Efficient Use of Energy

Physics Colloquium at UC Davis

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http://www.energy.ca.gov/commissioners/rosenfeld.html
or just Google “Art Rosenfeld”
Some Background Reading

• For a Full (51 page) Biography of Dr. Rosenfeld, see his web site at: http://www.energy.ca.gov/commissioners/rosenfeld_docs/index.html

• This Presentation Based on Work Published as:


The symposium is available at http://rael.berkeley.edu/files/apsenergy/
Does Anyone See A Problem With This Picture?
Two Energy Agencies in California

- The California Public Utilities Commission (CPUC) was formed in 1890 to regulate natural monopolies, like railroads, and later electric and gas utilities.
- The California Energy Commission (CEC) was formed in 1974 to regulate the environmental side of energy production and use.
- Now the two agencies work very closely, particularly to delay climate change.
- The Investor-Owned Utilities, under the guidance of the CPUC, spend “Public Goods Charge” money (rate-payer money) to do everything they can that is cost effective to beat existing standards.
- The Publicly-Owned utilities (20% of the power), under loose supervision by the CEC, do the same.
California Energy Commission Responsibilities

Both Regulation and R&D

• California Building and Appliance Standards
  – Started 1977
  – Updated every few years
• Siting Thermal Power Plants Larger than 50 MW
• Forecasting Supply and Demand (electricity and fuels)
• Research and Development
  – ~ $80 million per year
• CPUC & CEC are collaborating to introduce communicating electric meters and thermostats that are programmable to respond to time-dependent electric tariffs.

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

Actual (E/GDP drops 2.1%/year)

France

12% of GDP = $1.7 Trillion in 2005

7% of GDP = $1.0 Trillion In 2005
In 2005
$1.7 Trillion
Avoided Supply = 70 Quads in 2005

If E/GDP had dropped 0.4% per year

$1.0 Trillion
New Physical Supply = 25 Q

Actual (E/GDP drops 2.1% per year)

70 Quads per year saved or avoided corresponds to 1 Billion cars off the road
How Much of The Savings Come from Efficiency

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

<table>
<thead>
<tr>
<th>Item</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 Flourescent Lamps</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>95</strong></td>
</tr>
</tbody>
</table>

• 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.
California’s Energy Action Plan

- California’s Energy Agencies first adopted an Energy Action Plan in 2003. Central to this is the State’s preferred “Loading Order” for resource expansion.

- 1. Energy efficiency and Demand Response
- 2. Renewable Generation,
- 3. Increased development of affordable & reliable conventional generation
- 4. Transmission expansion to support all of California’s energy goals.

- The Energy Action Plan has been updated since 2003 and provides overall policy direction to the various state agencies involved with the energy sectors
Per Capita Electricity Sales (not including self-generation)
(kWh/person) (2006 to 2008 are forecast data)

2005 Differences
= 5,300 kWh/yr
= $165/capita

Per Capita Income in Constant 2000 $

<table>
<thead>
<tr>
<th></th>
<th>1975</th>
<th>2005</th>
<th>% change</th>
</tr>
</thead>
<tbody>
<tr>
<td>US GDP/capita</td>
<td>16,241</td>
<td>31,442</td>
<td>94%</td>
</tr>
<tr>
<td>Cal GSP/capita</td>
<td>18,760</td>
<td>33,536</td>
<td>79%</td>
</tr>
</tbody>
</table>
Utility Efficiency Programs at a cost of ~1% of electric bill

~15% of Annual Electricity Use in California in 2003

Appliance Standards

Building Standards

Annual Energy Savings from Efficiency Programs and Standards

GWh/year

Impact of Standards on Efficiency of 3 Appliances

New United States Refrigerator Use v. Time
and Retail Prices

Source: David Goldstein
Annual Energy Saved vs. Several Sources of Supply
In the United States

- 100 Million 1 KW PV systems
- conventional hydro
- renewables
- nuclear energy

Billion kWh/year

- Energy Saved Refrigerator Stds
- 100 Million 1 KW PV systems
- = 80 power plants of 500 MW each
In the United States

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)

<table>
<thead>
<tr>
<th>Source of Supply</th>
<th>Value in Billion $ (US)/year in 2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy Saved Refrigerator Stds</td>
<td>15</td>
</tr>
<tr>
<td>100 Million 1 KW PV systems</td>
<td>10</td>
</tr>
<tr>
<td>Conventional hydro</td>
<td>4</td>
</tr>
<tr>
<td>Renewables</td>
<td>2</td>
</tr>
<tr>
<td>Nuclear energy</td>
<td>20</td>
</tr>
</tbody>
</table>
Air Conditioning Energy Use in Single Family Homes in PG&E
The effect of AC Standards (SEER) and Title 24 standards

If only increases in house size -- no efficiency gains
Change due to SEER improvements
SEER plus Title 24
Comparison of 3 Gorges to Refrigerator and AC Efficiency Improvements

三峡谷电量与电冰箱、空调能效对比

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

~15% of Annual Electricity Use in California in 2003

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

Building Standards

Appliance Standards
California IOU’s Investment in Energy Efficiency

- **Profits decoupled from sales**
- **2% of 2004 IOU Electric Revenues**
- **Performance Incentives**
- **Market Restructuring**
- **Crisis**
- **IRP**
- **Forecast**

### Chart Details:
- **X-axis:** Years from 1976 to 2012
- **Y-axis:** Millions of $2002 per Year
- **Legend:**
  - Public Goods Charges
  - 2% of 2004 IOU Electric Revenues
  - Performance Incentives
  - Market Restructuring
  - Crisis
  - IRP
  - Forecast
Energy Efficiency Incentive Mechanism Earnings/Penalty Curve

\( \text{Earnings} = \text{ER} \times \text{PEB} \)

\( \text{PEB} = \text{Performance Earnings Basis} \)

\( \text{ER} = \text{Earnings Rate (or Shared-Savings Rate)} \)

Source: NRDC; Chang and Wang, 9/26/2007

Earnings capped at $450 million
Penalty capped at $450 million.

5¢/kWh, $25/kW, 45¢/therm below goals, or payback of negative net benefits (cost-effectiveness guarantee), whichever is greater.
To be published in Climatic Change 2008.

Global Cooling: Increasing World-wide Urban Albedos to Offset CO2

July 28, 2008

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A First Step In Geo-Engineering Which Saves Money and Has Known Positive Environmental Impacts
1000 ft² of a white roof, replacing a dark roof, offset the emission of 10 tonnes of CO₂
CO\textsubscript{2} Equivalency of Cool Roofs World-wide (Tropics+Temperate)

- Cool Roofs alone offset 24 Gt CO\textsubscript{2}
- Worth > €600 Billion
- To Convert 24 Gt CO\textsubscript{2} one time into a rate
- Assume 20 Year Program, thus
  1.2 Gt CO\textsubscript{2}/year
- Average World Car Emits 4 tCO\textsubscript{2}/year,
  equivalent to 300 Million Cars off the Road for 20 years.
• AT UC DAVIS:
• Daniel Sperling: Acting Director
• Alan Meier: Associate Director and Faculty Researcher
• Mark Modera: Director of the Western Cooling Efficiency Center
• Michael Siminovitch: Director of the California Lighting Technology Center (CLTC)
Methodology: Energy and Air-Quality Analysis

Strategies:
- Cooler Roofs
- Shade Trees
- Cooler Pavements
- All Vegetation

Processes:
- Reduces A/C Use
- Reduces Demand at Power Plants
- Area Sources Emit Less
- Slows Reaction Rates

Results:
- Less Energy Consumed
- Lower CO₂, NOₓ, and VOC Levels
- Lower Ozone Levels

Direct
Indirect
White is ‘cool’ in Bermuda
and in Santorini, Greece
Cool Roof Technologies

Old

flat, white

New

pitched, cool & colored

pitched, white
Cool Colors Reflect Invisible Near-Infrared Sunlight

![Solar Energy Distribution Chart]

- **UV**: 5% ultraviolet (300-400 nm)
- **Visible**: 43% visible (400-700 nm)
- **Near-Infrared**: 52% near-infrared (700-2500 nm)
Cool and Standard Brown Metal Roofing Panels

- Solar reflectance ~ 0.2 higher
- Afternoon surface temperature ~ 10°C lower
Designing Cool Colored Roofing

<table>
<thead>
<tr>
<th>Material</th>
<th>Solar Reflectance Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>cool concrete tile</td>
<td>+0.37</td>
</tr>
<tr>
<td>R ≥ 0.40</td>
<td></td>
</tr>
<tr>
<td>standard concrete tile (same color)</td>
<td>+0.26</td>
</tr>
<tr>
<td>R = 0.18</td>
<td></td>
</tr>
<tr>
<td>solar reflectance gain =</td>
<td>+0.23</td>
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<tr>
<td>R = 0.21</td>
<td></td>
</tr>
<tr>
<td>solar reflectance gain =</td>
<td>+0.15</td>
</tr>
<tr>
<td>R = 0.33</td>
<td></td>
</tr>
<tr>
<td>solar reflectance gain =</td>
<td>+0.29</td>
</tr>
<tr>
<td>R = 0.17</td>
<td></td>
</tr>
<tr>
<td>solar reflectance gain =</td>
<td>+0.29</td>
</tr>
<tr>
<td>R = 0.12</td>
<td></td>
</tr>
</tbody>
</table>

- **cool clay tile**
  - R ≥ 0.40
  - Courtesy MCA Clay Tile

- **cool metal**
  - R ≥ 0.30
  - Courtesy BASF Industrial Coatings

- **cool fiberglass asphalt shingle**
  - R ≥ 0.25
  - Courtesy Elk Corporation
Cool is Cool: From Cool Color Roofs to Cool Color Cars and Cool Jackets

- Toyota experiment (surface temperature 10K cooler)
- Ford is also working on the technology

Courtesy: BMW (http://www.ips-innovations.com/solar_reflective_clothing.htm)
The End

For More Information:

http://www.energy.ca.gov/commissioners/rosenfeld_docs/index.html

or just Google “Art Rosenfeld”
Cool Paving Materials:
Reflective Pavements are Cooler

- Fresh asphalt
  Albedo: 0.05
  Temperature: 123°F

- Aged asphalt
  Albedo: 0.15
  Temperature: 115°F

- Prototype asphalt coating
  Albedo: 0.51
  Temperature: 88°F
Temperature Effect on Rutting

![Temperature Effect on Rutting Graph](image)

**Source:** Dr. John Harvey, UC B Civil Engineering, Inst. Transpo. Studies
Simulated Meteorology and Air-quality Impacts in LA

Temperature Change

Ozone Concentration Change
Potential Savings in LA

- **Savings for Los Angeles**
  - Direct, $100M/year
  - Indirect, $70M/year
  - Smog, $360M/year

- **Estimate of national savings**: $5B/year
Solar Reflective Surfaces Also Cool the Globe

Source: IPCC
Effect of Solar Reflective Roofs and Pavements in Cooling the Globe

(Source: Akbari et al. 2008, in press Climatic Change)

- Increasing the solar reflectance of a m² of roofs by 0.40 (white roof) is equivalent to offsetting 63 kg CO₂ emissions (10 m² of white roof = 1 T CO₂ emission offset)
- Increasing the solar reflectance of a m² of roofs by 0.25 (cool roof) is equivalent to offsetting 63 kg CO₂ emissions (16 m² of cool roof = 1 T CO₂ emission offset)
- Increasing the solar reflectance of a m² of paved surfaces by 0.15 is equivalent to offsetting 38 kg CO₂ emissions
- Total world-wide emission offset from cool roofs and cool pavements is 44 GT CO₂
- 44 GT CO₂ is over one year of the world 2025 emission of 37 GT CO₂
- CO₂ emissions currently trade at ~$25/T; 44 GT CO₂ worth $1100 billion
A Global Action Plan: The Big Picture

• Develop an international to install cool roof/pavement in world’s 100 largest cities

• This is a simple measure that we hope to organize the world to implement **AND**

• **WE’D BETTER BE SUCCESSFUL!**

• We can gain practical experience in design of global measures to combat climate change