Energy Efficiency:
The first and most profitable way to delay Climate Change
EPA Region IX
June 9, 2008

Arthur H. Rosenfeld, Commissioner
California Energy Commission
(916) 654-4930
ARosenfe@Energy.State.CA.US

http://www.energy.ca.gov/commission/commissioners/rosenfeld.html
or just Google “Art Rosenfeld”
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)

12% of GDP = $1.7 Trillion in 2005

7% of GDP = $1.0 Trillion in 2005

France
Energy Consumption in the United States 1949 - 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></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>
</tr>
</tbody>
</table>

• Beginning in 2007 in California, reduction of “vampire” or standby losses
  - This will save $10 Billion when finally implemented, nationwide

• 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.
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’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
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
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

- Nuclear energy
- Conventional hydro
- Renewable energy systems
- 100 Million 1 KW
- Energy Saved Refrigerator Stds
- = 80 power plants of 500 MW each

Billion kWh/year
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)

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

Billion $ (US)/year in 2005

nuclear energy
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
United States Refrigerator Use, repeated, to compare with
Estimated Household Standby Use v. Time
Improving and Phasing-Out Incandescent Lamps

CFLs (and LEDs ?) – Federal (Harmon) Tier 2 [2020], allows Cal [2018]

Federal (Harmon) Tier 1 [2012 - 2014]

Best Fit to Existing Lamps

California Tier 2 [Jan 2008]

Nevada [2008]
California IOU’s Investment in Energy Efficiency

![Bar chart showing investment in energy efficiency from 1976 to 2012. Key events include:
- Profits decoupled from sales
- 2% of 2004 IOU Electric Revenues
- Performance Incentives
- Market Restructuring
- Crisis
- IRP
- Public Goods Charges
- Forecast]

Millions of $2002 per Year

COOL SURFACES AND SHADE TREES REDUCE ENERGY USE AND IMPROVE URBAN AIR QUALITY

Hashem Akbari
Heat Island Group
Ernest Orlando Lawrence Berkeley National Laboratory

Tel: 510-486-4287
E_mail: H_Akbari@LBL.gov
http://HeatIsland.LBL.gov
What Is a Heat Island?

Sketch of an Urban Heat-Island Profile

Late Afternoon Temperature

°F
°C

92
33
32
31
30

85
-30
-31
-32
-33

Rural
Commercial
Urban Residential
Suburban Residential
Suburban Residential
Downtown
Park
Rural Farmland
Temperature Trends in Downtown Los Angeles
From Orchards to Blacktops

Eruption of Krakatau, August 27, 1883

Slope = \((6^\circ F/50 \text{ yr})/(3.3^\circ C/50 \text{ yr})\)
= \((1^\circ F/8 \text{ yr})/(1^\circ C/14 \text{ yr})\)
Effect of Temperature Rise on Southern California Edison Peak Load (1988)

1 °F Change = 225 MW (1.6%)  
1 °C Change = 400 MW (2.9%)

Electric Power (4 pm Load in MW)

Daily Average Temperature
Effect of Temperature Rise on Peak Ozone Concentration

Smog, Measured as Ozone (PPHM)

Measured at Los Angeles, North Main 1985

Daily Maximum Temperature vs. Smog, Measured as Ozone (PPHM)
Mitigation Measures: Light-Colored Surfaces and Trees

• **Direct Effect**
  - Light-colored roofs reflect solar radiation, reduce air-conditioning use
  - Trees that shade buildings reduce air-conditioning use

• **Indirect Effect**
  - Light-colored surfaces in a neighborhood alter surface energy balance; result in lower ambient temperature
  - Vegetation in a neighborhood reduces ambient temperature by evapotranspiration
Orthophoto of Sacramento
ISP/LBNL Shingle With Whiter Roofing Granules

REFLECTING SOLAR HEAT

Black Shingle
R = 5 %, T = 180 °F

Conventional White Shingle
R = 29 %, T = 157 °F

Advanced White Shingle
R = 60 %, T = 128 °F
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**
- 5% ultraviolet (300-400 nm)
- 43% visible (400-700 nm)
- 52% near-infrared (700-2500 nm)
Cool and Standard Brown Metal Roofing Panels

- Solar reflectance ~ 0.2 higher
- Afternoon surface temperature ~ 10°C lower
Example: Dioxazine Purple Over Various Undercoats

- Two-layer system
  - top coat: thin layer of dioxazine purple (14-27 μm)
  - undercoat or substrate:
    - aluminum foil (~ 25 μm)
    - opaque white paint (~1000 μm)
    - non-opaque white paint (~ 25 μm)
    - opaque black paint (~ 25 μm)
Dioxazine Purple Reflectances

- over aluminum: $R_{\text{solar}} = 0.41$
- over opaque white: $R_{\text{solar}} = 0.42$
- over non-opaque white: $R_{\text{solar}} = 0.30$
- over opaque black: $R_{\text{solar}} = 0.05$
Designing Cool Colored Roofing

- **cool concrete tile**
  - R ≥ 0.40

- **standard concrete tile**
  - (same color)
  - R = 0.04

- **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

---

### Solar Reflectance Gain

- **cool concrete tile**
  - R = 0.41
  - R = 0.44
  - R = 0.44
  - R = 0.48
  - R = 0.46
  - R = 0.41

- **standard concrete tile**
  - (same color)
  - R = 0.04
  - R = 0.18
  - R = 0.21
  - R = 0.33
  - R = 0.17
  - R = 0.12

- **cool clay tile**
  - R = 0.40

- **cool metal**
  - R ≥ 0.30

- **cool fiberglass asphalt shingle**
  - R ≥ 0.25

---

---

---

---
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)
Development of Cool Paving Materials:

*Longer story than we have time*
Temperature Effect on Rutting

Source: Dr. John Harvey, UC B Civil Engineering, Inst. Transpo. Studies
Increased urban albedo and vegetation-canopy cover can lower urban air temperatures, which can decrease electricity use, emissions, and ozone air pollution.

This involves modifying ~ ½ of the built up area (roofs, paved surfaces) or adding ¼ million trees in smaller urban areas.

Improved models are important for enforceable strategies.

First ‘urbanized’ model (Taha 2007;2008) estimates effects at individual building scales and shows significant positive impacts on meteorology and ozone.

Model will be used in SIP Control Measure development for the Sacramento Metropolitan AQMD (Sacramento Non-Attainment Area) in evaluating impact of urban forests on ozone.

**Potential air-quality improvements from UHI control**

![1-hr average ozone -- Sacramento](image)

Source: Taha (2007)
Potential air-quality improvements from UHI control

A: Simulated daily maximum 8-hour average ozone in Sacramento (at the Folsom / Natoma monitor location). B: reduction (%) in daily maximum as RRF resulting from heat island control.

August 1st, simulated 1-hr ozone at a location in Sacramento (eastern domain) and changes resulting from UHI control (this is an alternate view of figure on page 1).

Source: Taha (2007)
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
Cool Roofs Standards in the U.S.

- Building standards for reflective roofs
  - American Society of Heating and Air-conditioning Engineers (ASHRAE): New commercial and residential buildings
  - California Title 24 Building Energy Standard
  - Many other states: Georgia, Florida, Hawaii, …

- Air quality standards
  - South Coast AQMD
  - S.F. Bay Area AQMD
  - EPA’s SIP (State Implementation Plans)
Cool Surfaces also Cool the Globe
WHITEWASHING THE GREEN HOUSE

• Cool roof standards are designed to reduce a/c demand, save money, and save emissions. In Los Angeles they will eventually save ~$100,000 per hour
• Annual savings in the U.S. = $1-2B; ~ 7 M tons CO₂
• Annual savings in the world = $10-15B; ~ 100 M tons CO₂
• But higher albedo surfaces (roofs and pavements) directly cool the world (0.01 K) quite independent of avoided CO₂. So we discuss the effect of cool surfaces for tropical and temperate cities. That will turn out to offset ~$1Trillion of CO2 over perhaps 20 years
Radiation Forcing of CO$_2$ Concentration

- Myhre (1998) formula
  \[ RF = 5.35 \ln\left(\frac{CO_2}{CO_2_0}\right) \quad [W/m^2] \]
- \[ \delta RF = 5.35 \frac{\delta CO_2}{CO_2} \quad [W/m^2] \]
- Area of Earth = 5.08x10$^{14}$ [m$^2$]
- CO$_2$ in atmosphere = 3x10$^3$ [GT]
- Hence, RF per T of CO$_2$ ≈ 1 kW/ T CO$_2$
Dense Urban Areas are 1% of Land

- Area of the Earth = \(5.08 \times 10^{14} \text{ m}^2\)
- Land Area (29%) = \(148 \times 10^{12} \text{ m}^2\) \[1\]
- Area of the 100 largest cities = \(0.38 \times 10^{12} \text{ m}^2 = 0.26\%\) of Land Area for 670 M people
- Assuming 3B live in urban area, urban areas = \([3000/670] \times 0.26\% = 1.2\%\) of land
- But smaller cities have lower population density, hence, urban areas = 2% of land
- Dense, developed urban areas only 1% of land \[2\]
Potentials to Increase Urban Albdeo is 0.1

- Typical urban area is 25% roof and 35% paved surfaces
- Roof albedo can increase by 0.25 for a net change of $0.25 \times 0.25 = 0.063$
- Paved surfaces albedo can increase by 0.15 for a net change of $0.35 \times 0.15 = 0.052$
- Net urban area albedo change at least 0.10
Effect of Solar Reflective Roofs and Pavements in Cooling the Globe

(Source: Akbari et al. 2008, submitted to Climatic Change)

- Increasing the solar reflectance of a m² of roofs by 0.25 is equivalent to sequestering 31-57 kg CO₂ from atmosphere (18-32 m² of cool roof = 1 T CO₂ removed from atmosphere)
- Increasing the solar reflectance of a m² of paved surfaces by 0.15 is equivalent to sequestering 18-34 kg CO₂ from atmosphere
- World-wide equivalent atmospheric carbon reduction of reflective roofs and pavements is 22 - 40 GT CO₂
- Equivalent CO₂ emission reduction of reflective roofs and pavements = [22 – 40] /0.55 = 40 - 73 GT CO₂
- 40 -73 GT CO₂ is 1-2 years of the world 2025 emission of 37 GT CO₂ per year
- CO₂ emissions currently trade at ~$25/T; 40 – 73 GT CO₂ worth $1000 - $1800 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
Cool Roof Programs around the World

- U.S.
- Europe
- Asia
- Middle East
- China
- India (Hyderabad demos; see graphs; funded by U.S.AID)
Practical Guidelines

- EPA Guidebook (1992)
  - Good practical information
  - Greatest focus on trees

- EPA is working on a new edition