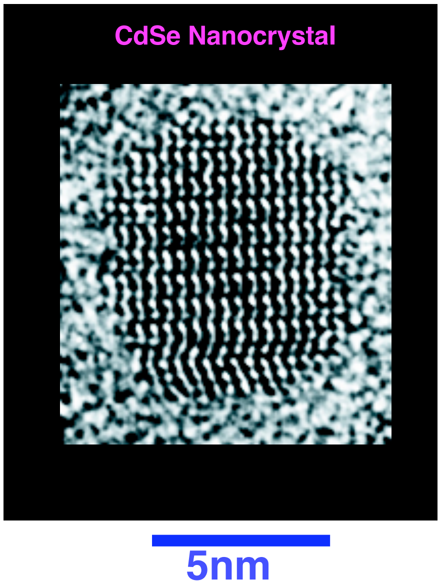
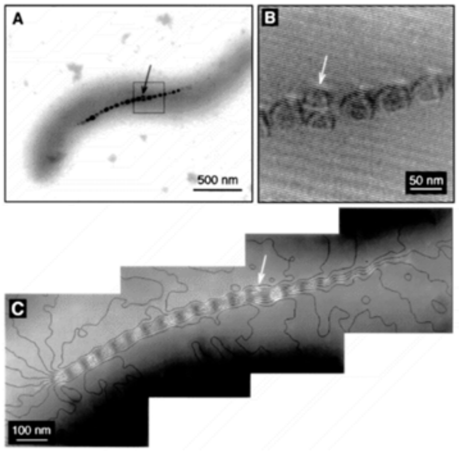
Conjunction of Soft and Hard Matter





Nanocrystals in Magnetotactic Bacteria

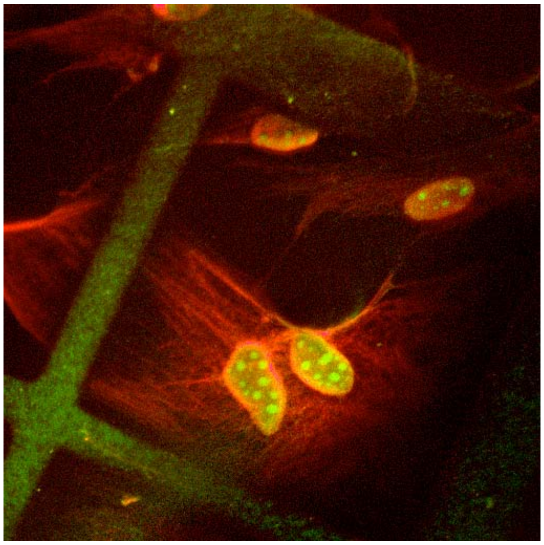


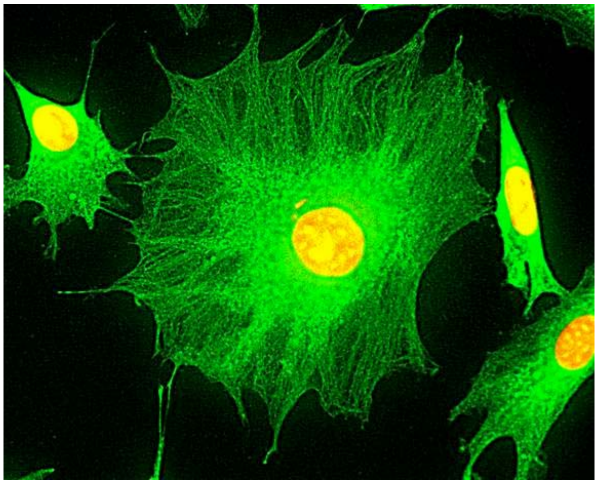
Magnetospirillum magnetotacticum

TEM images from Frankel, R. B., Bazylinski, D. A., et. al. *Science* **1998**, *282*, 1868-1870

- Exploitation of a fundamental scaling law
- Maximum size for a magnet to be a “single domain,” with no defects (tens of nm)
- Least amount of material to achieve the greatest degree of magnetization.

Quantum Dot Cell Labeling

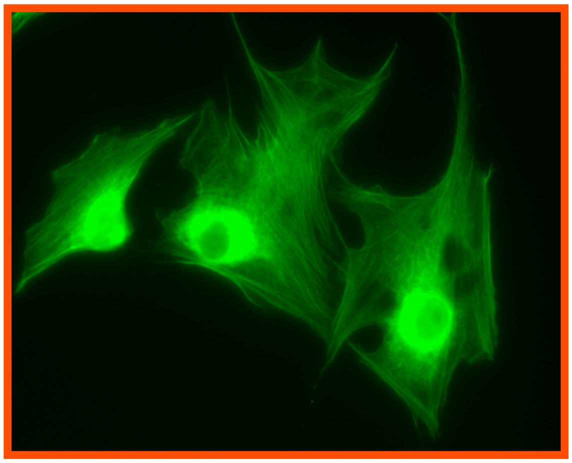




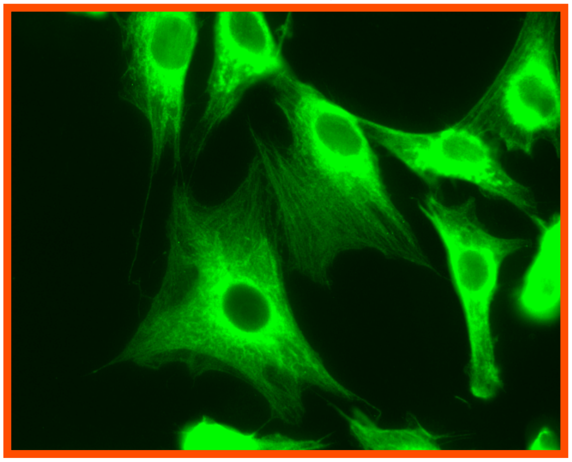
Bruchez, M.; Moronne, M.; Gin, P.; Weiss, S.; Alivisatos, A. P., *Science* **1998**, *281*, 2013-2016.

Photostability Comparison (Video)

Alexa 488



Green QDs



Courtesy Quantum Dot Corporation

Streptavidin coated QDots are now available for purchase from www.qdots.com

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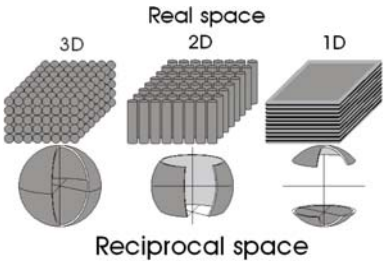
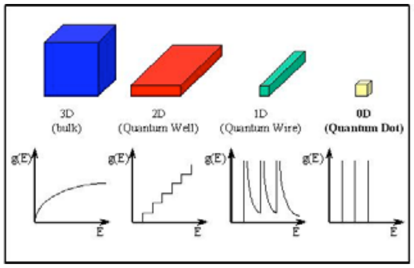
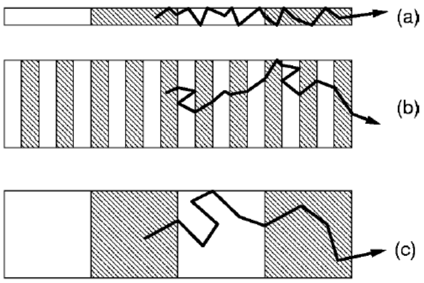
dimensionality to control light, electricity, and heat…

photons



electrons



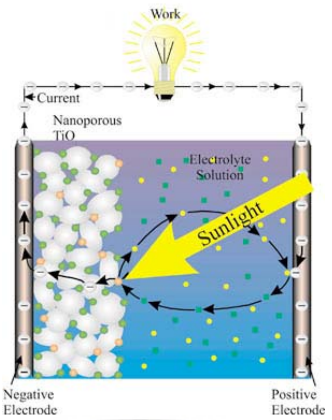


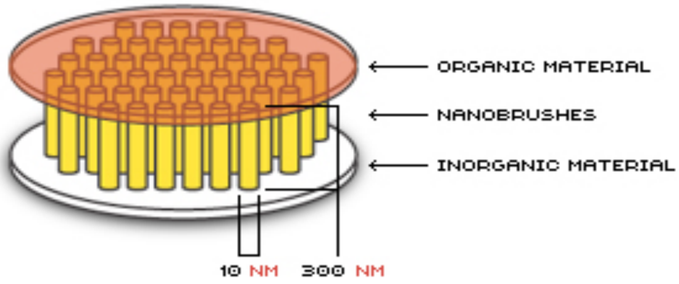
phonons

Measurement of scaling laws, synthetic control...

Nanotechnology solar cells

Grätzel cell





Absorption

↓

Exciton Diffusion

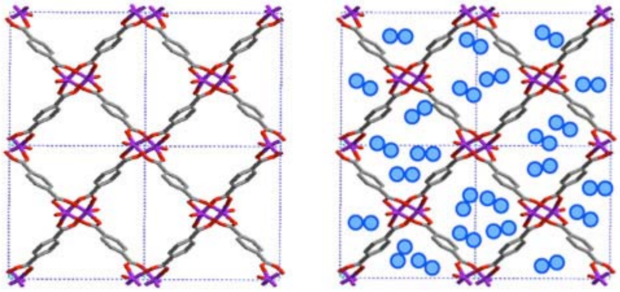
↓

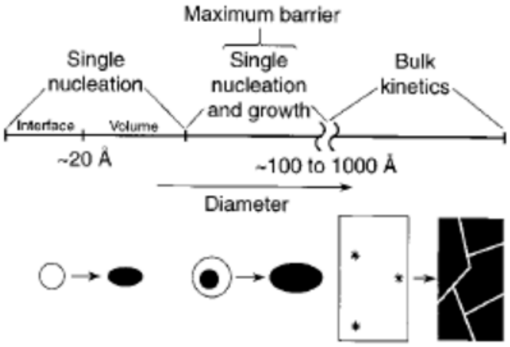
Charge Transfer

↓

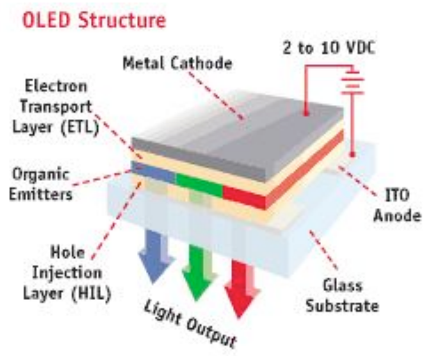
Charge Transport

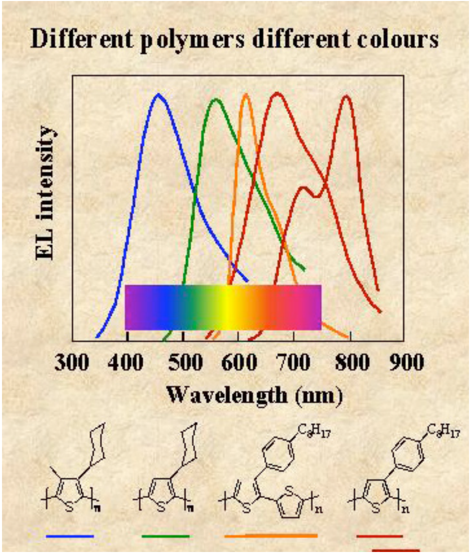
Nanotechnology and Hydrogen Storage



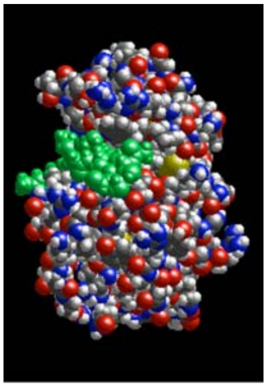


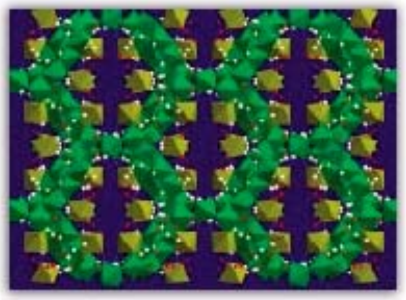
Nanotechnology and Solid State Lighting

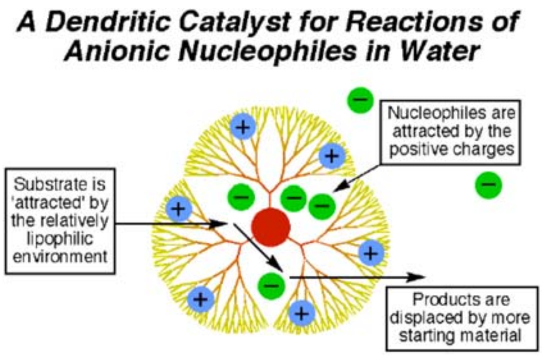




Nanotechnology and selective chemical transformation







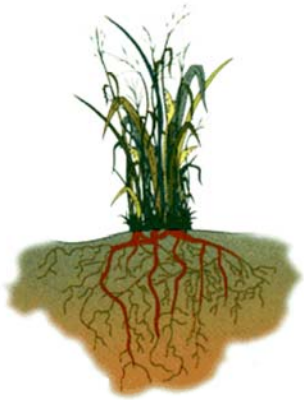
A Dendritic Catalyst for Reactions of Anionic Nucleophiles in Water

Nucleophiles are attracted by the positive charges

Substrate is 'attracted' by the relatively lipophilic environment

Products are displaced by more starting material

Issues of production



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Professor of Chemistry and Materials Science, University of California, Berkeley
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About the Speaker

Paul Alivisatos

Paul Alivisatos is Professor of Chemistry and Materials Science at the University of California, Berkeley, and Assoc. Director for Physical Sciences at the Lawrence Berkeley National Lab. His research concerns the structural, optical, electrical, and thermodynamic properties of nanocrystals. He is a member of the National Academy of Science, the founding editor of Nano Letters, and the scientific founder of Quantum Dot corporation and Nanosys, Inc.

Nanotechnology for the Hydrogen Economy

George Crabtree
Senior Scientist and Director
Materials Science Division

with
Millie Dresselhaus MIT
Michelle Buchanan ORNL

OSTP Hot Topics in Science and Technology
Nanotechnology: Energizing our Future
August 10, 2005

Argonne National Laboratory

Office of Science
U.S. Department of Energy

A U.S. Department of Energy
Office of Science Laboratory
Operated by The University of Chicago

Preview

Hydrogen: a solution to world energy challenges

- supply, security, local/regional pollution, climate change

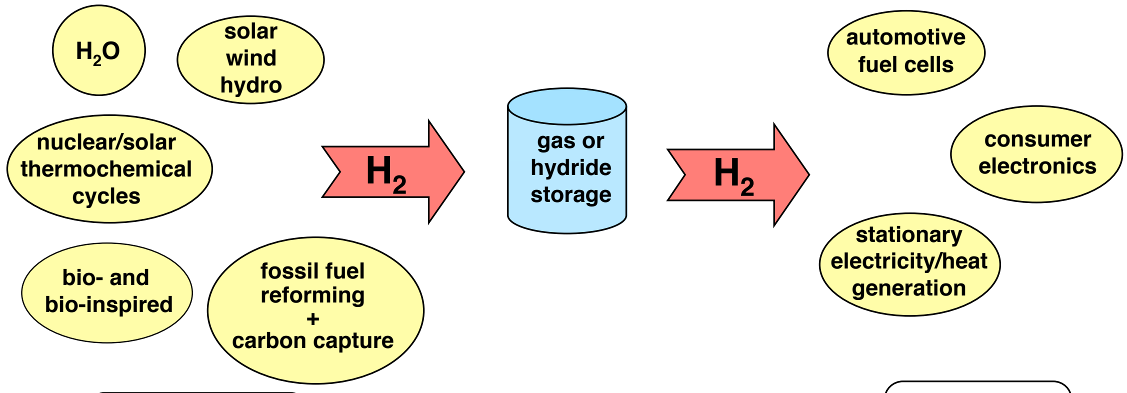
Basic research challenges and nanoscience solutions

- production
- storage
- use in fuel cells

The two hydrogen economies

- incremental: where we are now
- mature: where we need to be
- nanotechnology bridges the gap

The Hydrogen Economy



H_2O

solar
wind
hydro

nuclear/solar
thermochemical
cycles

bio- and
bio-inspired

fossil fuel
reforming
+
carbon capture

H_2

gas or
hydride
storage

H_2

automotive
fuel cells

consumer
electronics

stationary
electricity/heat
generation

production

storage

use
in fuel cells

9M tons/yr

150 M tons/yr
(light trucks and cars in 2040)

4.4 MJ/L (Gas, 10,000 psi)
8.4 MJ/L (LH2)

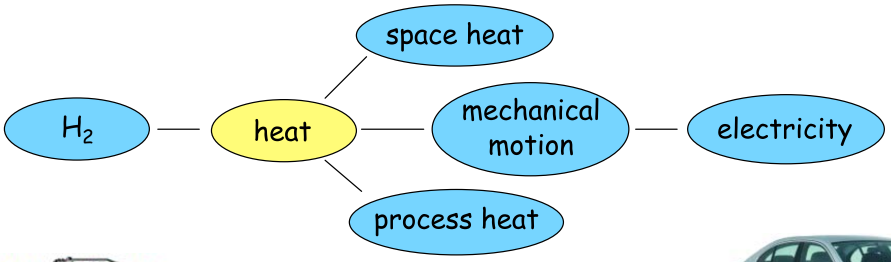
9.72 MJ/L
(2015 FreedomCAR Target)

\$3000/kW

~ \$300/kW
mass producton

\$30/kW
(Internal Combustion Engine)

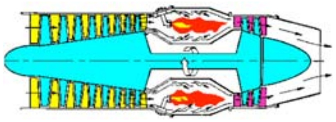
Hydrogen Use Today: Combustion



H_2 — heat — mechanical motion — electricity

space heat

process heat



replace fossil fuels in
heat engines/heat sources

gas turbines

electricity generation

jet engines

H_2/natural gas mixtures

space heat, stoves

internal combustion engines

BMW: 184 hp, 133 mph

190 mile range

liquid hydrogen/gasoline

Ford, Mazda, Hydrogen Car Co

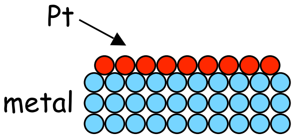
within technological reach

Hydrogen Use Tomorrow: Fuel Cells

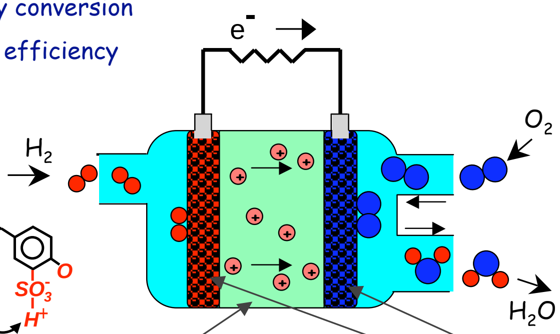
H_2 — electricity

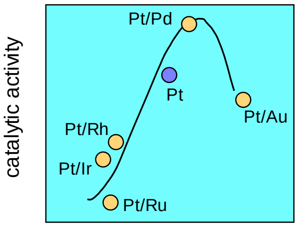
eliminate combustion and heat
from energy conversion

up to 60% efficiency



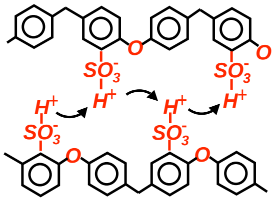
monolayer catalysts
Pt/metal substrate





metal substrate

R. Adzic, M. Mavrikakis, et al., *Angew. Chem. Int. Ed.* 44. 2132 (2005)

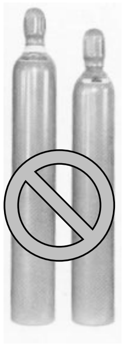


better membranes
higher temperature
higher ion conductivity

designed nanoscale architectures

better catalysts
less Pt
higher activity

Hydrogen Storage Today: Gas and Liquid



gaseous storage

5000 psi = 350 bar

10000 psi = 700 bar
fiber reinforced
composite containers

liquid storage

standard in stationary applications

portable cryogenics for auto

30-40% energy lost to liquifaction

within technological reach

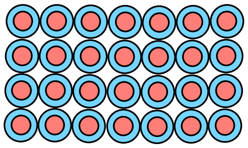
Hydrogen Storage Tomorrow: Solid State

300 mile driving range ⇒ storage density higher than liquid H_2

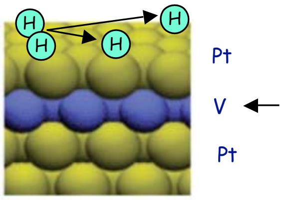
short refill time, good acceleration ⇒ fast charge, release rates

grand challenge for hydrogen economy:
viable hydrogen compounds

composite nanostructured media



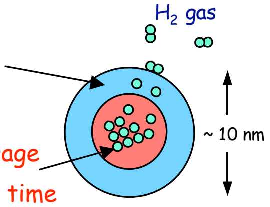
core-shell architecture
nanoparticle medium
high surface area



near-surface alloys

sub-surface atom controls surface behavior

- low H_2 surface binding energy
- high H_2 surface dissociation rate



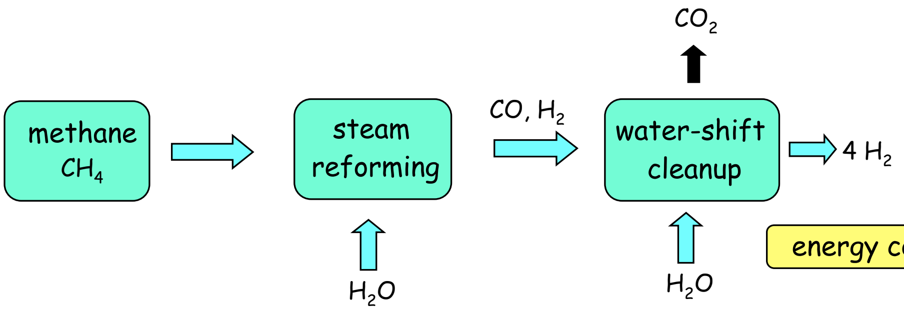
shell : dissociation
$H_2 \Leftrightarrow 2H$

core: high density storage
nanoscale ⇒ fast transit time

design by computer modeling
multi-node clusters, density functional theory
target promising nanoscale architectures

M. Mavrikakis et al., *Nature Materials* **3**, 810 (2004)

Hydrogen Production Today: Reform Fossil Fuels



energy content conserved

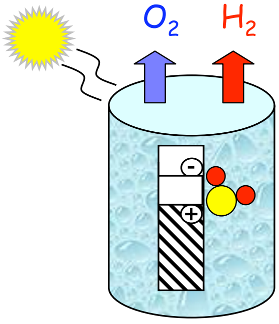
need 10 - 15 times today's production
for light trucks and cars in 2040

technology in place
incremental effect on energy

Energy Impact

- depletion of fossil resource
- dependence on foreign supply
- fossil pollution unchanged
- greenhouse emissions unchanged

Hydrogen Production Tomorrow: Splitting H_2O



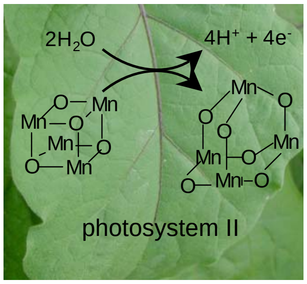
solar electrolysis

functional integration at the nanoscale

molecular transfer of energy and charge

6-18% efficiency in laboratory

abundant resource
no geopolitical constraints
environmentally benign

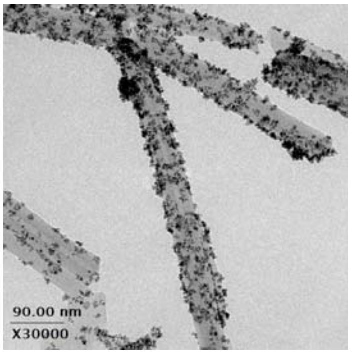


bio-inspired nanoscale assemblies

inexpensive Mn catalyst

room temperature

"one molecule at a time"



porphyrin nanotube hybrids

porphyrin: harvests light

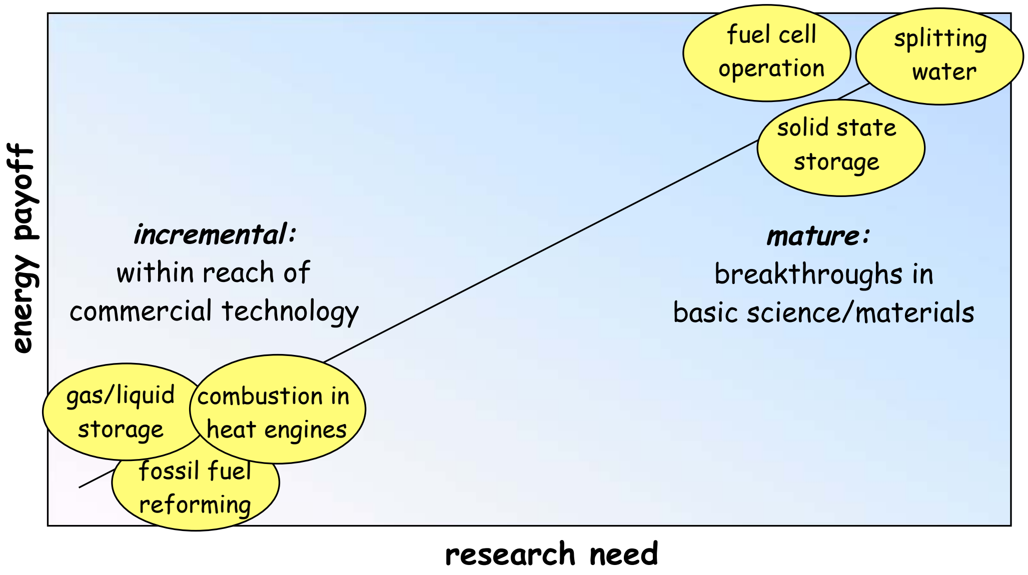
Pt, Au: catalyst & electrodes

assembly splits water in sunlight

J A Shelnutt., et al.,
J. Am. Chem. Soc. 126, 635 (2004)

nanoscale hydrogen production

The Two Hydrogen Economies



fuel cell operation

splitting water

solid state storage

incremental:
within reach of
commercial technology

mature:
breakthroughs in
basic science/materials

gas/liquid storage

combustion in heat engines

fossil fuel reforming

energy payoff

research need

nanoscience bridges the gap

About the Speaker

George W. Crabtree

George Crabtree is a Senior Scientist at Argonne National Laboratory and Director of its Materials Science Division. He holds a B.S. in Engineering from Northwestern University and Ph.D. in Condensed Matter Physics from the University of Illinois at Chicago, specializing in the electronic properties of metals. He has won numerous awards, most recently the Kammerlingh Onnes Prize for his work on the properties of vortices in high temperature superconductors. This prestigious prize is awarded only once every three years; Dr. Crabtree is its second recipient. He has won the University of Chicago Award for Distinguished Performance at Argonne twice, and the U.S. Department of Energy's Award for Outstanding Scientific Accomplishment in Solid State Physics four times, a notable accomplishment. He has an R&D 100 Award for his pioneering development of Magnetic Flux Imaging Systems, is a Fellow of the American Physical Society, and is a charter member of ISI's compilation of Highly Cited Researchers in Physics.

Dr. Crabtree has served as Chairman of the Division of Condensed Matter of the American Physical Society, as a Founding Editor of the scientific journal Physica C, as a Divisional Associate Editor of Physical Review Letters, as Chair of the Advisory Committee for the National Magnet Laboratory in Tallahassee, Florida, and as Editor of several review issues of Physica C devoted to superconductivity. He has published more than 400 papers in leading scientific journals, and given approximately 100 invited talks at national and international scientific conferences. His research interests include materials science, nanoscale superconductors and magnets, vortex matter in superconductors, and highly correlated electrons in metals. Most recently he served as Associate Chair of the Basic Energy Sciences Workshop on Solar Energy Untilization, the subject of his presentation to the San Diego Regional Energy Office Conference on Solar Energy.

Solar Energy and Nanotechnology

Based on:

Basic Research Needs for Solar Energy Utilization:

Report of the Basic Energy Sciences Workshop on Solar Energy Utilization

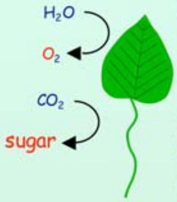
Nathan S. Lewis
George L. Argyros Professor of Chemistry
California Institute of Technology
with
George Crabtree, Argonne NL
Arthur Nozik, NREL
Mike Wasielewski, Northwestern
Paul Alivisatos, UC-Berkeley

Solar Energy Utilization

Solar Electric

.001 TW PV
$0.30/kWh w/o storage

1.5 TW electricity
$0.03-$0.06/kWh (fossil)



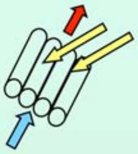
natural photosynthesis

Solar Fuel

1.4 TW solar fuel (biomass)

11 TW fossil fuel
(present use)

~ 14 TW additional energy by 2050



50 - 200 °C
space, water heating

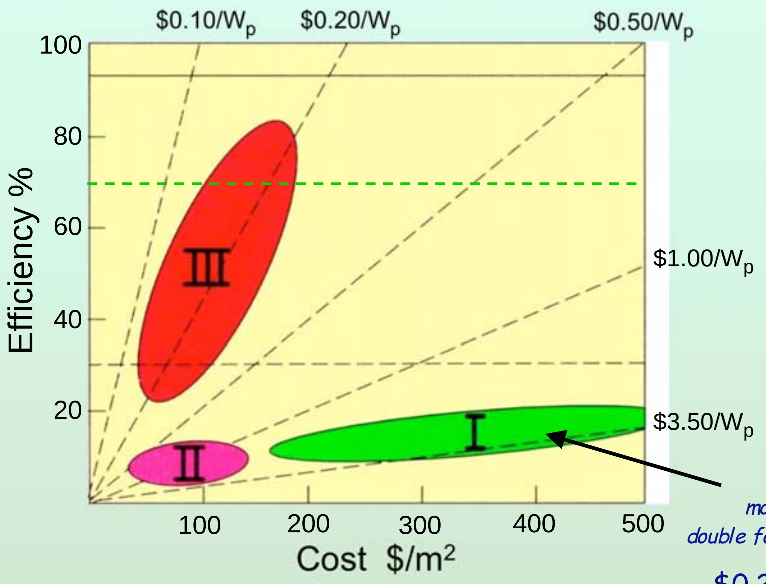
500 - 3000 °C
heat engines
electricity generation
process heat

Solar Thermal

0.002 TW

2 TW
space and water heating

Solar Energy Costs



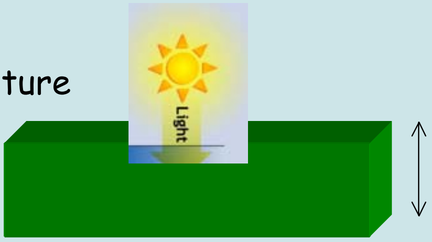
module cost only
double for balance of system

$0.25-0.50/kW-hr

competitive electric power: $\$1.00/W_p = \$0.05/\mathrm{kWh}$
competitive primary power: $\$0.20/W_p = \$0.01/\mathrm{kWh}$
including cost for storage

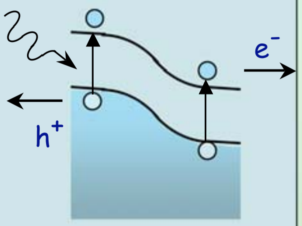
Solar Energy Conversion

Capture

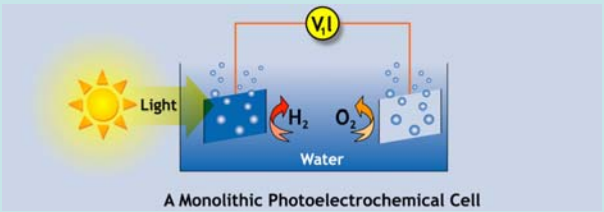


100 nm-100 μm

Conversion

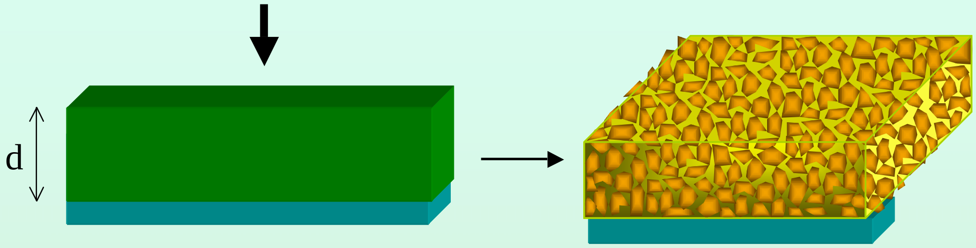


Storage

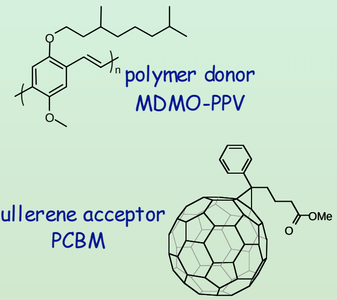


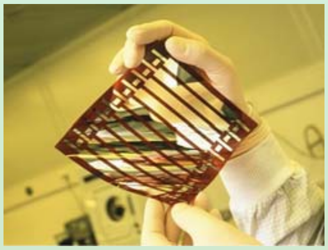
A Monolithic Photoelectrochemical Cell

“Solar Paint”



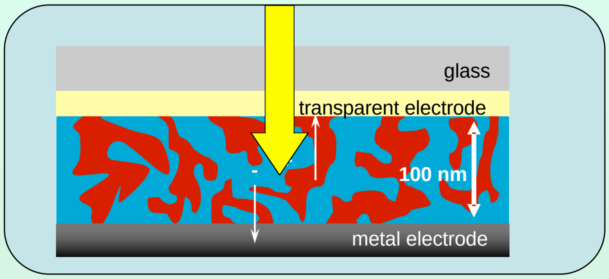
“Fooling “inexpensive particles into behaving as single crystals

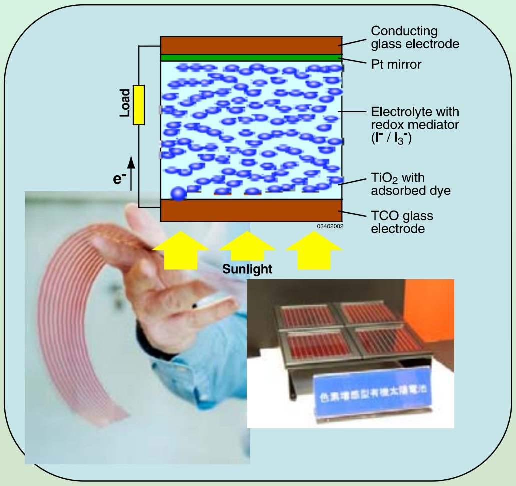


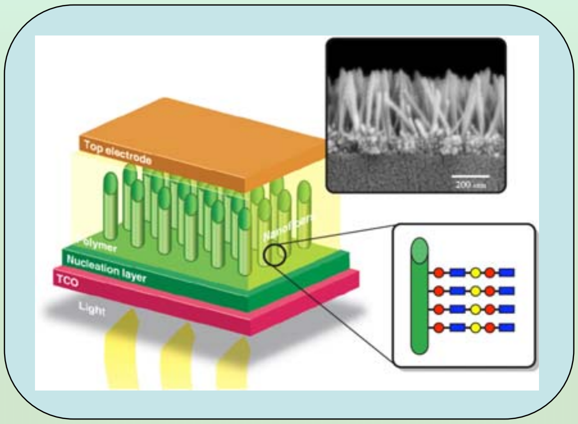


inexpensive processing, conformal layers

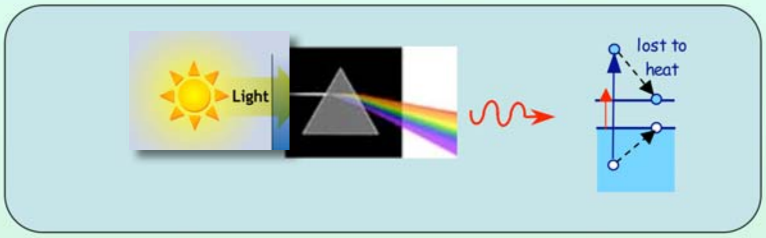
Interpenetrating Nanostructured Networks

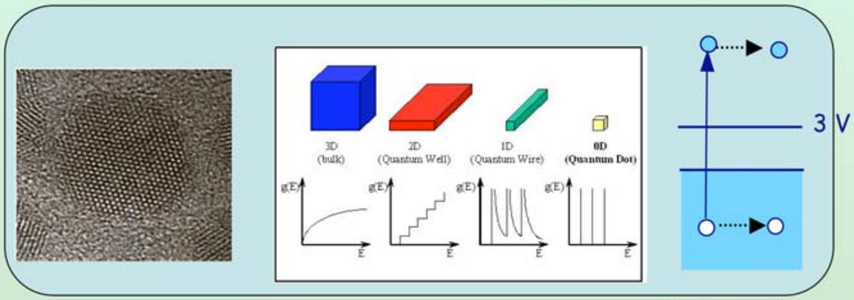




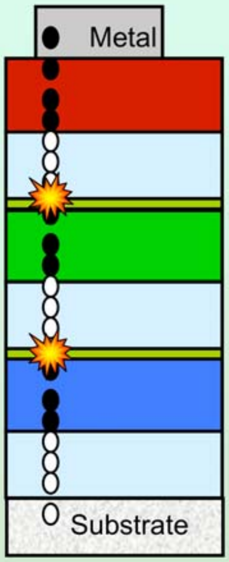


Ultra-high Efficiency Solar Cells





hot carriers

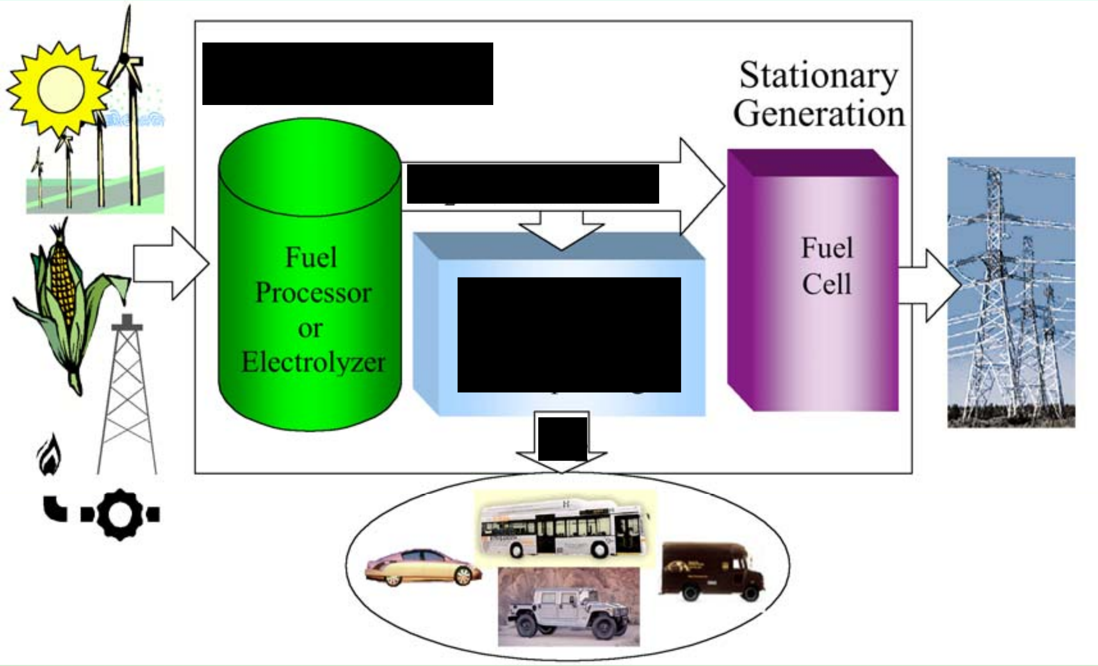


multiple junctions

rich variety of new physical phenomena
understand and implement

Storage: The Need to Produce Fuel

"Power Park Concept"



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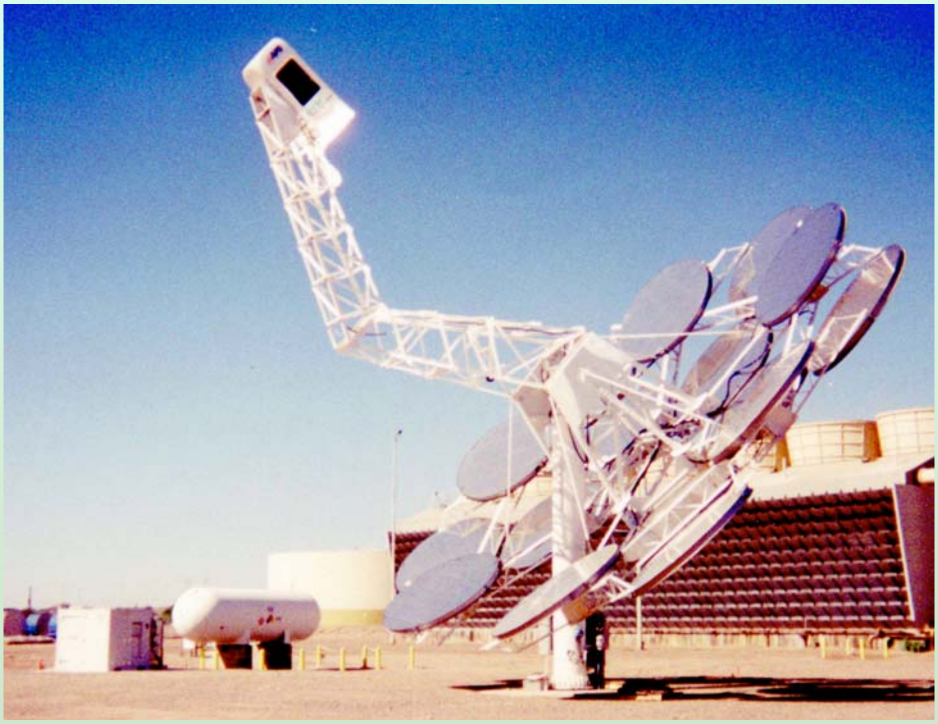
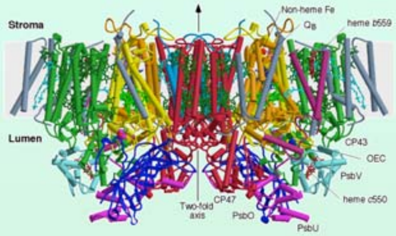
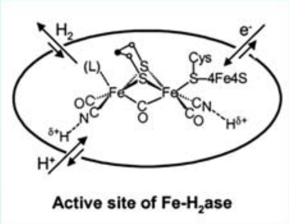
Solar Thermal + Electrolyzer System



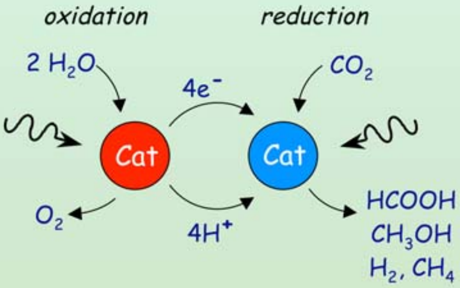
Solar-Powered Catalysts for Fuel Formation





photosystem II

hydrogenase
$2H^+ + 2e^- \Leftrightarrow H_2$


oxidation *reduction*

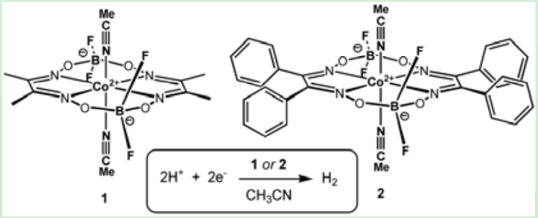
$2\ H_2O$ CO_2

$4e^-$

Cat Cat

O_2 $4H^+$

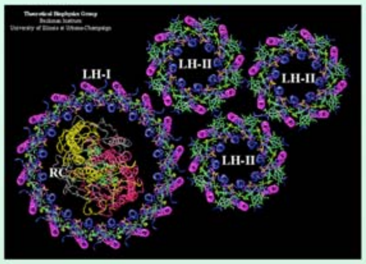
$HCOOH$
CH_3OH
H_2, CH_4



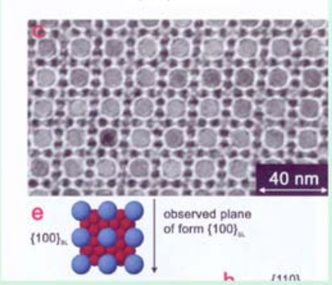
Solar Land Area Requirements

Control of Materials Properties Through Nanoscience

biological

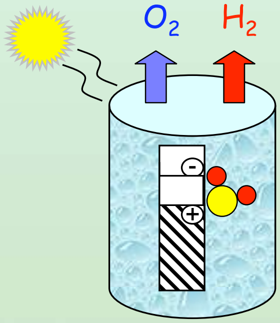


physical



mechanical

Self-assembly of complex structures

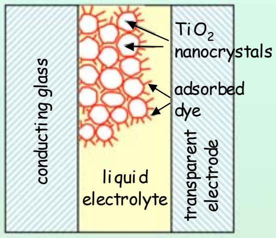


Hydrogen from water and sunlight

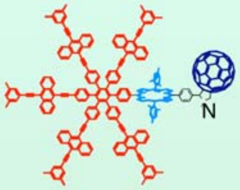
demonstrated efficiencies 10-18% in laboratory

Nanoscience and Solar Energy

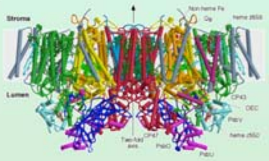
manipulation of photons, electrons, and molecules



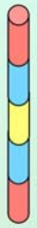
quantum dot solar cells



artificial photosynthesis



natural photosynthesis



nanostructured thermoelectrics

nanoscale architectures
top down lithography
bottom up self-assembly
multi-scale integration

characterization
scanning probes
electrons, neutrons, x-rays
smaller length and time scales

theory and modeling
multi-node computer clusters
density functional theory
10 000 atom assemblies

Solar energy is interdisciplinary nanoscience

Basic Research Needs for Solar Energy

- ***The Sun is a singular solution to our future energy needs***
  - capacity dwarfs fossil, nuclear, wind . . .
  - sunlight delivers more energy in **one hour** than the earth uses in **one year**
  - free of greenhouse gases and pollutants
  - secure from geo-political constraints
- ***Enormous gap between our tiny use of solar energy and its immense potential***
  - Incremental advances in today's technology will not bridge the gap
  - Conceptual breakthroughs are needed that come only from high risk-high payoff basic research
- ***Interdisciplinary research is required***
  physics, chemistry, biology, materials, nanoscience
- ***Basic and applied science should couple seamlessly***

Basic Research Needs for Solar Energy Utilization

Report of the Basic Energy Sciences Workshop on Solar Energy Utilization April 18-21, 2005

Office of Science

http://www.sc.doe.gov/bes/reports/abstracts.html#SEU

About the Speaker

Nathan S. Lewis

Nathan S. Lewis is the George L. Argyros Professor of Chemistry at the California Institute of Technology. He holds a B.S. and M.S. degree in 1977 Chemistry from Caltech, and a Ph.D. in 1981 from MIT. From 1981-1986, he was an Assistant Professor at Stanford University, from 1986-1988 he was an Associate Professor at Caltech, and from 1988-present he is a full professor at Caltech. Lewis' research interests involve artificial photosynthesis to enable solar energy conversion to directly form chemical fuels, and chemical microsensors for widely disseminated early warning systems for chemical terrorist events in homeland security.

Lewis is an author or co-author of over 200 papers, and has received numerous awards including a Presidential Young Investigator Award, the Americal Chemical Society Award in Pure Chemistry, and the Princeton Environmental Award. He has served on the editorial boards of the *Journal of the Electrochemical Society* and *Accounts of Chemical Reseach*, and is on currently on the board of *Chemical Reviews*. He has attended the World Economic Forum in 2000 and 2001, and consults for government, industry, and academia on energy technology and energy policy. He is a member of the Technology Advisory Council of BP, and has been a founding participant in several succesful start-up high technology companies. He also consults for government on a broad array of national security-related topics, and has been the chair of the visiting committee for the Department of Applied Science at Brookhaven National Laboratory. Along with George Crabtree, Lewis was the co-chair of the recent workshop sponsored by the DOE Office of Basic Energy Sciences on *Basic Research Needs for Solar Energy Utilization,* which is the basis for today's OSTP briefing.

OSTP Hot Topics in Science and Technology Series
Nanotechnology: Energizing Our Future

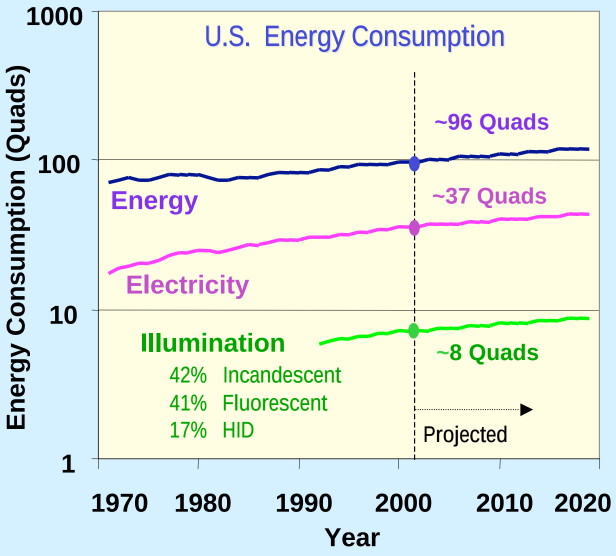
Nanotechnology for Solid State Lighting

10 August 2005

Harriet Kung
Director, Materials Sciences and Engineering Division
Office of Basic Energy Science
Office of Science, DOE

harriet.kung@science.doe.gov
(301) 903-1330

Lighting is a Large Fraction of Energy Consumption

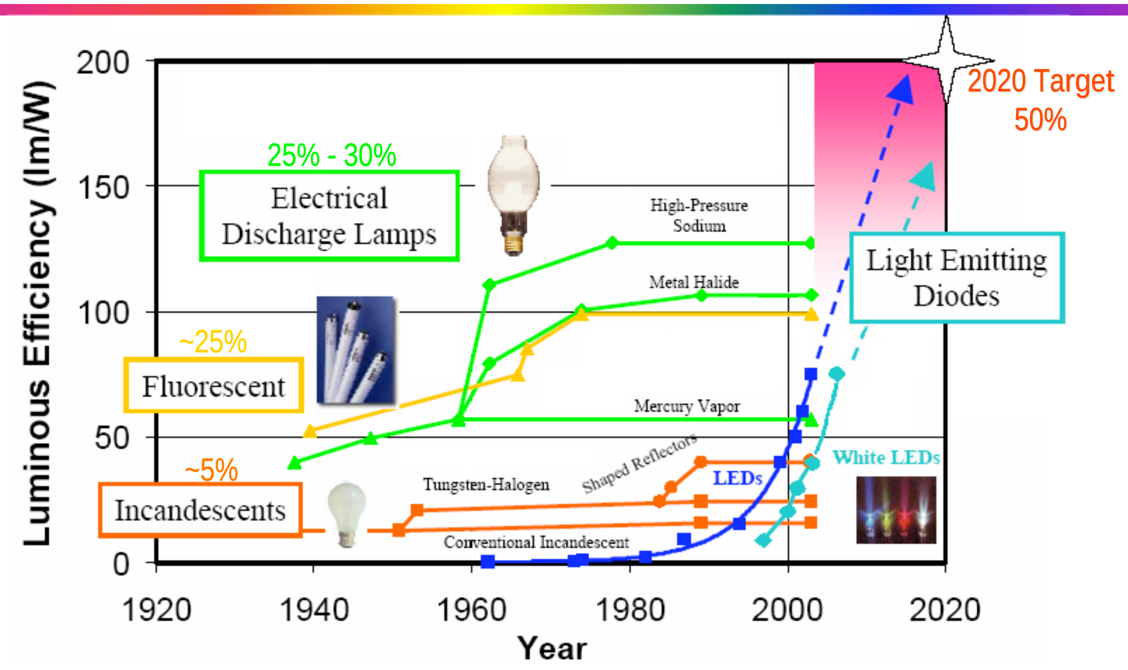


Efficiencies of Energy Technologies in Buildings

Heating:	70-80%
Electrical Motors:	85-95%
Incandescent Lighting:	~5%
Fluorescent Lighting:	~25%
Metal Halide Lighting:	~30%

Lighting consumes ~20% of U.S electricity and yet has very low efficiency

Solid State Lighting Offers Great Potential for Energy Savings



50% conversion efficiency (200 lm/W) in SSL in 2025 could lead to:

- Reduced Electricity Consumption (525 TW-hr/Yr) and Cost ($35 B/Yr)
- Decreases in New Power Plant Needs (75 GW) and CO_2 Emission (87 Mtons)

Ref: J.Y. Tsao, Laser Focus World, May 2003 and references therein

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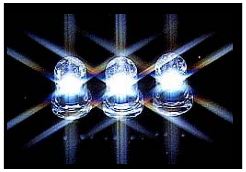
Solid State Lighting: Semiconductor-Based Lighting Technology

Inorganic Light Emitting Diodes (LEDs)

- III-V semiconductors-based device
- High brightness point sources
- Potential high efficiency & long lifetime



Organic Light Emitting Diodes (OLEDs)

- Organic semiconductors-based device
- Large area diffuse sources
- Thin and flexible
- Ease of fabrication

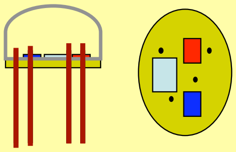
Current LEDs are predominantly in mono-chrome or niche applications.

High brightness, broad-band white light is needed for general illumination applications.

White Light Solid State Lighting

Multi-LED

Multi-chip LED
(with control circuitry)



Mix light from multiple LEDs of different color

✓Potential High Efficiency

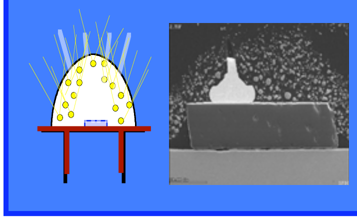
✓Precise Control of Color and Power Output

Color Likely Sensitive to Temperature

Higher Materials and Processing Costs

LED + Phosphors

Blue or UV LED + Phosphors



Use blue or near-UV LED to pump a mixture of phosphors

✓ Good Temperature Stability

✓ Lower Cost

Limited Control of Color and Power Output

Lower Energy Conversion Efficiency

Current Market Status & Technology Gaps

	Efficiency (lm/W)	Price ($/klm)
Incandescent (75 W)	13	~$0.60
Fluorescent (T8)	83	~$0.73
HID (Metal Halide)	100	~$1.27
SSL (White Light)	~50 → (200*)	~$150 → (less than $2*)

* 2020 Milestones in a SSL Technology Roadmaps developed by SSL Community *http://lighting.sandia.gov*

LED Research Advancements and Opportunities

New Materials

New Classes of Light Emitters:

AlInGaP – Red, Yellow InGaN – Blue, Green

Lattice Matched Substrates

Semiconductor Nanomaterials and Nanostructures

Thin Film and Bulk Crystal Growth, Self-Assembly

UV-Stable Packaging / Encapsulant Materials

Photon Creation

Interplay between Electron-hole Injection and Recombination, Band Structure, Defects, Impurities, and Strain

Photon Extraction

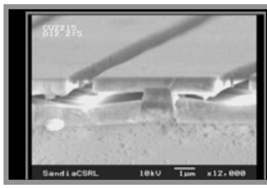
Manipulation of Optical Modes by use of Optical Microcavities and Photonic Lattices

3D Nanostructuring, Surface Plasmons

Photon Wavelength Conversion

New Phosphors – New Material Families and Nanoscience Approaches

New Approaches to Optical Index Matching and Photon Guiding

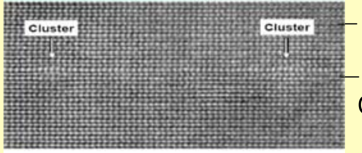


Cantilever epitaxy reduces defect density in GaN

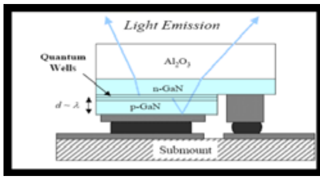
J. Simmons et al., SNL

Nanoscale Indium clustering in InGaN

LBNL and Lumileds CRADA, NCEM HRTEM image

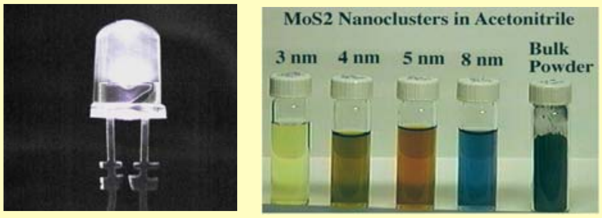


2.8 nm InGaN Quantum Well



Microcavity effects for increased light extraction

Shen et. al., *Appl. Phys. Lett.* 82, 2221 (2003).

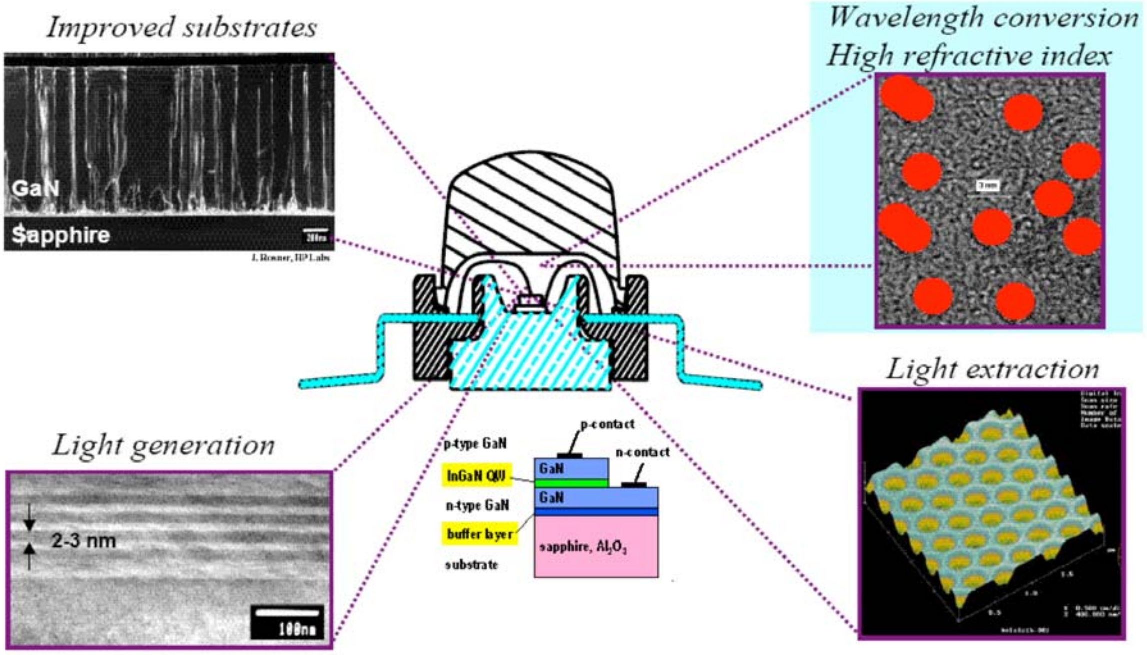


Nano quantum dots provide tunable phosphors

Nanotechnology-Enabled LED Research Breakthroughs

Nanoscale substrate patterning reduces GaN defects by 100 times

Nano quantum dots as phosphors



2-3 nm InGaN quantum well structure

Photonic crystal LEDs

Source: G. Craford, Lumleds, 2004 DOE Nanosummit

Nanoscale Research Opportunities in OLEDs

1. Organic Semiconductors

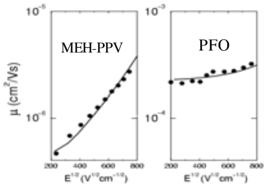
Defect Tolerant

The Wonders of Chemistry-

Guided by Quantum Chemistry and Intuition

Widely Tunable Properties

Semiconducting and metallic polymer "inks" A. Heeger, UCSB

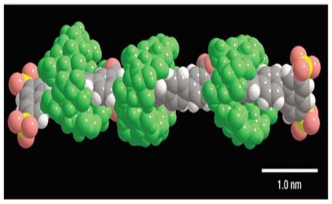


Mobilities Modeling D. Smith, LANL

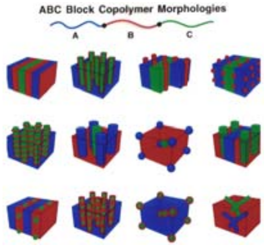
2. Synthesis and Processing

Solution and Vacuum Processing

Self Assembly at the Molecular Level



Chemical structures of the polyrotaxanes Cacialli et al, Nature Materials



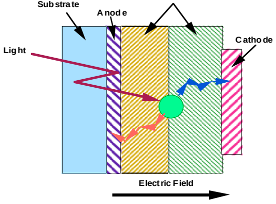
Block Copolymer Morphologie

3. Nanoscale Manipulation

Charge Injection

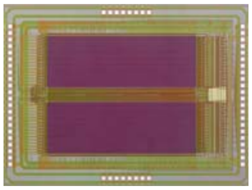
Tailored Transport & Optical Process

Will Benefit Other Organic Electronics



Organic PVs

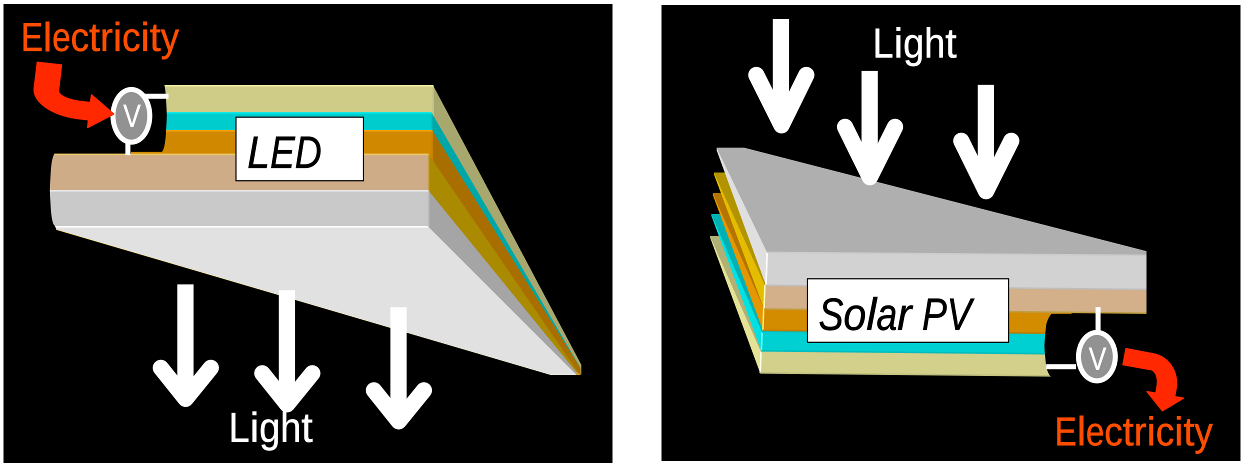
Bradley, Imperial College London



1MB prototype chip
shown by Motorola in June 2002

Synergy between Solar Photovoltaic & LED

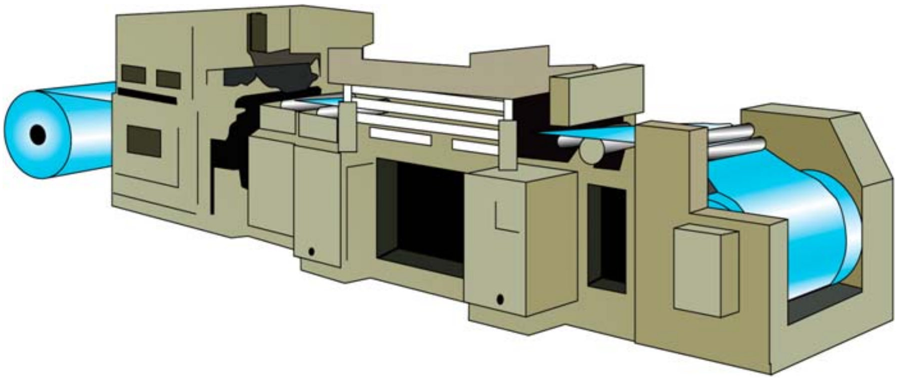
Converting between electricity and light - LED works as a reverse solar PV cell



Common Issues
- Nanomaterials and New Design for High Efficiency Conversion
- Device Reliability and Materials Degradation
- Novel Nanoscale Synthesis& Processing

OLEDs and Organic Electronics

Semiconductor Processing $\xrightarrow{?}$ Newspaper Processing



Broad range of applications based on organic electronics:

Organic PV	Integrated Circuits
Organic Sensors	Display and Lighting

Nanotechnology could assist the paradigm shift.

Change a Light, Change the World

- The century old, low conversion efficiency technologies still dominate world lighting application.
- Semiconductor based Light Emitting Diodes offer significant savings in energy consumption.
- Nanoscale basic research presents new opportunities to advance solid-state lighting technologies.

Acknowledgments:
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SNL: Jeff Tsao, Jerry Simmon; LANL: Darryl Smith

About the Speaker

Dr. Harriet Kung has served as the Director of Materials Sciences and Engineering Division in DOE's Office of Basic Energy Sciences (BES) since June 2004. Her Division supports a broad-based basic research program engaged in fundamental studies of materials sciences and engineering. The research seeks to understand the atomistic basis of materials properties and behavior and how to make materials perform better at acceptable cost through innovative materials design, synthesis, and processing. The program fulfills DOE missions by the development of materials that improve the efficiency, economy, environmental acceptability, and safety in energy generation, conversion, transmission, and utilization.

Before joining DOE in 2002, Dr. Kung was a technical staff member and a project leader in the Materials Science and Technology Division at Los Alamos National Laboratory (LANL). Her main research interest focuses on novel synthesis and characterization of nanostructured materials and their mechanical and physical behavior. In addition, she has conducted research in high temperature superconductivity and devices. She has published ~ 100 refereed papers, and has given more than 50 technical presentations at conferences and universities, including one plenary lecture and 25 invited talks. She has served as a guest editor for several special scientific journal issues, and has been involved in organizing eight international symposia/workshops.

At DOE, she was involved in the planning and execution of three BES-sponsored workshops: *Basic Research Needs to Assure a Secure Energy Future, Basic Research Needs for the Hydrogen Economy, and Basic Research Needs for Effective Solar Energy Conversion*. She has served as the point of contact for the Office of Science on basic hydrogen research, and has participated in various international hydrogen research coordination activities. She is currently serving as the leader of the Fundamental Research subgroup in an OSTP Hydrogen R&D Task Force to develop interagency coordination plans on basic hydrogen research. She also led a joint BES-EERE workshop on Basic Research Needs for Organic Electronic Materials in support of the solid state lighting technologies.

Dr. Kung received her Ph.D. degree in Materials Science and Engineering with a minor in Applied and Engineering Physics from Cornell University. She is the recipient of numerous awards including the DOE Distinguished Postdoctoral Fellowship award and several performance and leadership service awards at LANL.