From the Lab to the Marketplace to Standards
LBNL’s 75th Anniversary

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Nuclear Physics

A Course Given by ENRICO FERMI at the University of Chicago. Notes Compiled by Jay Orear, A. H. Rosenfeld, and R. A. Schluter
Energy Intensity in the United States 1949 - 2005

If intensity dropped at pre-1973 rate of 0.4%/year

Actual (E/GDP drops 2.1%/year)
Energy Consumption in the United States 1949 - 2005

Avoided Supply = 70 Quads in 2005

If E/GDP had dropped 0.4% per year

Actual (E/GDP drops 2.1% per year)

70 Quads per year saved or avoided corresponds to 1 Billion cars off the road

New Physical Supply = 25 Q

$ 1.7 Trillion

$ 1.0 Trillion
Environmental Equivalent of Avoiding 70 Quads

- 70 Quads = 33 Mbod (Million barrels of oil per day)
  = 40% of World oil production of 80 Mbod

- 70 Quads = 1 Billion cars off the road, impressive since there are only 600 million cars on the road
How Much of The Savings Come from Efficiency?

- Easiest to tease out is cars
  - In the early 1970s, only 14 miles per gallons
  - Now about 21 miles per gallon
  - If still at 14 mpg, we’d consume **75 billion gallons more** and pay **$225 Billion more** at 2006 prices
  - But we still pay **$450 Billion per year**
  - If California wins the “Schwarzenegger-Pavley” suit, and it is implemented nationwide, we’ll save **another $150 Billion per year**

- Commercial Aviation improvements save another **$50 Billion per year**

- Appliances and Buildings are more complex
  - We must sort out true efficiency gains vs. structural changes (from smokestack to service economy).
How Much of The Savings Come from Efficiency (cont’d)?

- Some examples of estimated savings in 2006 based on 1974 efficiencies minus 2006 efficiencies

<table>
<thead>
<tr>
<th></th>
<th>Billion $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space Heating</td>
<td>40</td>
</tr>
<tr>
<td>Air Conditioning</td>
<td>30</td>
</tr>
<tr>
<td>Refrigerators</td>
<td>15</td>
</tr>
<tr>
<td>Fluorescent Tube Lamps</td>
<td>5</td>
</tr>
<tr>
<td>Compact Fluorescent Lamps</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>95</strong></td>
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</tbody>
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- Beginning in 2007 in California, reduction of “vampire” or stand-by losses
  - This will save $10 Billion when finally implemented, nation-wide

- Out of a total $700 Billion, a crude summary is that 1/3 is structural, 1/3 is from transportation, and 1/3 from buildings and industry.
A supporting analysis on the topic of efficiency from Vice-President Dick Cheney

“Had energy use kept pace with economic growth, the nation would have consumed 171 quadrillion British thermal units (Btus) last year instead of 99 quadrillion Btus”

“About a third to a half of these savings resulted from shifts in the economy. The other half to two-thirds resulted from greater energy efficiency”

Energy Intensity -- California and the United States

Conservation measures have led to a reduction in energy intensity. The graph shows a comparison between the United States and California.

- The United States has reduced its energy intensity to 54% of its 1973 intensity.
- California has reduced its energy intensity to 46% of its 1973 intensity.

The intensity is measured in thousand Btus per dollar, with the data adjusted to year 2000 values.
Per Capita Electricity Sales (not including self-generation)
(kWh/person) (2005 to 2008 are forecast data)

Δ = 4,000 kWh/yr
= $400/capita
Carbon Dioxide Intensity and Per Capita CO2 Emissions -- 2001
(Fossil Fuel Combustion Only)

United States

Australia
Canada
Netherlands

Belgium

California

Denmark
Germany
New Zealand

Japan

Austria

Italy

S. Korea

France

Mexico

India

China

Tons of CO2 per person

intensity (tons of CO2 per 2000 US Dollar)
CO2 Emissions in California Including Electricity Imports
1990 - 2004

14 year growth rate of 1.1%/year
Comparison of Fuel Economy – Passenger Vehicles

Japan
EU
China
Australia
Canada
California (Pavley)

~

US

MPG Converted to CAFE Test Cycle

(1) dotted lines denote proposed standards
(2) MPG = miles per gallon

Index (1972 = 1.00) of U.S. Energy Use, GDP, Energy Intensity and Carbon Dioxide
last 10-year CO2 growth = 1.3% per year

e/gdp
quads
gdp
CO2 (combustion)
Per Capita Electricity Consumption

Source: http://www.eia.doe.gov/emeu/states/sep_use/total/csv/use_csv
Impact of Standards on Efficiency of 3 Appliances

Impact on Lighting of Building + Appliance Standards

- United States Best Practice measured in Watts/Sq. Ft. of Commercial Building floor area.
- In 1974 = 4 Watts/Sq. Ft.
- In 2006 = 0.8 Watts/Sq. Ft.
- An Enlightened reduction to 1/5
- Drivers: Standards, electronic ballasts, and currently, “scotopic” (blue-ish) color, all thanks to LBNL and Sam Berman.
New Refrigerator Energy Use: 71% will be saved when stock completely turns over to 2001 Standards

Billion kWh per Year

Energy Needed

Energy Saved

At 1974 Efficiency

At 2002 Efficiency
Annual Energy Saved vs. Several Sources of Supply

Energy Saved
Refrigerator Stds
100 Million 1 KW
PV systems
conventional hydro
nuclear energy

Billion kWh/year
Value of Energy to be Saved (at 8.5 cents/kWh, retail price) vs. Several Sources of Supply in 2005 (at 3 cents/kWh, wholesale price)

- Nuclear energy
- Conventional hydro
- Renewables
- PV systems
- Energy Saved Refrigerator Stds

Billion $ (US)/year in 2005

100 Million 1 KW
United States Refrigerator Use, repeated, to compare with
Estimated Household Standby Use v. Time

Average Energy Use per Unit Sold (kWh per year)

- Refrigerator Use per Unit
- 1978 Cal Standard
- 1980 Cal Standard
- 1987 Cal Standard
- 1990 Federal Standard
- 1993 Federal Standard
- 2001 Federal Standard

Estimated Standby Power (per house)
Comparison of 3 Gorges to Refrigerator and AC Efficiency Improvements

三峡电量与电冰箱、空调能效对比

Savings calculated 10 years after standard takes effect. Calculations provided by David Fridley, LBNL
Annual Peak Savings from Efficiency Programs and Standards

~ 22% of Annual Peak in California in 2003
i.e. 22% in 30 years

Utility Efficiency Programs at a cost of
~1% of electric bill

Building Standards

Appliance Standards
Growth = 1.5% / yr
Illuminating Space vs. the Street
Heat Mirror Windows – Steve Selkowitz, LBNL

- Low Emissivity films are required by building standards world-wide. They reflect far infrared radiation. Retain indoor heat in winter, reflect outdoor heat in summer. They double the R-value of double glazing, and the inside pane is warm to the touch – more comfortable

- Before low-E, windows were 30% of the heat load of a home – now 15%.

- During a Montana winter, a north-facing low-E window, facing a snowy sunlit slope, is a net energy gainer.

- “Selective film are required for Commercial Buildings in California. They reflect far- and near-infrared radiation, and halve the solar gain through windows; including car windshields in BMW’s etc.

- Modern windows save ~1 Mbd of oil equivalent, = Alaskan oil.
Cool Colors Reflect Invisible Near-Infrared Sunlight

![Solar Energy Distribution Diagram]

- **5% ultraviolet (300-400 nm)**
- **43% visible (400-700 nm)**
- **52% near-infrared (700-2500 nm)**
http://www.nwhi.net/Vinyl_Windows/Low_E_Glass.htm
Temperature Rise of Various Materials in Sunlight
Dr. Hashem Akbari, LBNL Heat Island Group

![Graph showing temperature rise vs. solar absorptance for various materials.](image-url)
Temperature Trends in Downtown Los Angeles

From Orchards to Blacktops

Eruption of Krakatau, August 27, 1883

Slope = \( \frac{6^\circ F}{50 \text{ yr}} \) / \( \frac{3.9^\circ C}{50 \text{ yr}} \)

\( = \frac{1^\circ F}{8 \text{ yr}} / \frac{1^\circ C}{14 \text{ yr}} \)
Potential Savings in LA

◆ **Savings for Los Angeles**
  - Direct, $200M/year
  - Indirect, $140M/year
  - Smog, $360M/year

◆ **Estimate of national potential savings**: $5B/year
Cool Colors Reflect Invisible Near-Infrared Sunlight

![Solar Energy Distribution Graph](image)

- 5% ultraviolet (300-400 nm)
- 43% visible (400-700 nm)
- 52% near-infrared (700-2500 nm)
From Cool Color Roofs to Cool Color Cars

- Toyota experiment (surface temperature 10K cooler)
- Ford and Fiat are also working on the technology
UV Water Purification

Diagram showing a UV lamp, aluminum reflector, curved stainless steel pan, biologically contaminated water in, and disinfected water out.
Kothapeta (Dec. 2005) commissioning test

Source: Dr. Ashok Gadgil, LBNL
Typical interior layout of the WaterHealth Community System Installation in Kothapeta

Source: Dr. Ashok Gadgil, LBNL
Ashok Gadgil at LBNL points out if UV treatment replaces boiling 10 tons of water per day, each system avoids 3 tons of CO2 per day. An American car emits only 4 tons of CO2 per YEAR. Cost of an avoided ton of CO2 is $0.35, vs. EU price of $20.

- Meet / exceed WHO and US EPA criteria
- Energy efficient: 60 watts disinfects 1 ton / hour
- Low cost: 4 cents disinfects a ton of water
- Reliable, Mature components
- Can treat un-pressurized water
- Rapid throughput: 12 seconds under lamp
- Low maintenance: once every three months
- >50 units now operating in India and Philippines

http://www.waterhealth.com/
Dr. Ashok Gadgil’s Darfur Cookstove Project

In Nov.-Dec. 2005, he visited Darfur camps, and showed that with a $10 metal stove, and training to use it, only half the fuelwood is needed.

The stove saves fuelwood worth $160 annually for a refugee family

Since that time, Ashok Gadgil has improved stove efficiency by another factor of two

http://www.osti.gov/bridge/servlets/purl/878538-hMpqN3/878538.PDF
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http://www.ifc.org/led
Evan Mills at LBNL points out the following:

- If 1.6 billion people could replace kerosene lamps with LEDs, emissions would drop by the equivalent of 1.3 million barrels of petroleum per day

http://eetd.lbl.gov/emills/PUBS/Fuel_Based_Lighting.html

- The above estimate was for residential lamps only
- Including commercial uses, Mills estimates > 2 Mboe
- For comparison, U.S. gasoline use is 9 Mboe
Hurricane lanterns

- Teachers grading homework with light levels 1% of western standards

Tanzania (teachers’ home)
Productive uses

Tanzania: fruit seller - flame [left]; 1-watt white LED [right]
Productive uses: big market driver

Tanzania: shoe seller - flame [left]; 1-watt white LED [right]
Growth = 1.5%/yr
This talk available on my web page

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