Arun Majumdar

Director, Environmental Energy Technologies Division

Faculty Scientist, Materials Sciences Division

Professor, Depts. Of Mechanical Engineering & Materials Science and Engineering, UC Berkeley

EETD Organization

Advanced Energy Tech.
(Russo) - 95 staff
- Battery Program
- Physical/Chemical tech.
- Combustion tech.

Indoor Environment
(Fisk) - 63 staff
- Environmental Chemistry & Exposure
- Airflow and pollutant transport
- Commercial building & indoor env. Quality
- Energy performance & buildings

Atmospheric Sciences
(Brown) - 26 staff
- Atmospheric Processes & Air quality
- Atmosphere & global climate
- Emissions
- Aerosols

Building Technology Dept.
(Selkowitz) - 66 staff
- Windows & daylighting
- Commercial buildings systems
- Lighting systems
- Simulations
- Demand response
- Applications

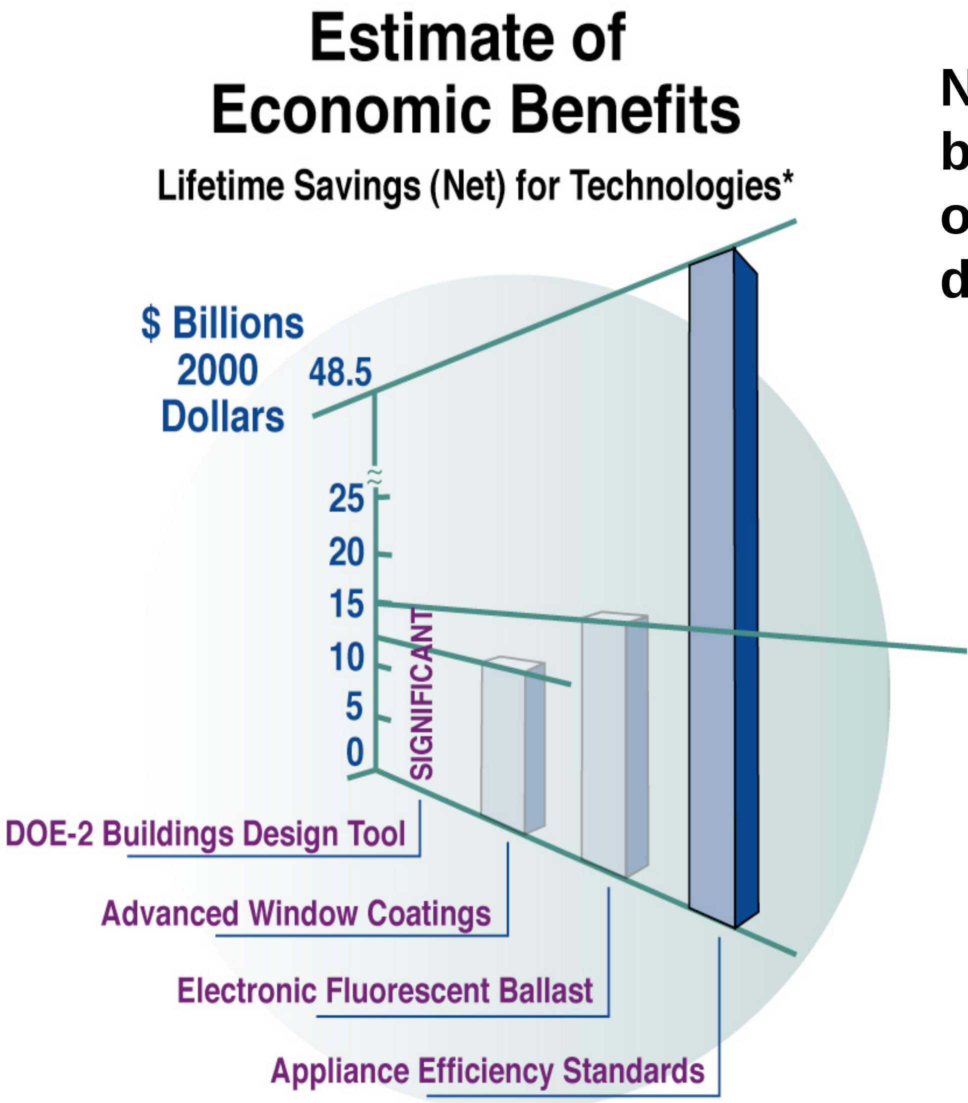
Energy Analysis Dept.
(McMahon)- 123 staff
- Electricity Markets & Policy
- China energy
- International Energy Studies
- Govt & Industry Programs
- Energy Efficiency Studies
- End use forecasting & market assessment
- Heat islands
- Independent research projects

2007 IPCC Nobelists from EETD

1. Mark Levine
2. Surabi Menon
3. Evan Mills
4. Lynn Price
5. Jayant Sathaye
6. Ernst Worrell
7. Maithili Iyer
8. Phil Haves
9. Stephane de la Rue du Can

Prior Impacts of EETD's Efficiency R&D

From National Academy of Sciences Report



NAS estimate of economic benefits of EE R&D assigns $23 of $30 billion in savings to LBNL - derived technologies

Additional $48 billion in savings from energy efficiency standards for 9 residential products

- ***Primary energy*** **savings**
  - = **9% of 2025 residential energy use**
- ***Carbon reductions in 2025***
  - = **132 million metric tons CO_2/year**

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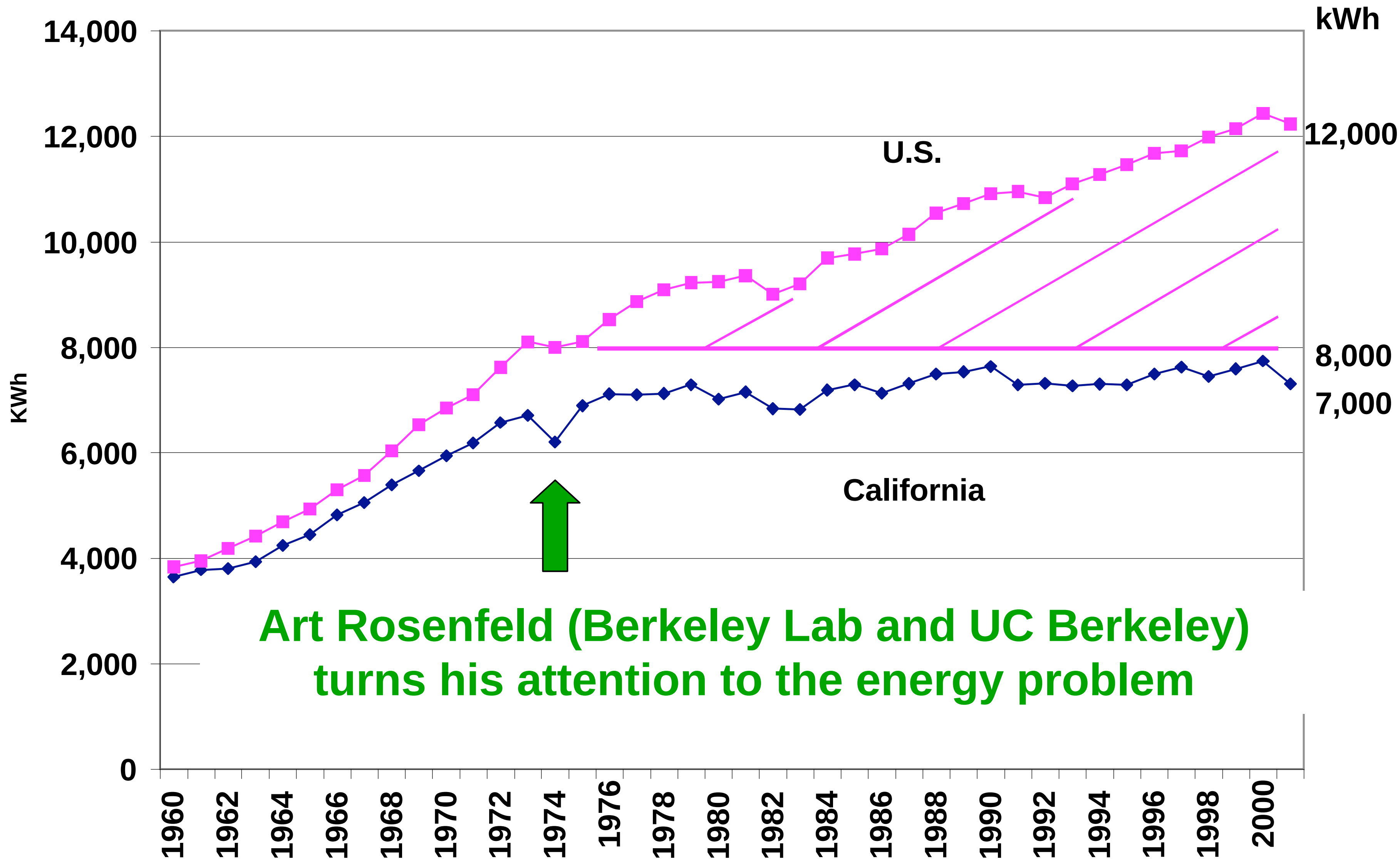
Per Capita Electricity in the U.S. and California (1960-2001)

(Karin)



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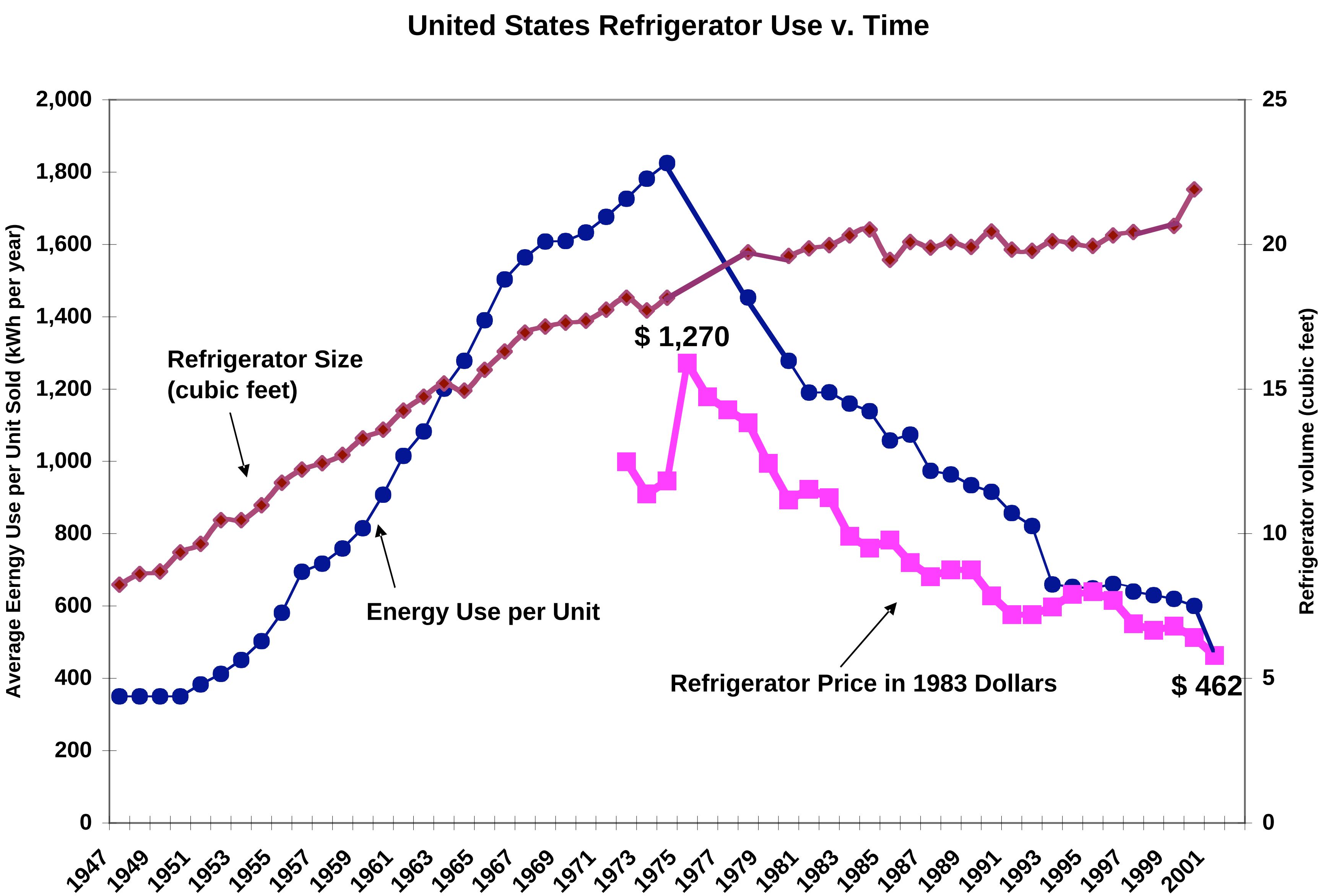
U.S. Refrigerator Energy Use



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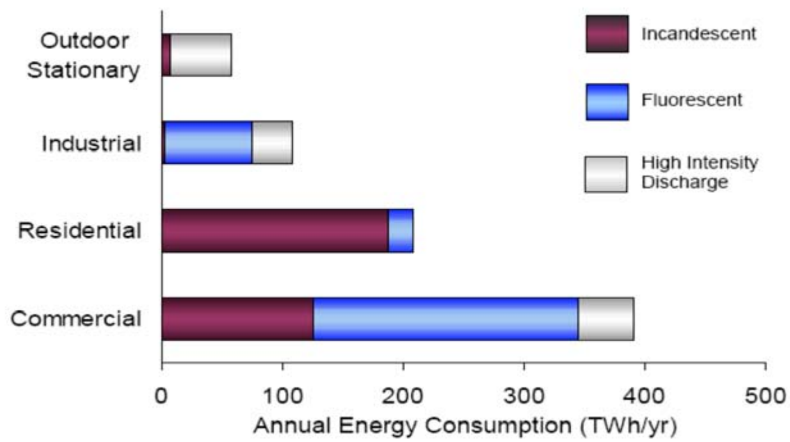
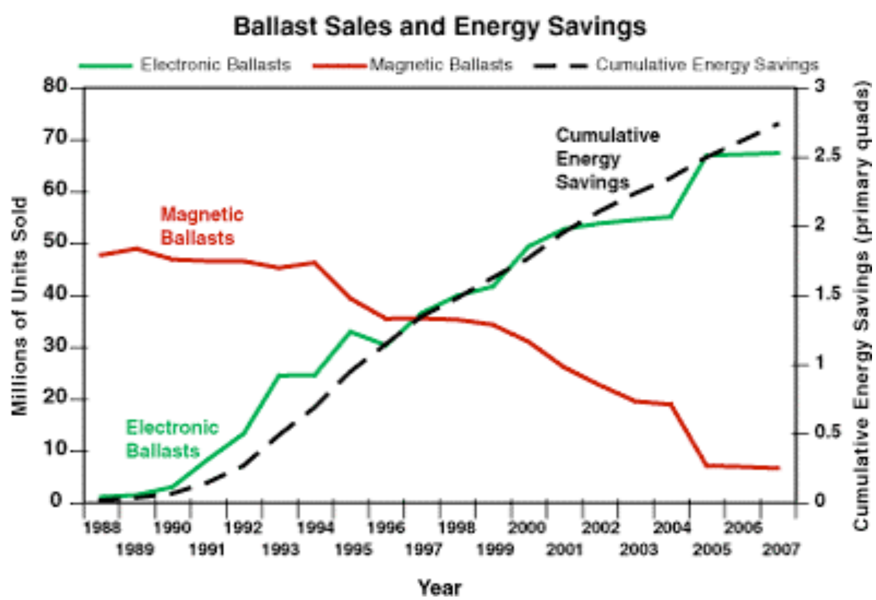
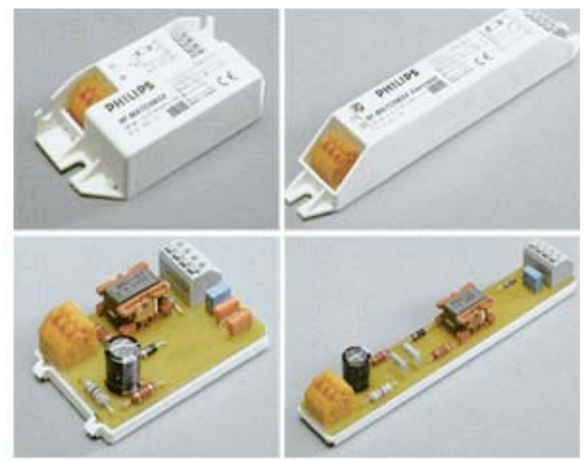
Fluorescent Lighting

390 Billion kWh used for lighting in all commercial buildings in 2001







1 quad = 300 billion kW-hr

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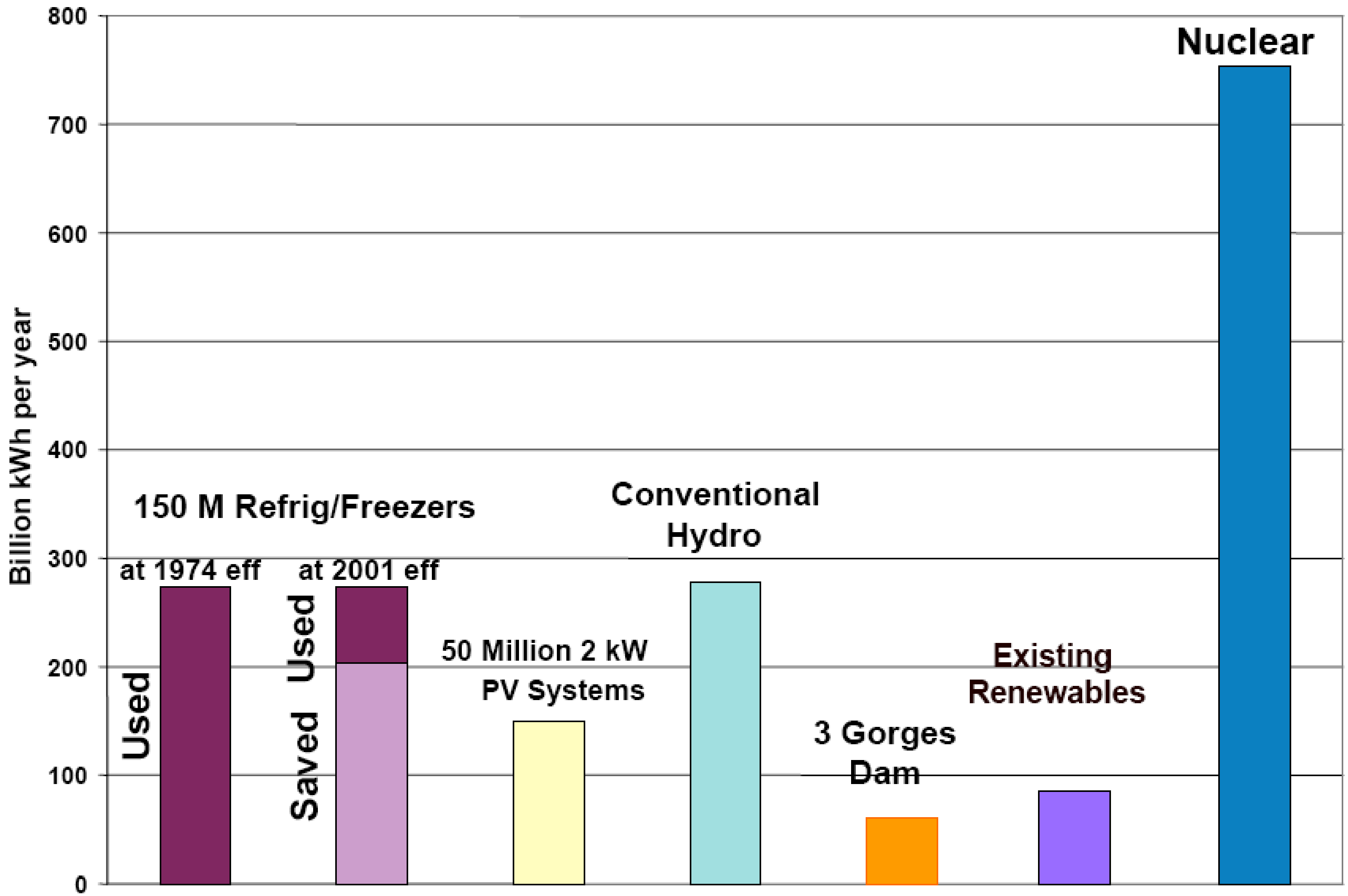
US Electricity Use of Refrigerators and Freezers compared to sources of electricity



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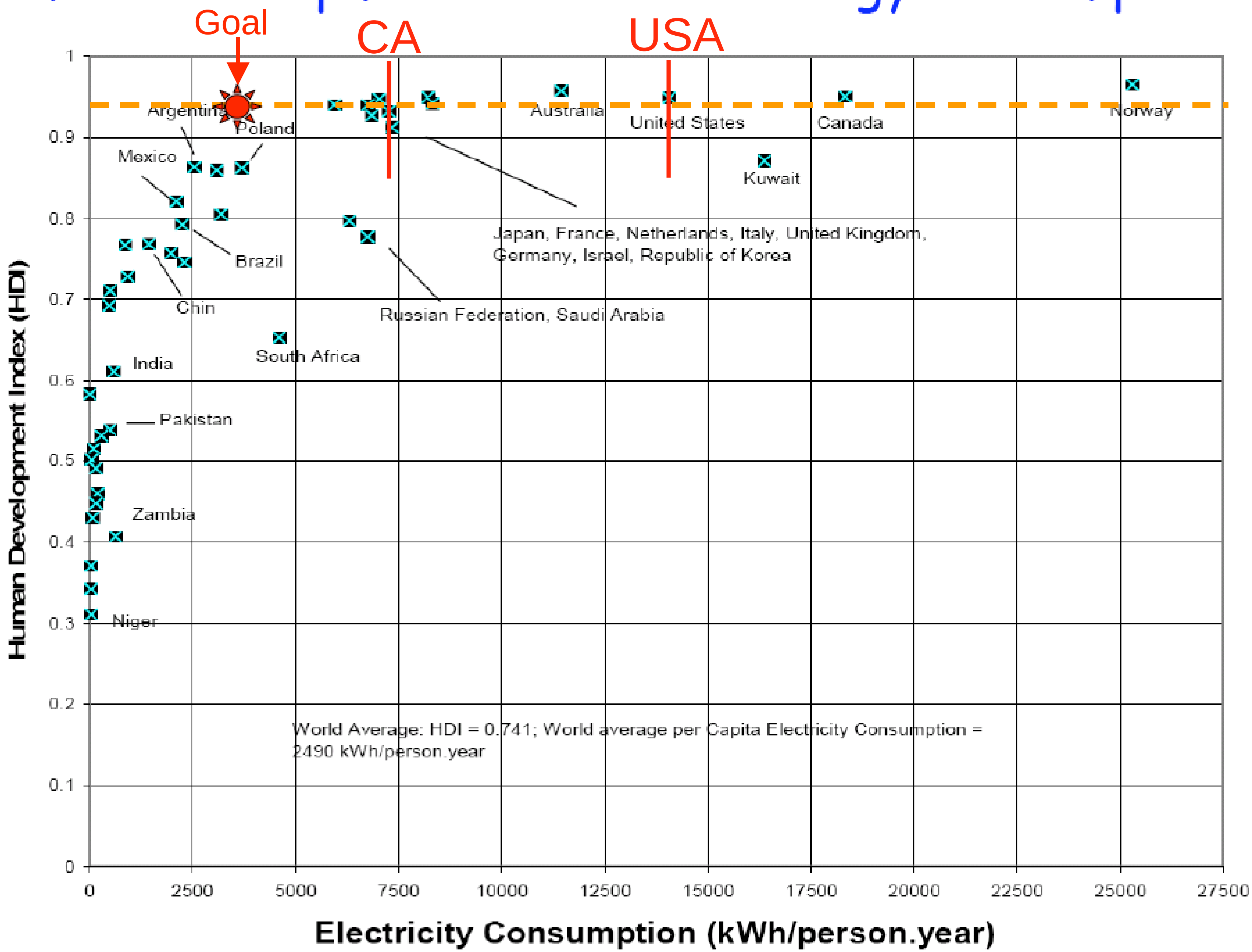
Human Development Index vs. Energy consumption



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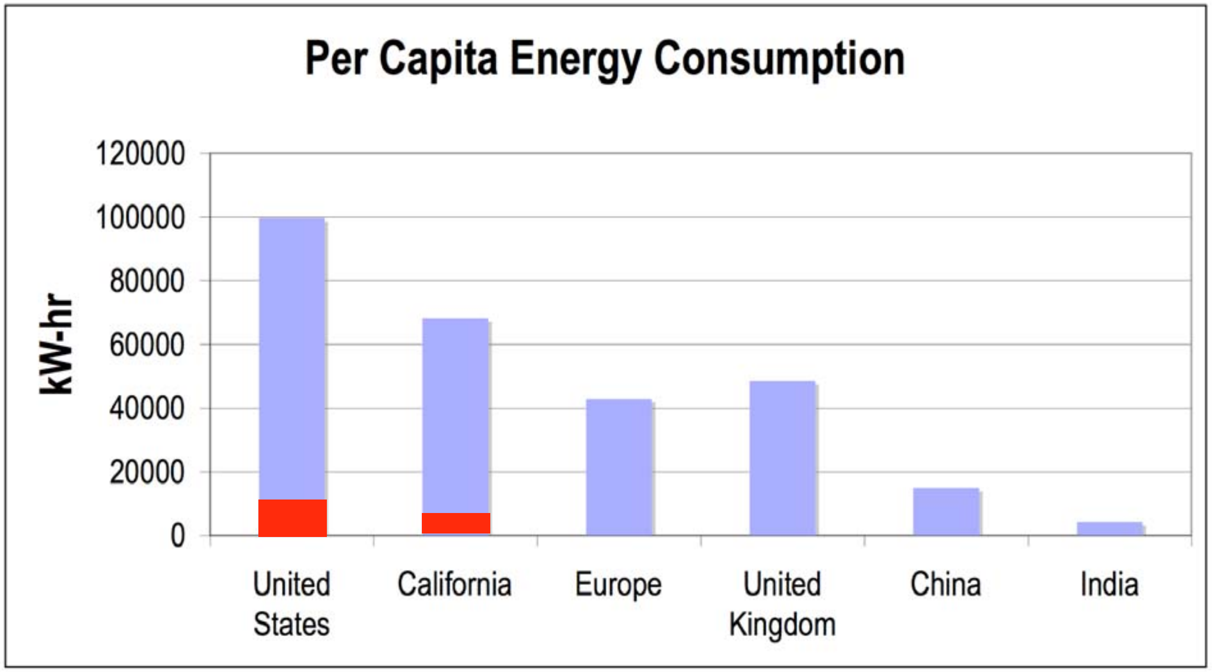
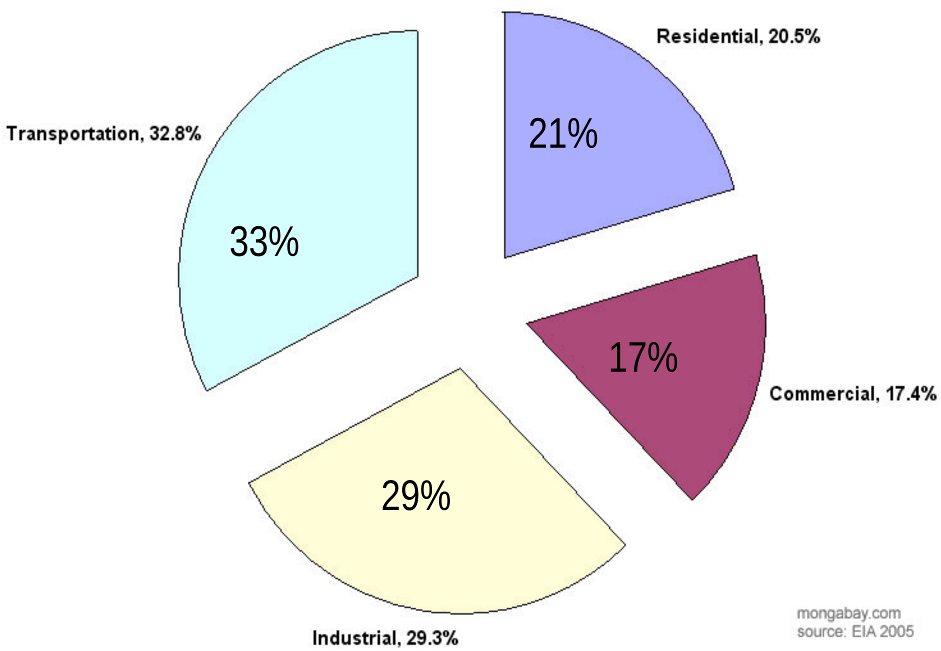
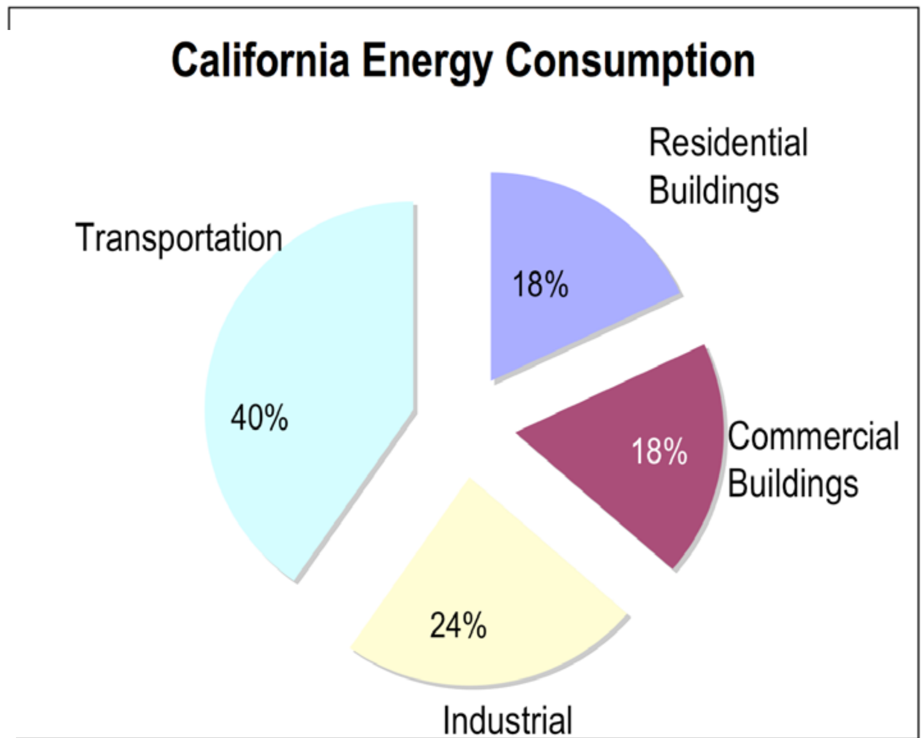
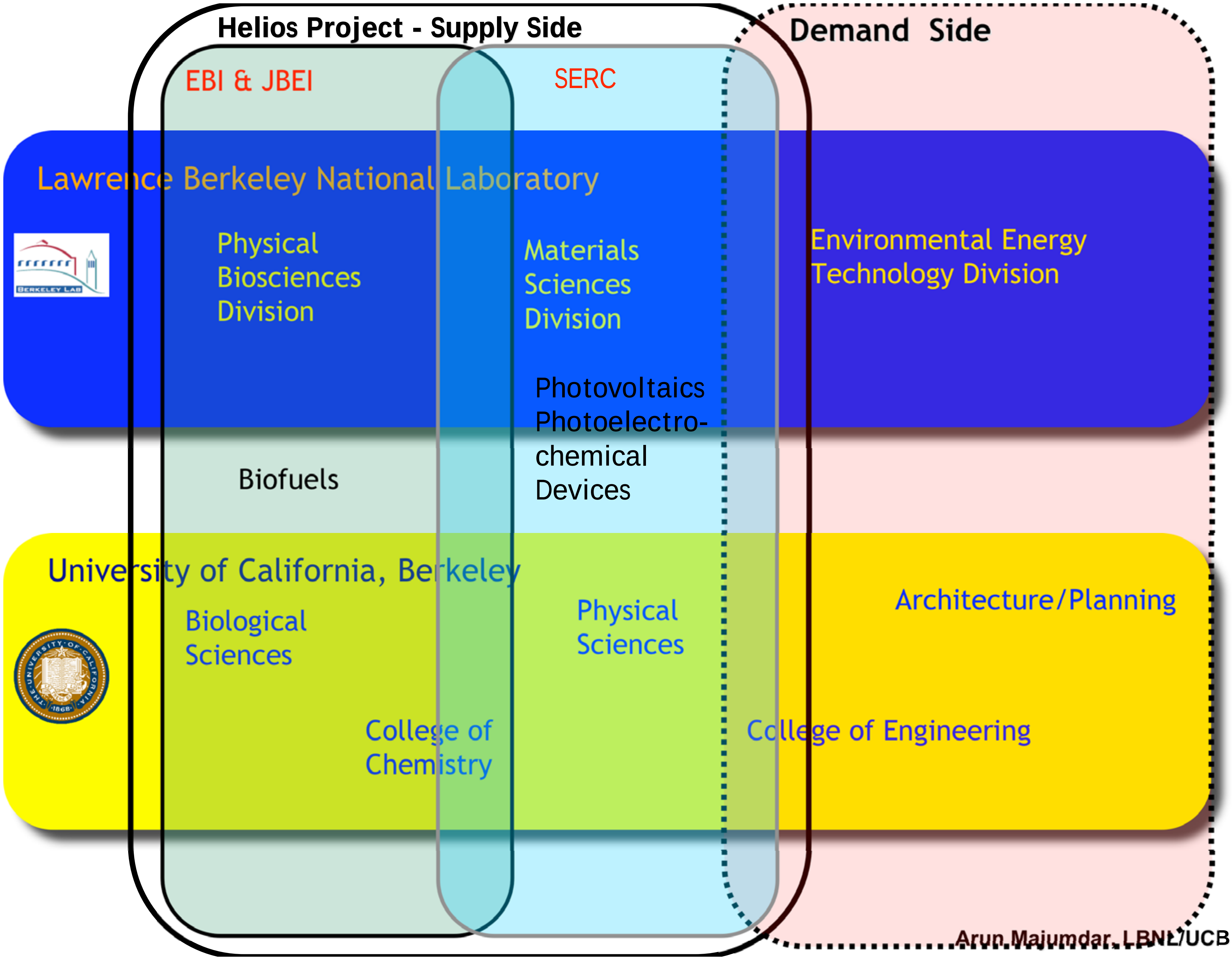


US Energy Consumption






Helios Project - Supply Side
Demand Side
EBI & JBEI
SERC
Lawrence Berkeley National Laboratory
Physical Biosciences Division
Materials Sciences Division
Environmental Energy Technology Division
Photovoltaics Photoelectro-chemical Devices
Biofuels
University of California, Berkeley
Biological Sciences
Physical Sciences
Architecture/Planning
College of Chemistry
College of Engineering
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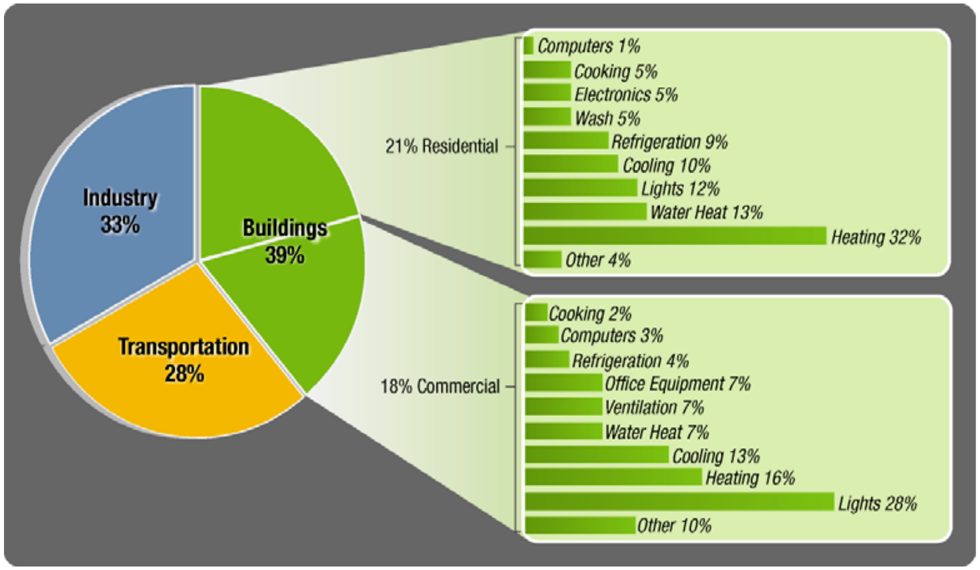
Demand Side



U.S. Buildings consume

- 39% of total U.S. energy
- 71% of U.S. electricity
- 54% of U.S. natural gas

U. S. Buildings produce 48% of Carbon emissions

U.S. Commercial Buildings annual energy bill: $120 billion (2004)

Commercial Building Energy Intensities are increasing

- Electrical Energy consumption *doubled* in last 18 years
- 25% growth projection through 2030

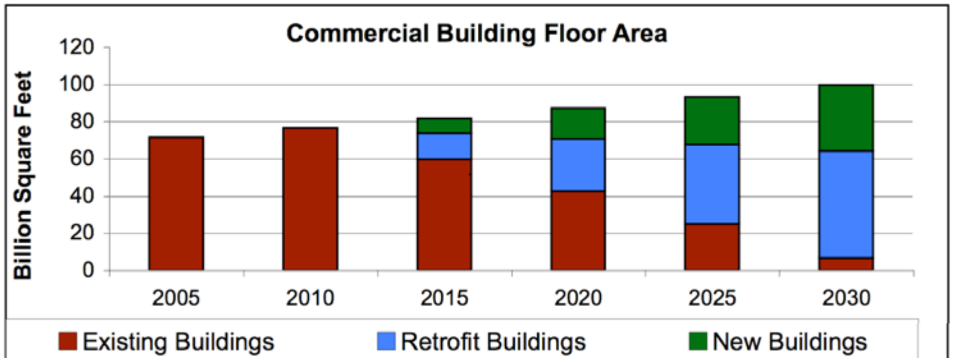
High Performance Buildings Research & Implementation Center (HiPerBRIC)

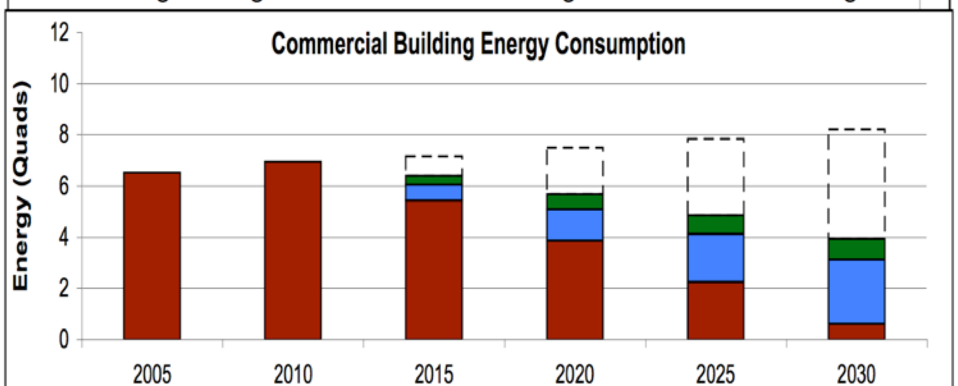
National Lab-Industry-University Partnership

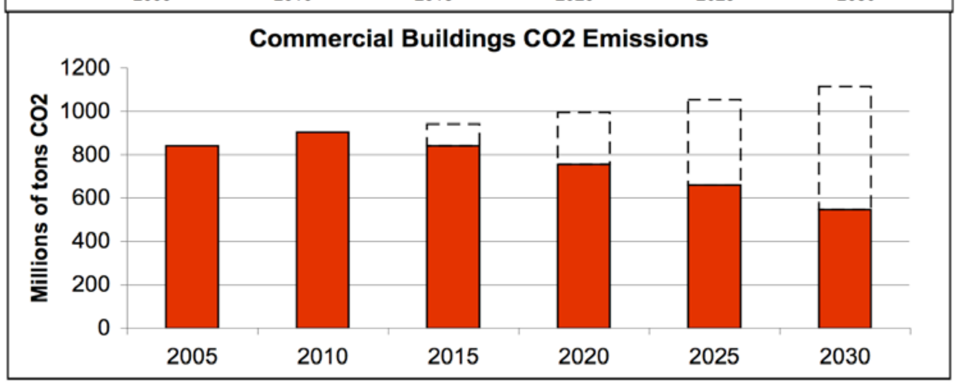
Arun Majumdar
Director, Environmental Energy Technologies Division

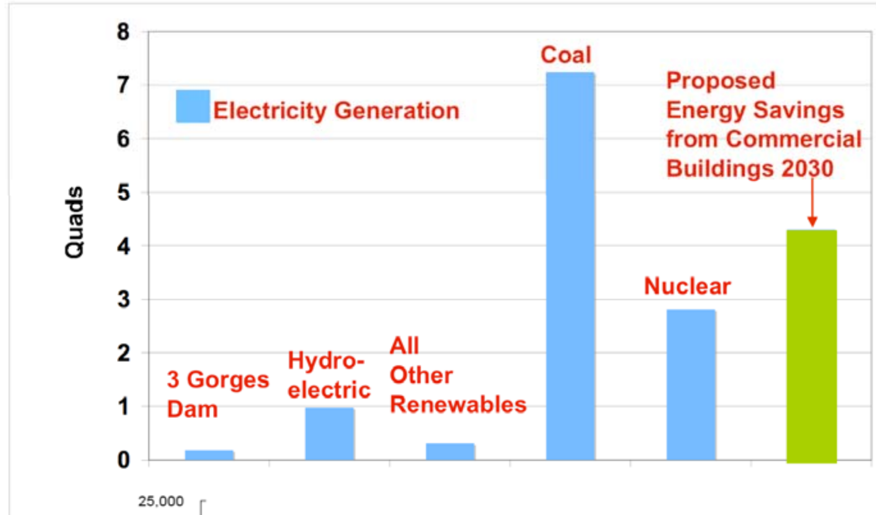
Transforming Commercial Buildings Energy Management

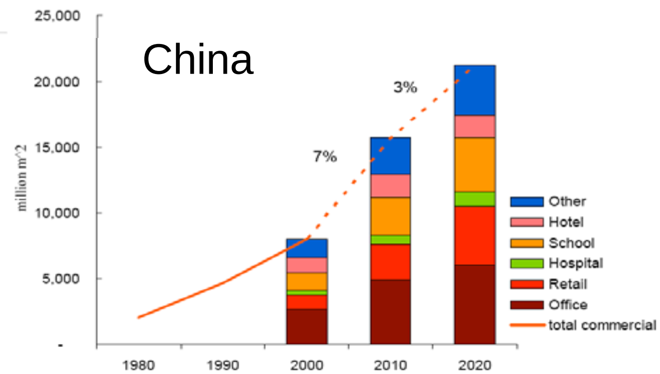
By 2030
- 90% reduction in new buildings
- 50% reduction in retrofitted old buildings

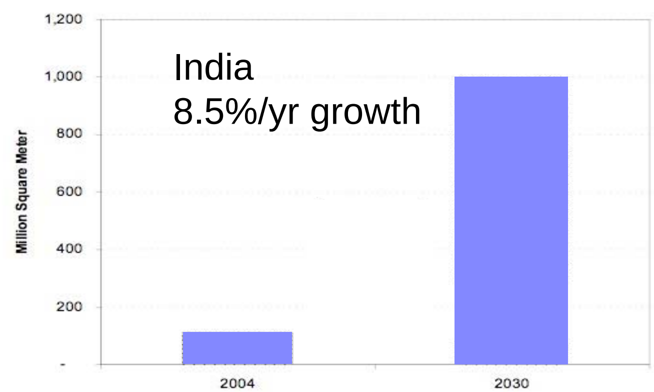






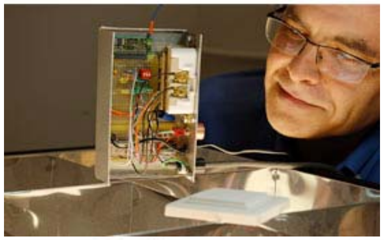






Zero Energy Building

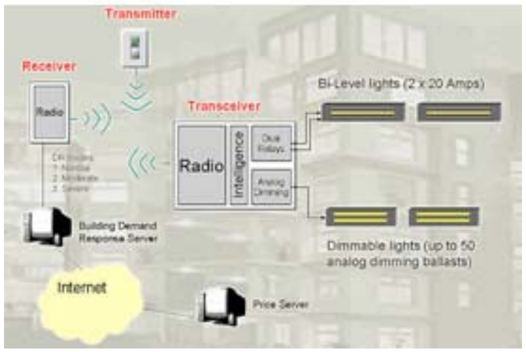
Creating a New Generation of Net-Zero Energy, Carbon-Neutral Buildings



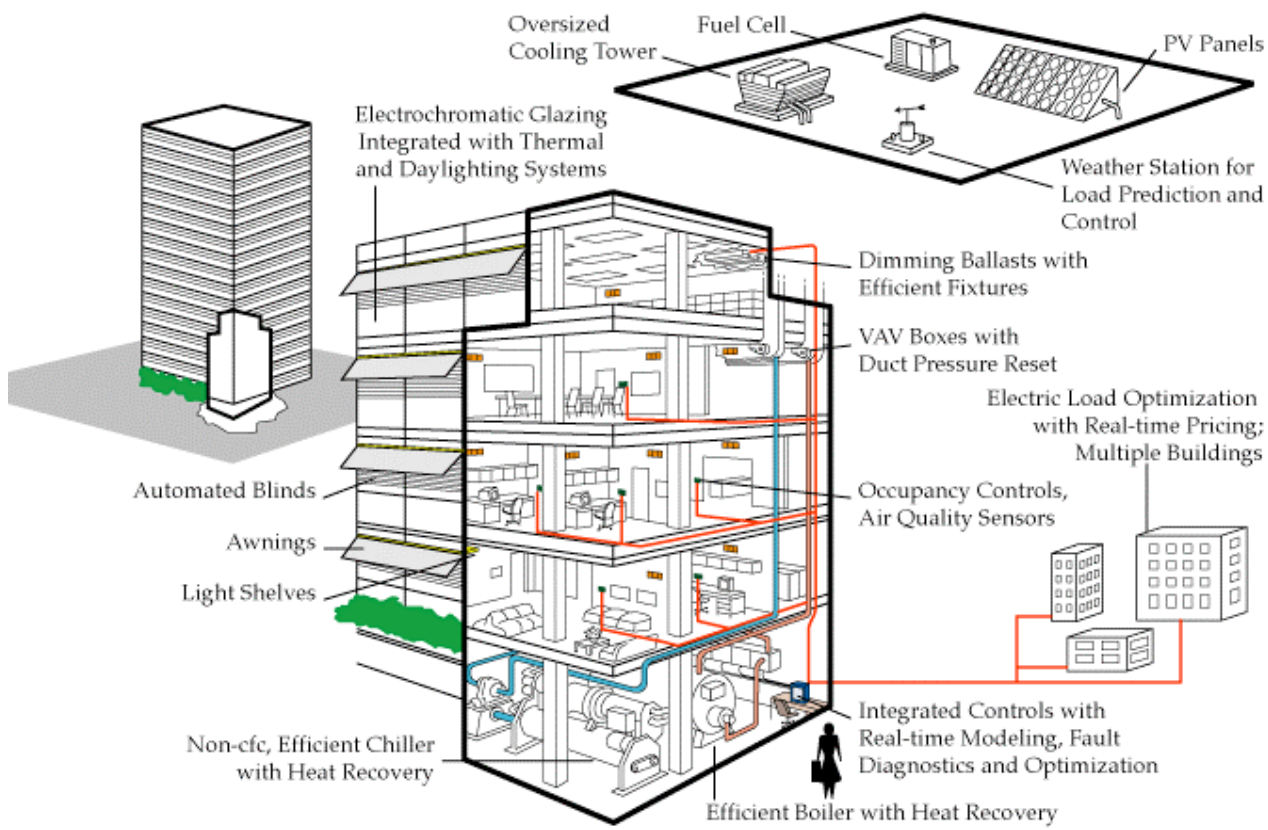
Automation
- Energy sensors & actuators
- Wireless communication
- Feedback control systems

Functional Building Materials
- Thermal
- Structural

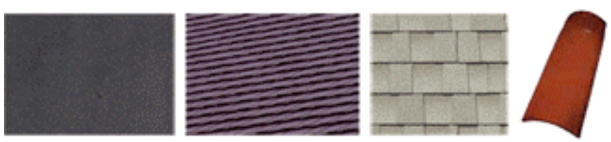
Tunable Windows

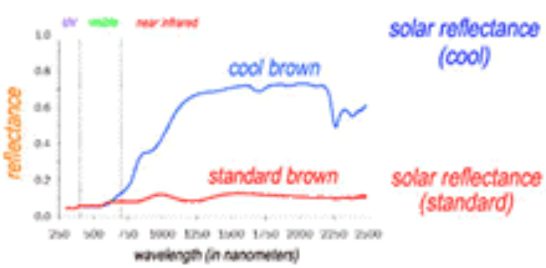


Commercial Building with Integrated System Design and Operations



Cool Stuff





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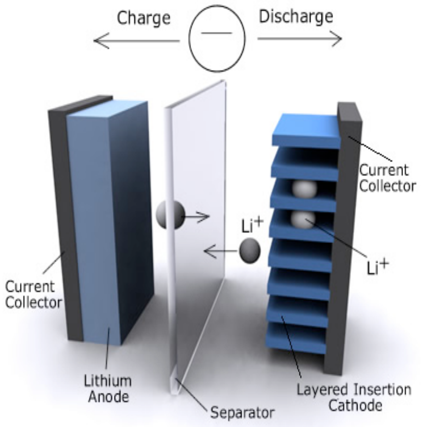
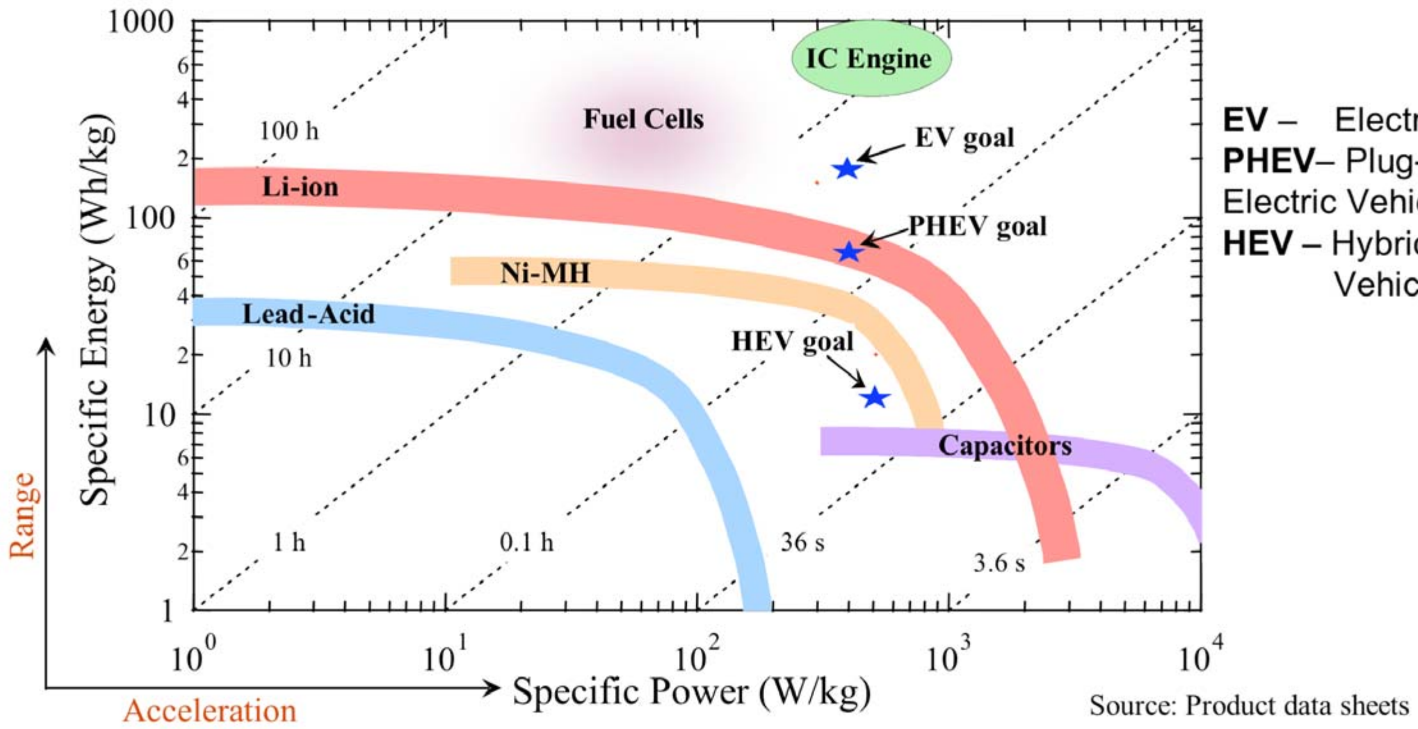
Transportation

Batteries





EV – Electric Vehicle
PHEV– Plug-in Hybrid-Electric Vehicle
HEV – Hybrid-Electric Vehicle

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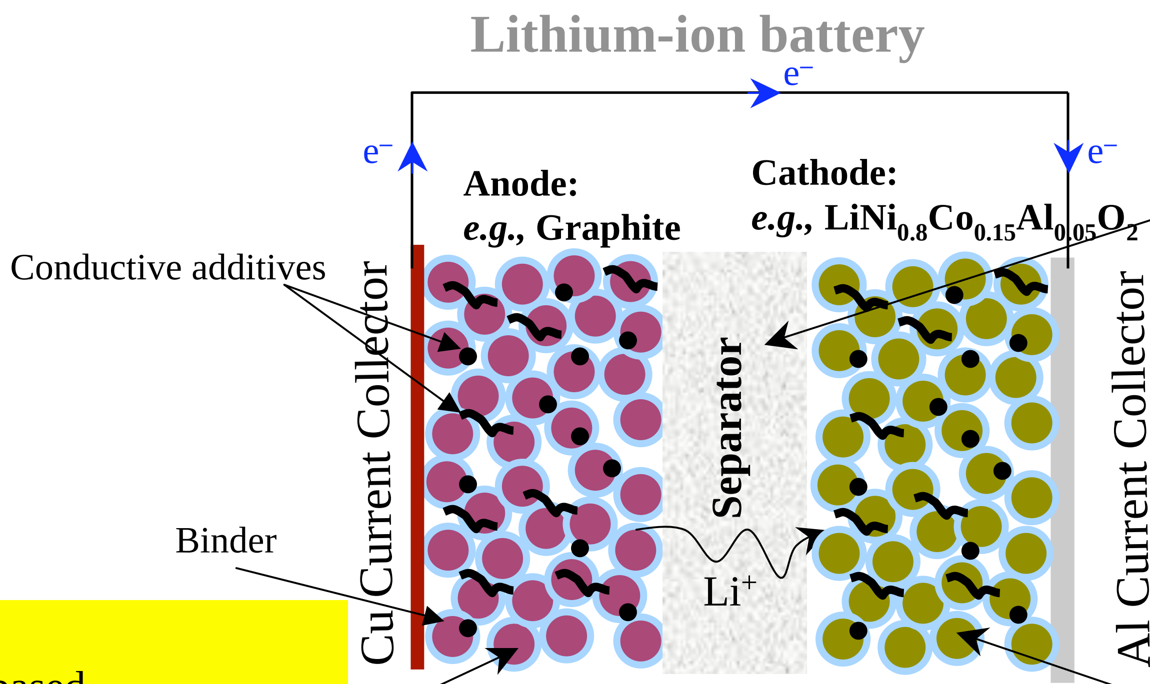
Li Ion Batteries



Electrolyte:
- Liquid organic solvents
- Gel
- Polymers
- Ionic liquids

Anode:
- Carbon-based
- Alloys and intermetallics
- Oxides
- Lithium-metal

Cathode:
- Layered transition-metal oxides
- Spinel-based compositions
- Olivine-based compositions

- A lithium-ion battery is not a single chemistry (unlike a lead-acid battery)

- Presently three classes of cathodes, four classes of anodes, and four classes of electrolytes under consideration for Li-ion cells

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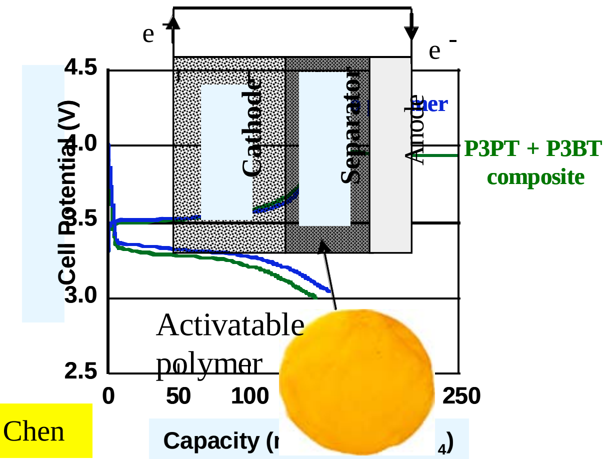
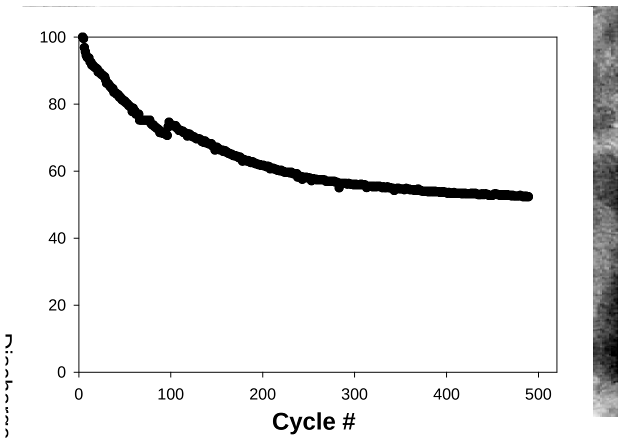
Recent Successes



Polymer for Overcharge Protection:

Developed an activatable-polymer separator that becomes electronically conductive at high voltages. This prevents voltage excursions above the operating range.

T. Richardson and G. Chen



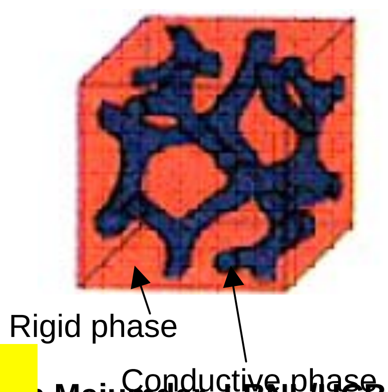
Composite alloy anodes:

Developed a microwave-based technique to deposit nanosized tin particles in a carbon matrix. Carbon matrix allows the accommodation of the large volume changes during cycling, thereby increasing battery life.

R. Kostecki

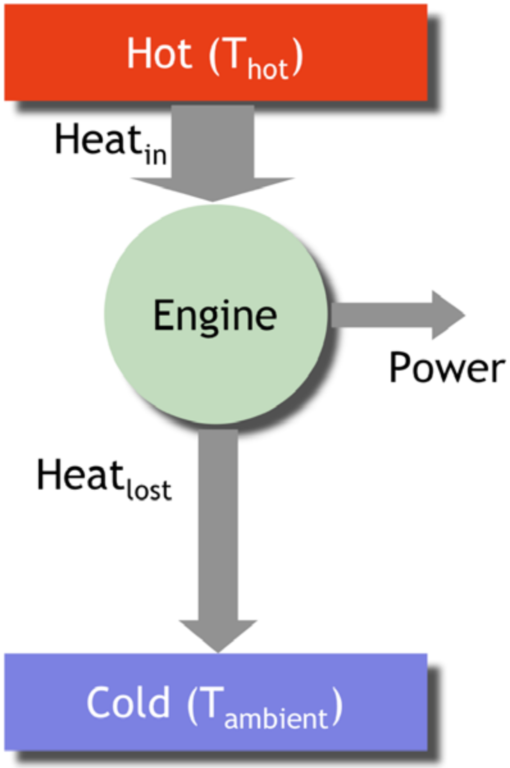
Block Copolymers for Li-metal Batteries:

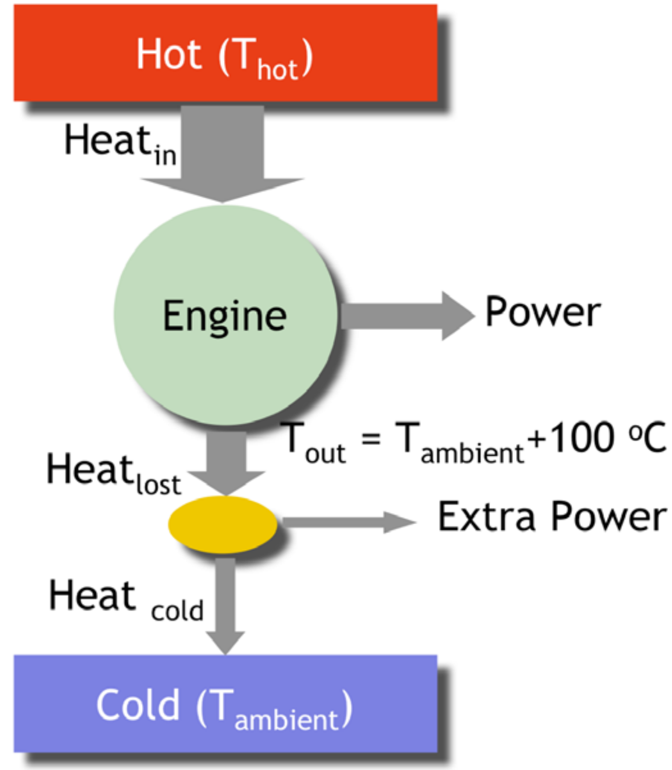
Developed a block co-polymer separator with one phase with high mechanical strength and second phase with high ionic conductivity. When placed against Li-metal the separator prevents growth of dendrites.



N. Balsara

Energy Conversion





Power = 10 TrillionWatts
Efficiency = Power/$Heat_{in}$ ~ 40%
$Heat_{in}$ = 25 TW
$Heat_{lost}$ = 15 TW

Efficiency ~ 3 %
Extra Power = 0.45 TW
US Electrical Capacity = 1 TW (2005)

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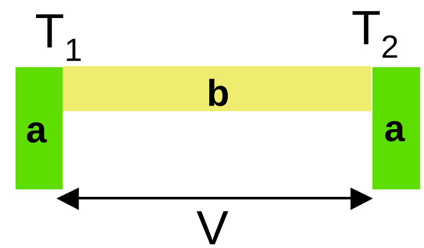
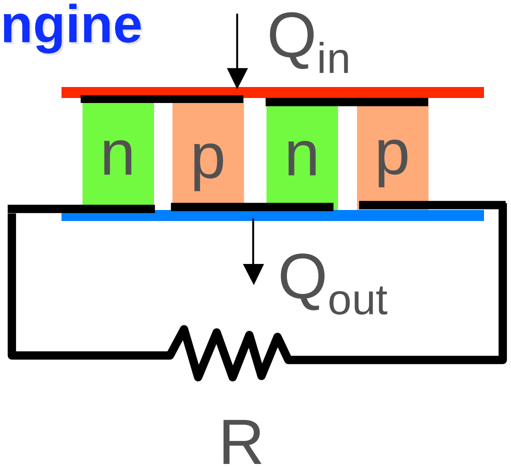
Thermoelectricity & Energy Conversion

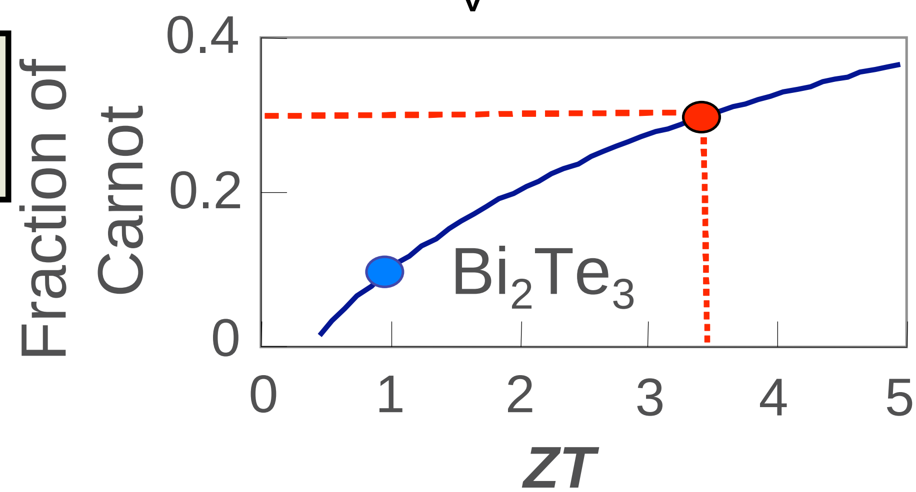
Seebeck Coefficient, $S = V/\Delta T$



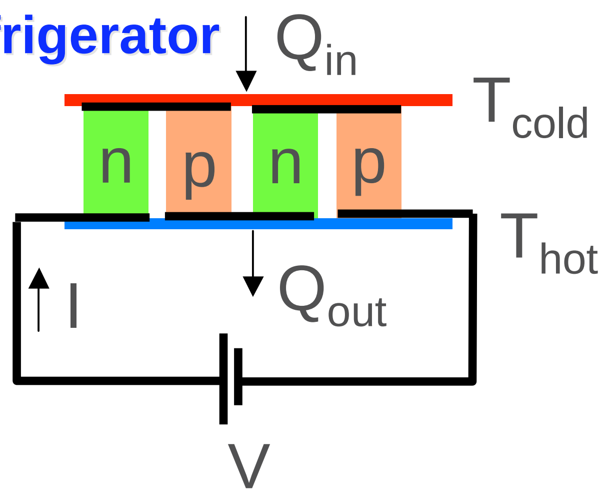
Engine



$$ZT = \frac{S^2 \sigma T}{k}$$

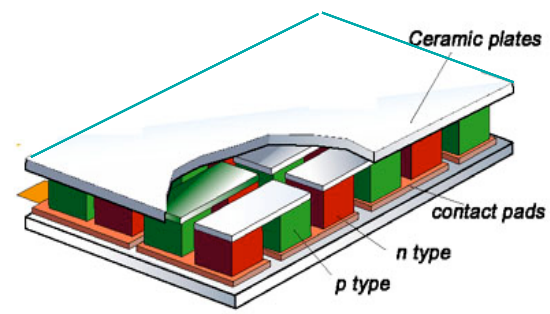


Refrigerator



Bismuth Telluride

(low efficiency, expensive)



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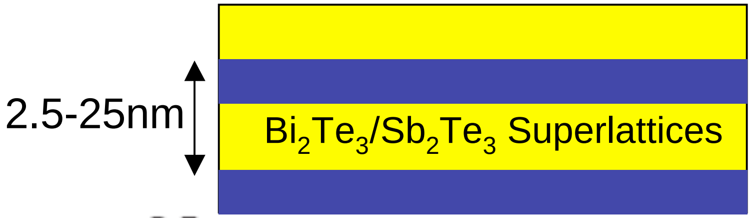
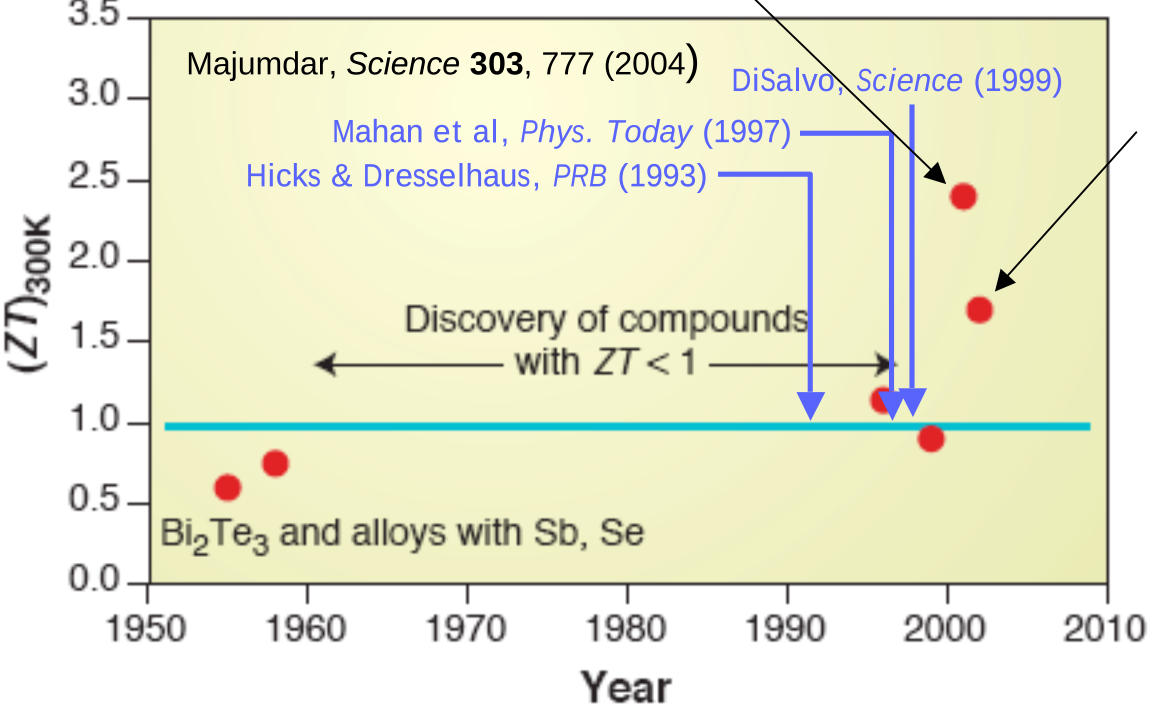
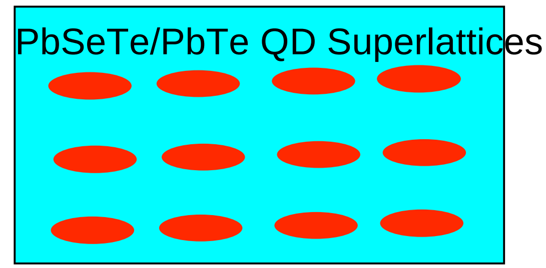
History

Venkatasubramanian et al. *Nature* **413**, 597 (2001)





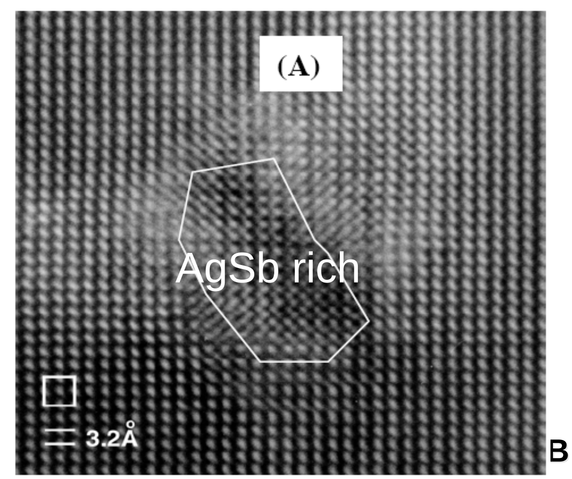
Harman et al., *Science* **297**, 2229 (2002)



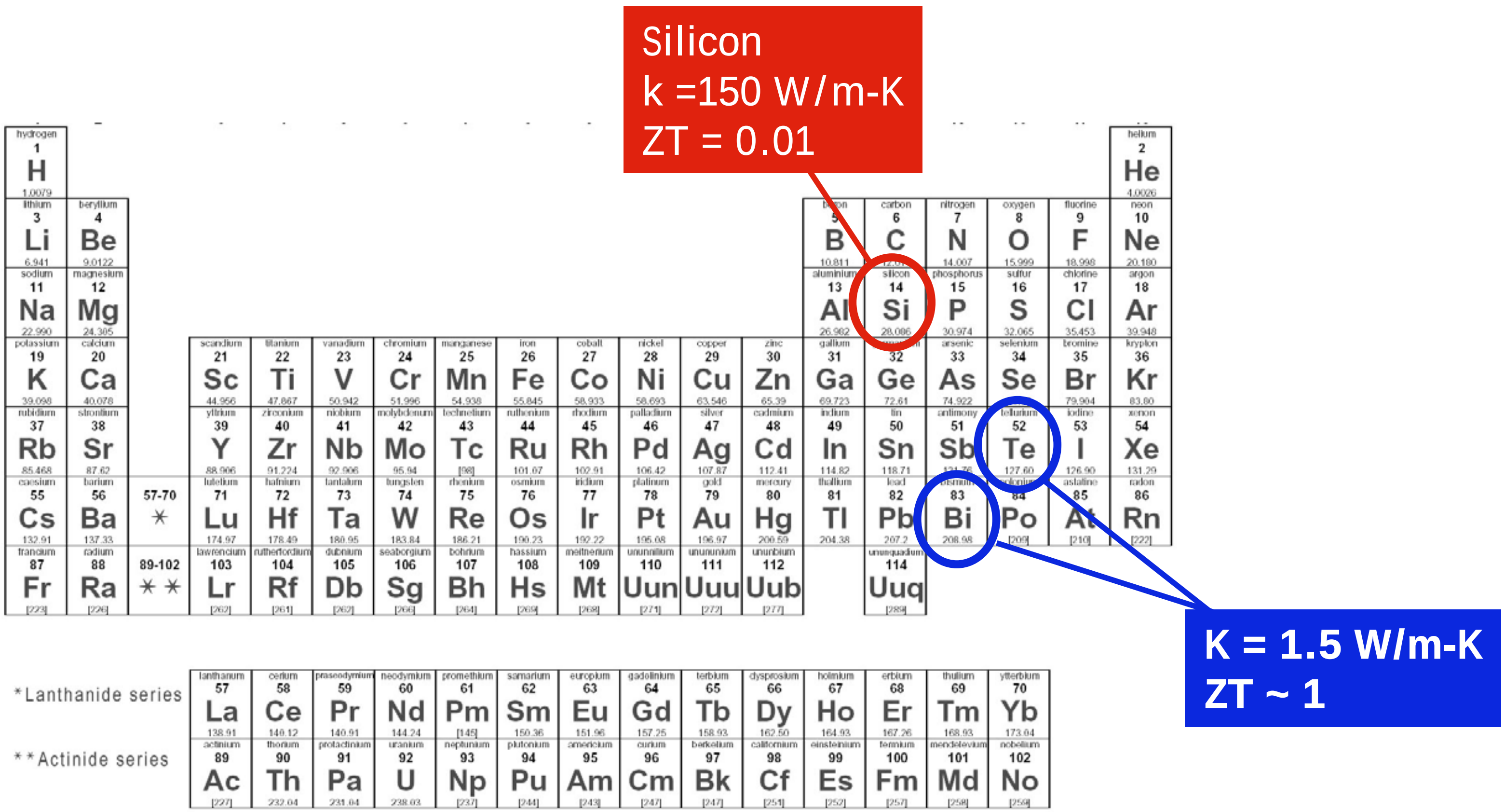
$$ZT = \frac{S^2 \sigma T}{k \downarrow}$$

Hsu et al., *Science* **303**, 818 (2004)

$AgPb_{18}SbTe_{20}$
ZT = 2 @ 800K



Heat Conduction



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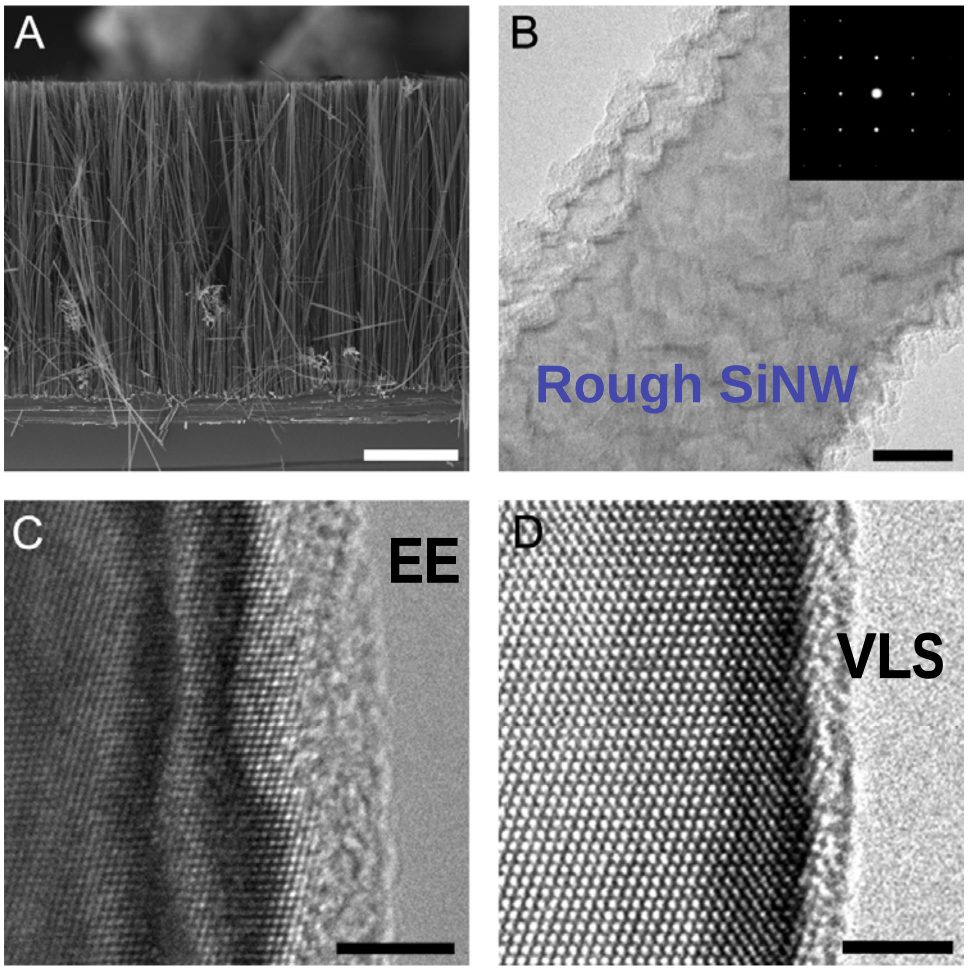
Electroless Etched Si Nanowires

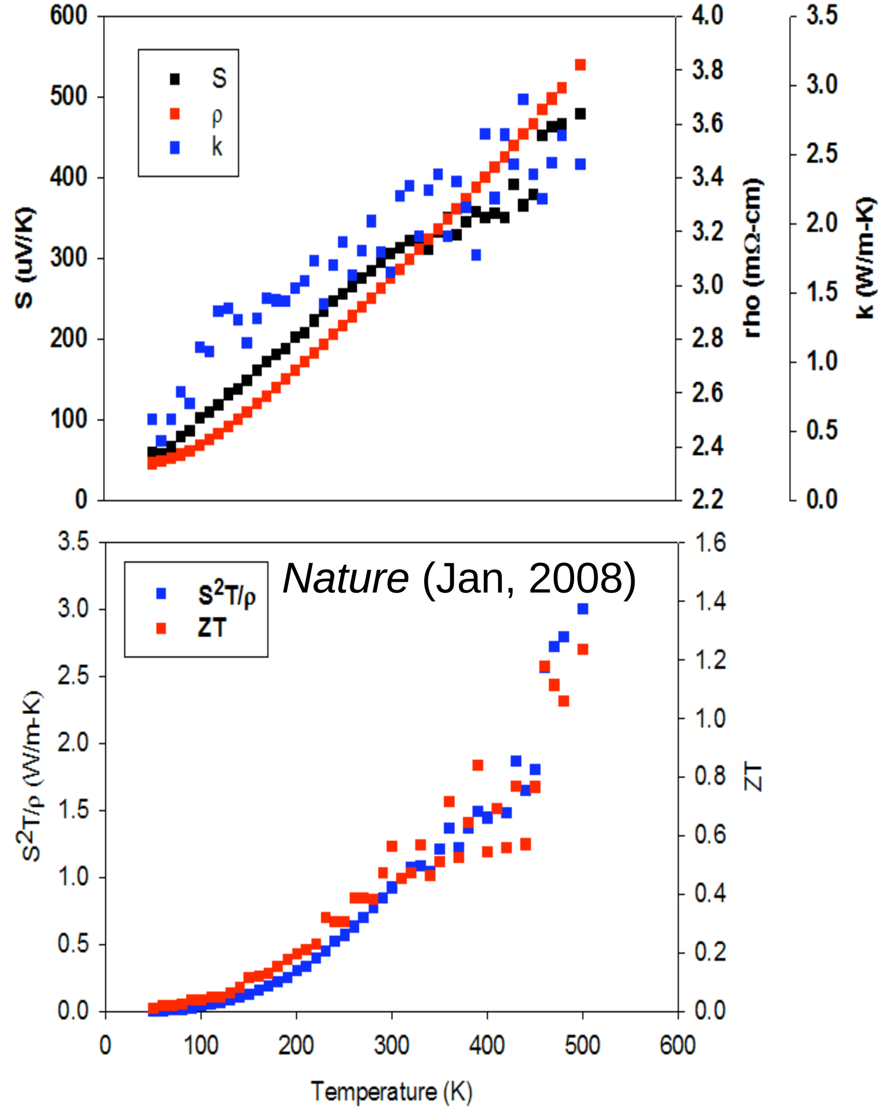
Wafer-Scale Wet Etching Process

Reduction: $Ag^+ + e^-$ -----> Ag $E^0_{red} = 0.7996$ V

Oxidation: $Si + 6F^-$ -----> $SiF_6^{2-} + 4e^-$ $E^0_{ox} = 1.24$ V

Etching of Si at 50 ^{0}C in 5M HF, 0.02M $AgNO_3$ for 1h





Peidong Yang (LBNL/UCB)

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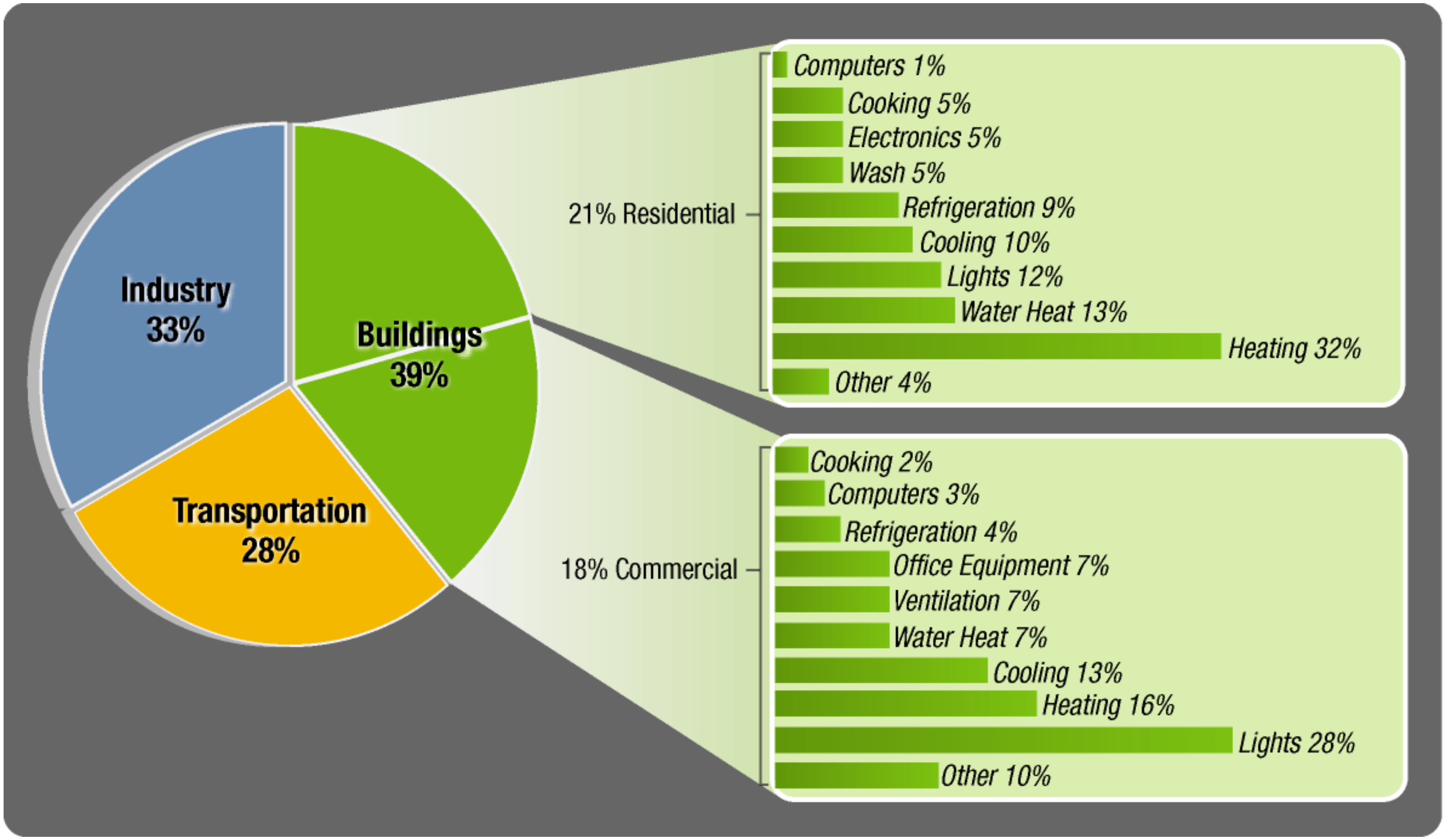
Demand Side

Buildings consume 39% of total U.S. energy

- ***71% of electricity and 54% of natural gas***



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