# *Energy Efficiency:*
# *The first and most profitable way to delay Climate Change*
# *EPA Region IX*

***June 9, 2008***

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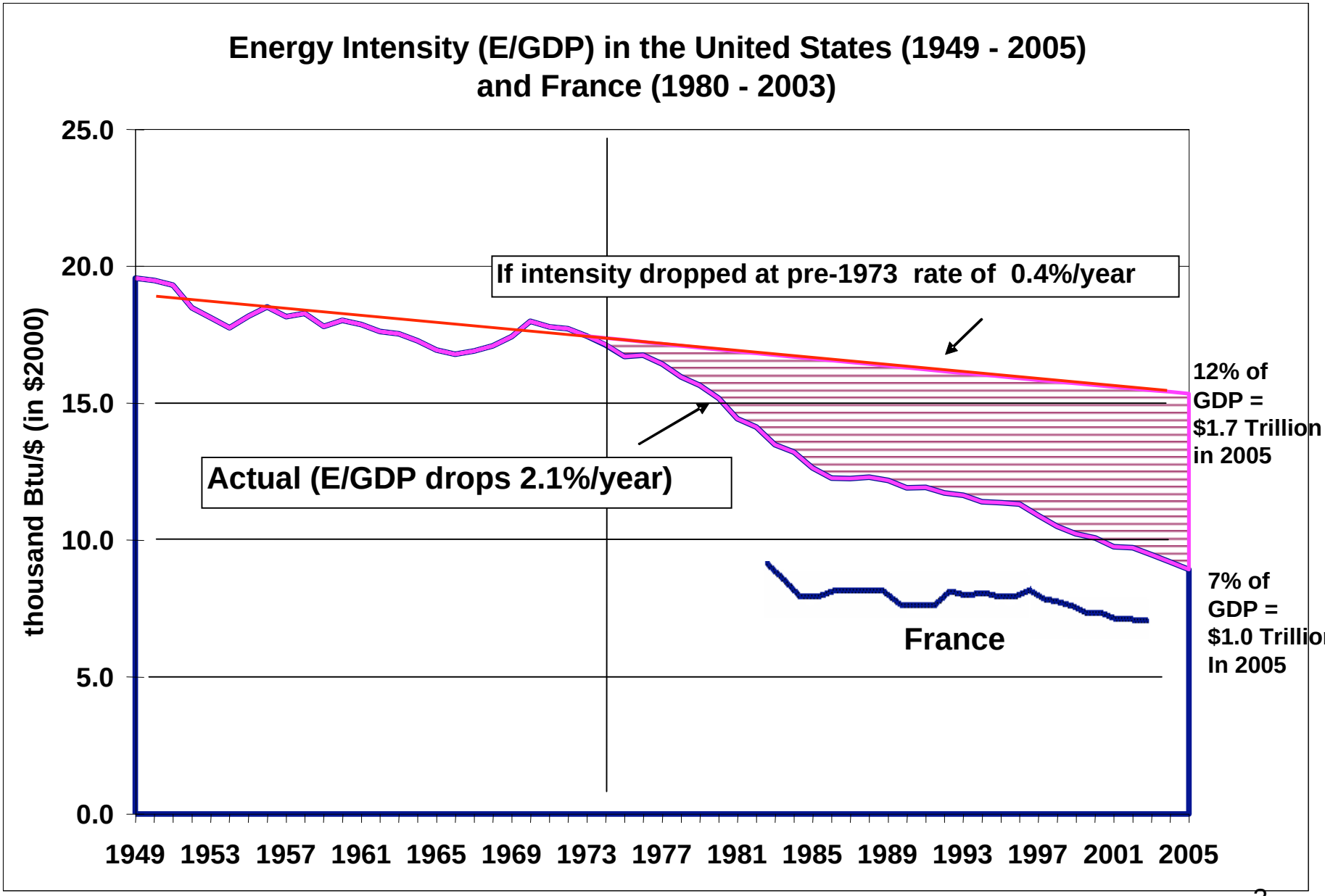
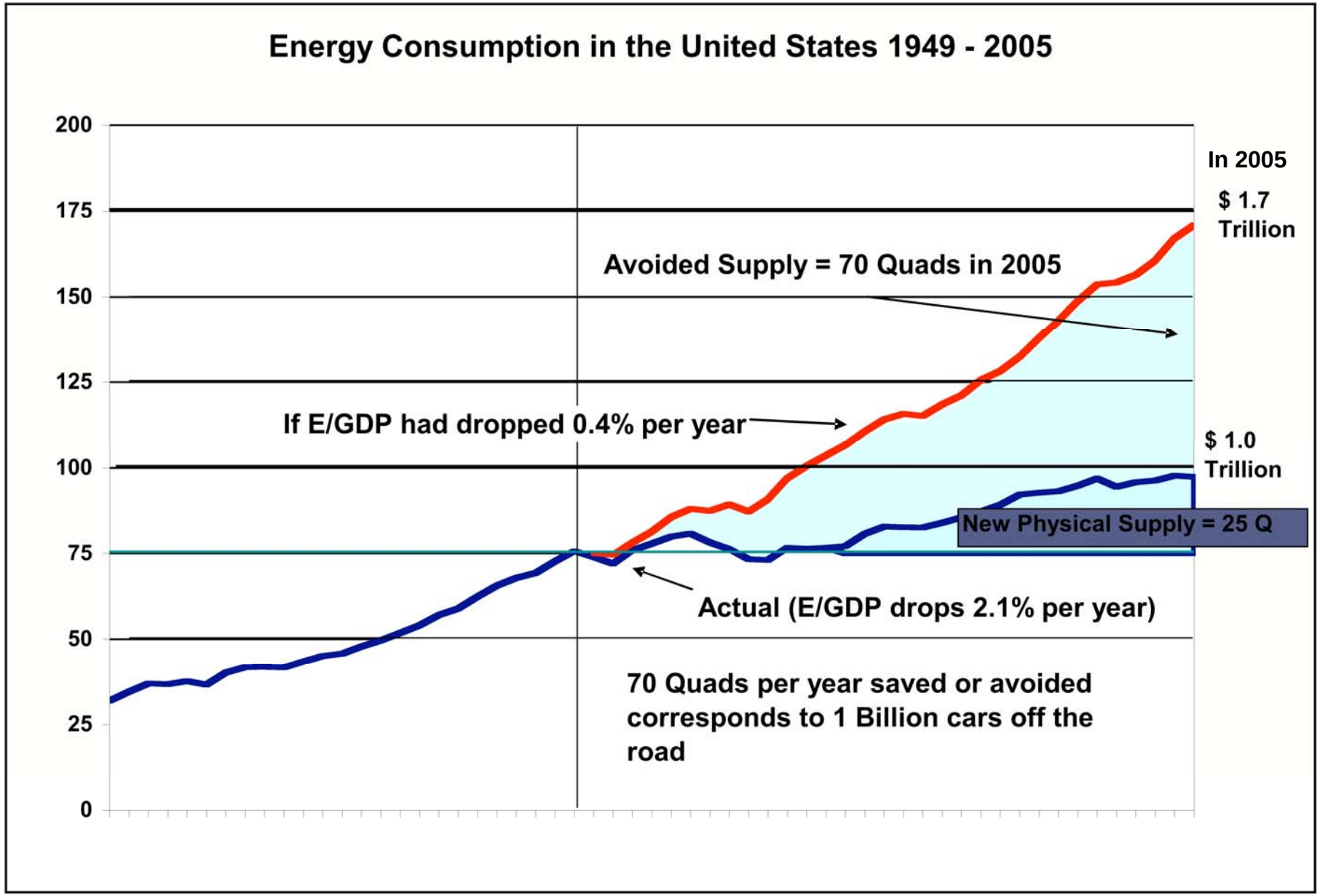
**http://www.energy.ca.gov/commission/commissioners/rosenfeld.html**
**or just Google "Art Rosenfeld"**

# 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.


Energy Intensity (E/GDP) in the United States (1949 - 2005)
and France (1980 - 2003)
thousand Btu/$ (in $2000)
25.0
20.0
15.0
10.0
5.0
0.0
1949
1953
1957
1961
1965
1969
1973
1977
1981
1985
1989
1993
1997
2001
2005
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


Energy Consumption in the United States 1949 - 2005
200
175
150
125
100
75
50
25
0
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

| | Billion $ |
|---|---|
| **Space Heating** | **40** |
| **Air Conditioning** | **30** |
| **Refrigerators** | **15** |
| **Fluorescent Tube Lamps** | **5** |
| **Compact Floursecent Lamps** | **5** |
| **Total** | **95** |

- 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.

# Two Energy Agencies in California

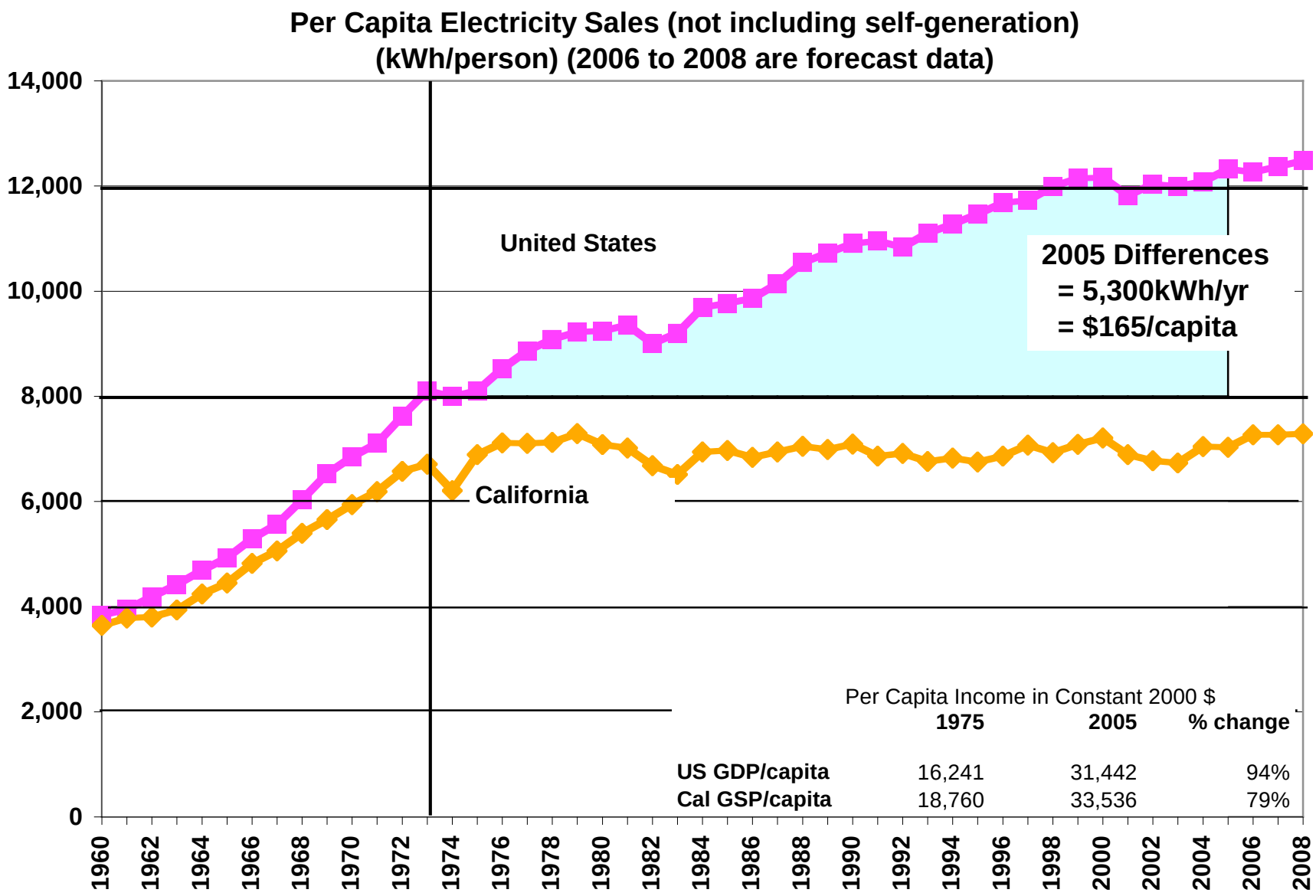
- The California Public Utilities Commission (CPUC) was formed in 1890 to regulate natural monopolies, like railroads, and later electric and gas utilities.
- The California Energy Commission (CEC) was formed in 1974 to regulate the environmental side of energy production and use.
- Now the two agencies 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

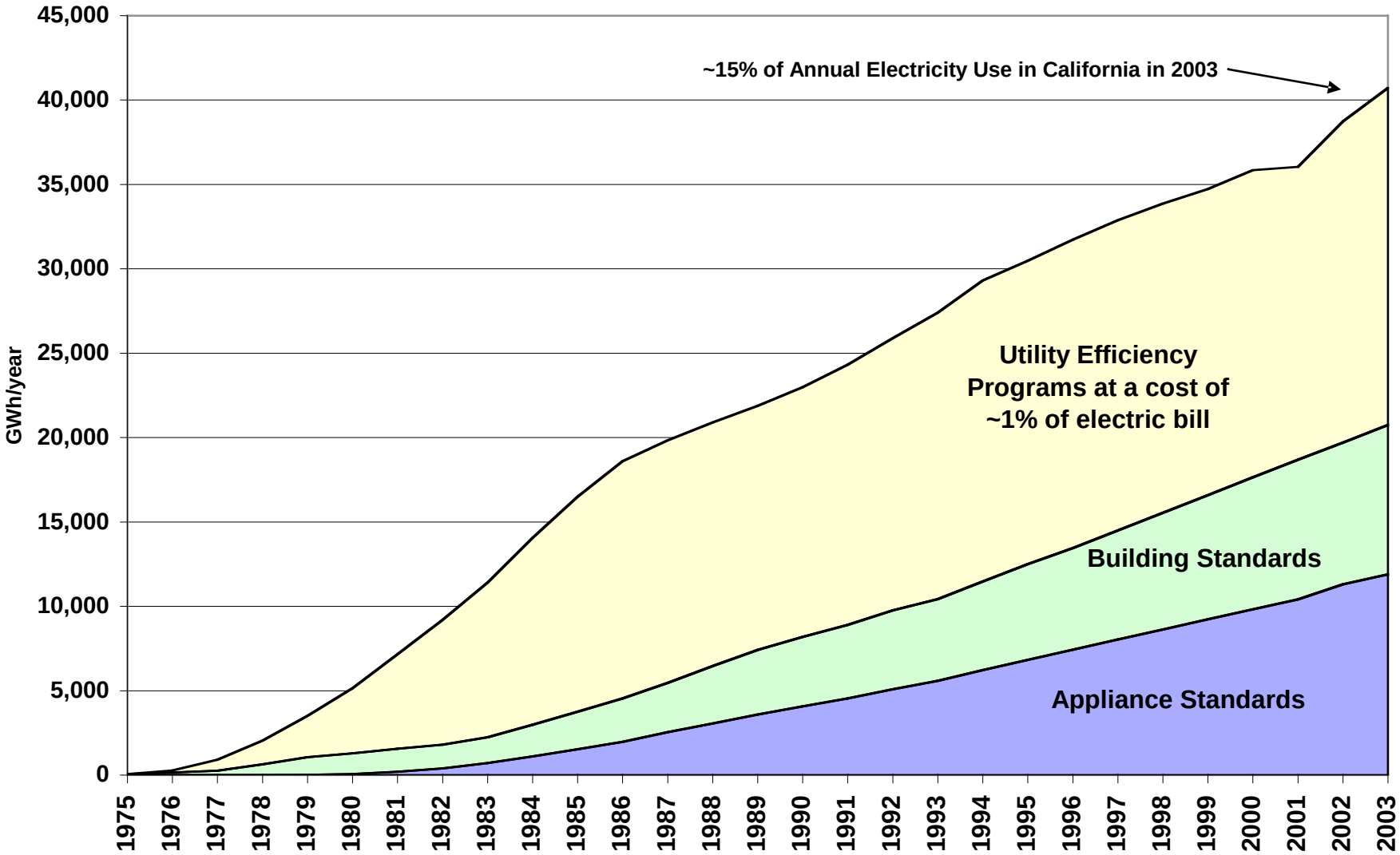
- California's Energy Agencies first adopted an Energy Action Plan in 2003. Central to this is the State's preferred "Loading Order" for resource expansion.

- 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.

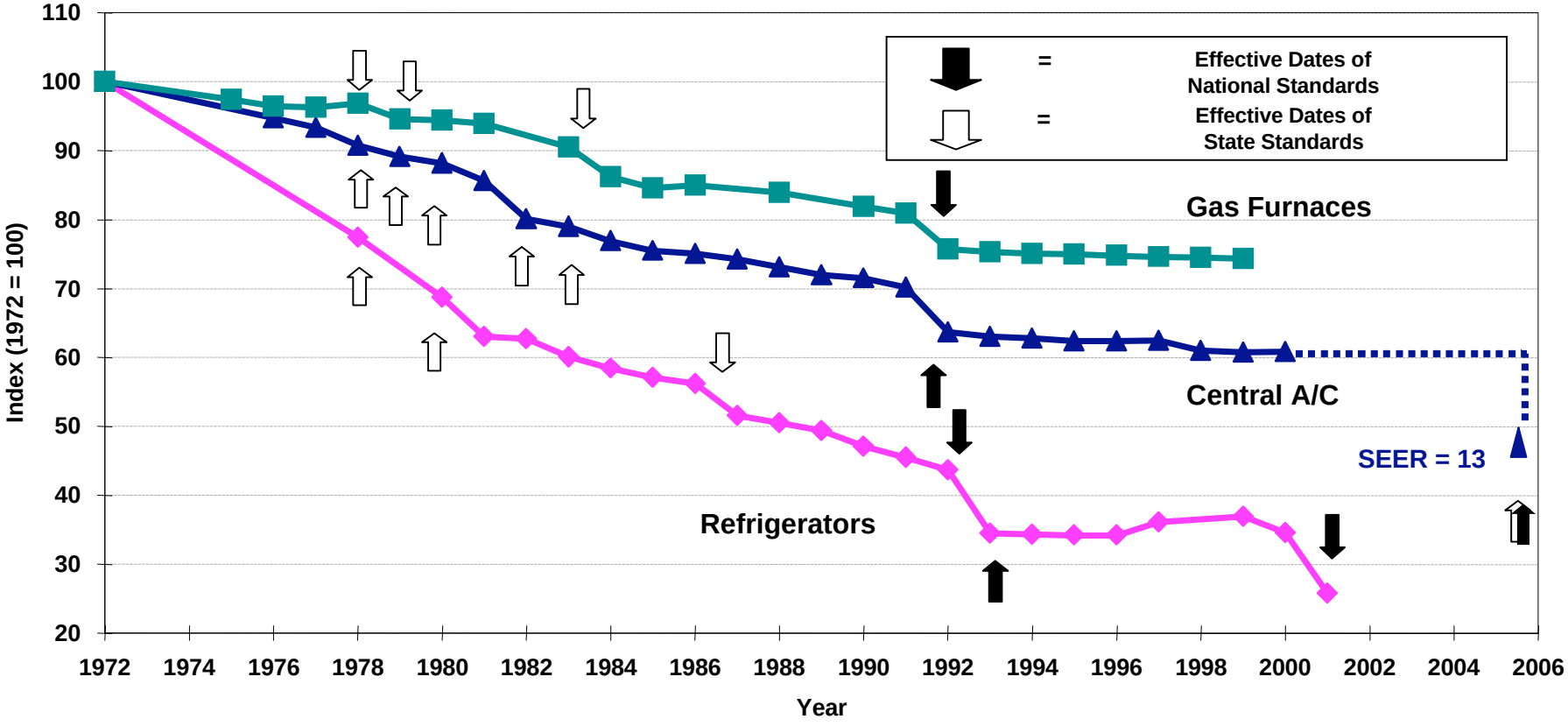
- The Energy Action Plan has been updated since 2003 and provides overall policy direction to the various state agencies involved with the energy sectors


Per Capita Electricity Sales (not including self-generation)
(kWh/person) (2006 to 2008 are forecast data)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
United States
California
2005 Differences
= 5,300kWh/yr
= $165/capita
Per Capita Income in Constant 2000 $
1975
2005
% change
US GDP/capita 16,241 31,442 94%
Cal GSP/capita 18,760 33,536 79%
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008

## Annual Energy Savings from Efficiency Programs and Standards



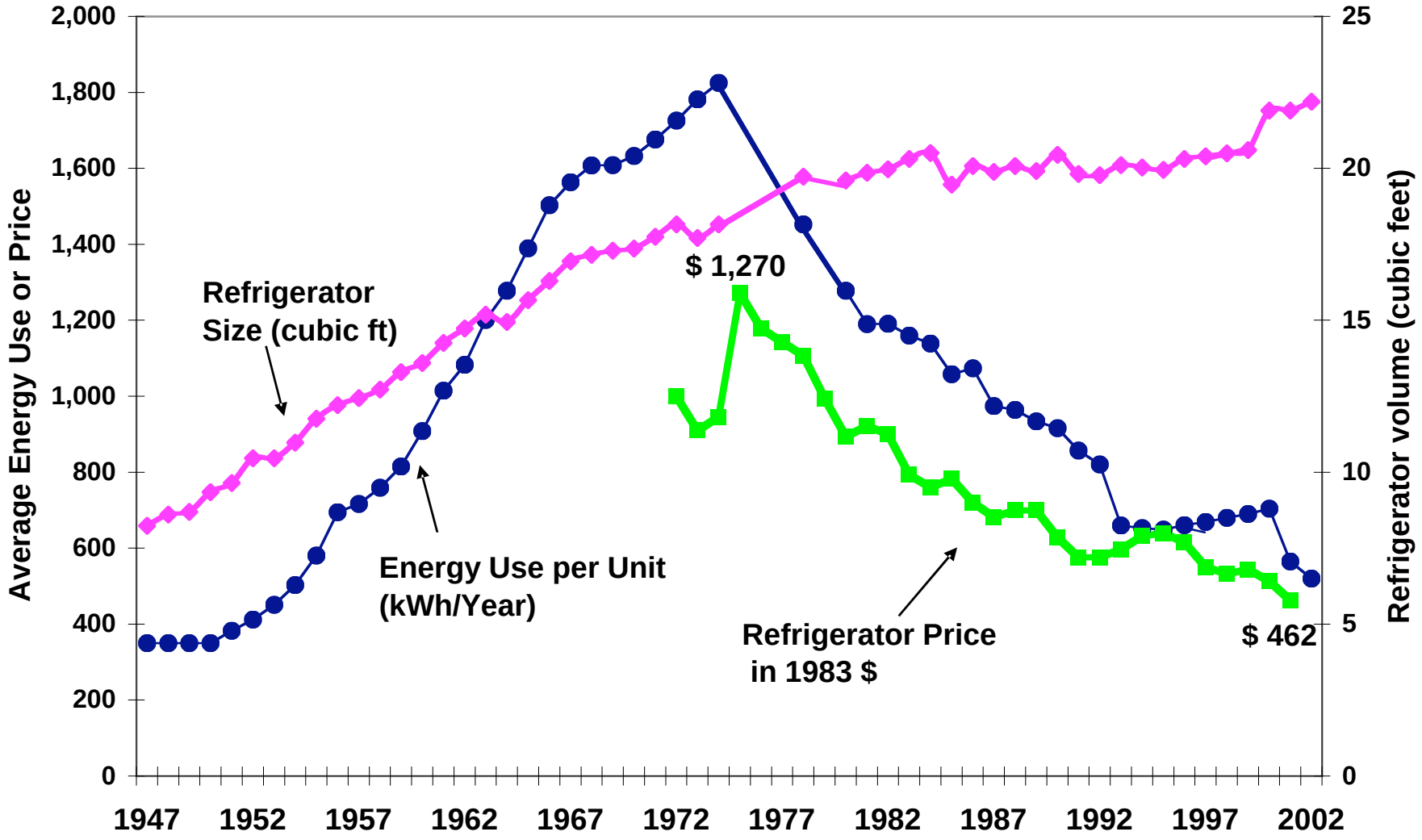
# Impact of Standards on Efficiency of 3 Appliances




Source: S. Nadel, ACEEE,

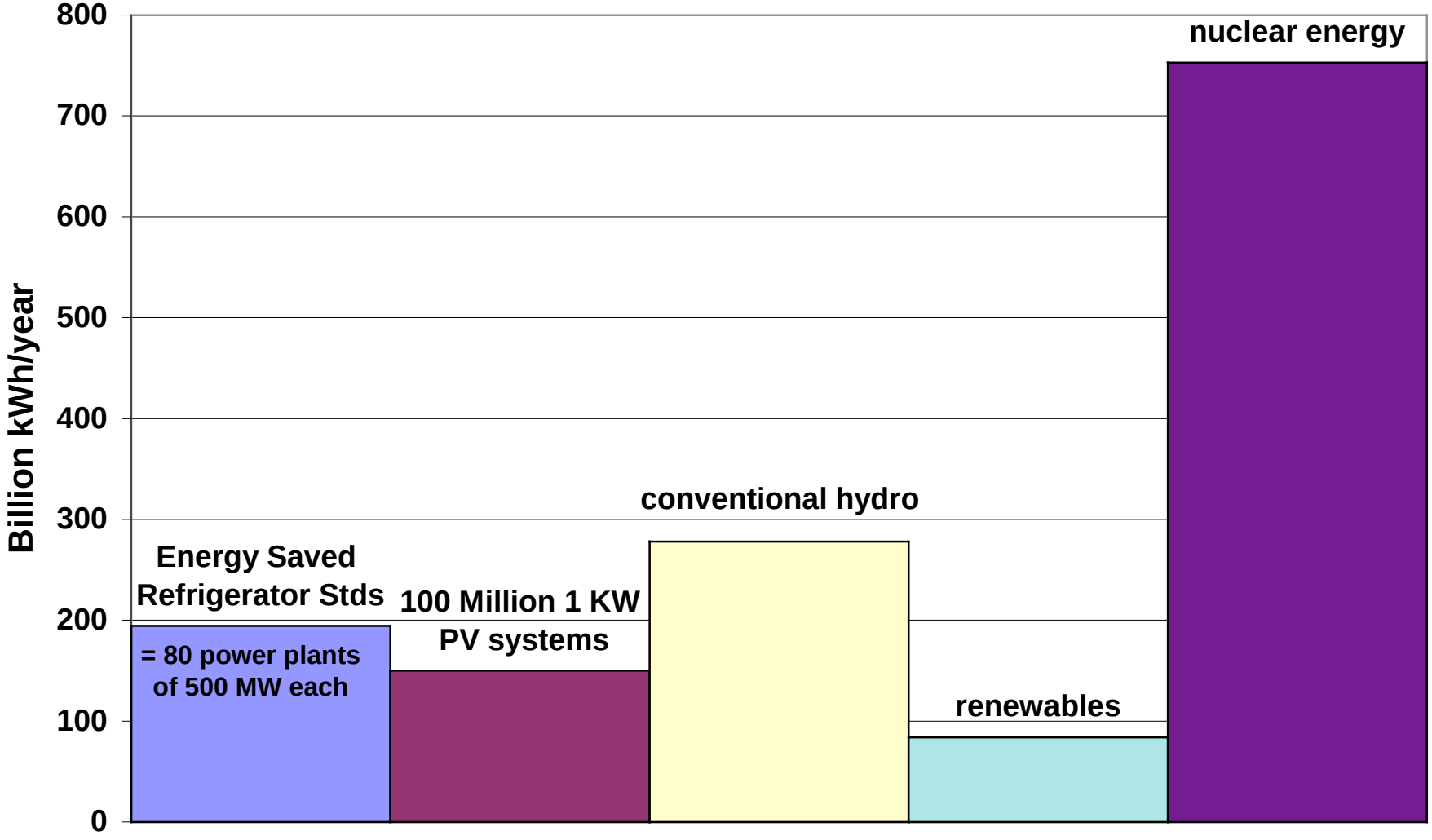
in ECEEE 2003 Summer Study, www.eceee.org

# New United States Refrigerator Use v. Time and Retail Prices



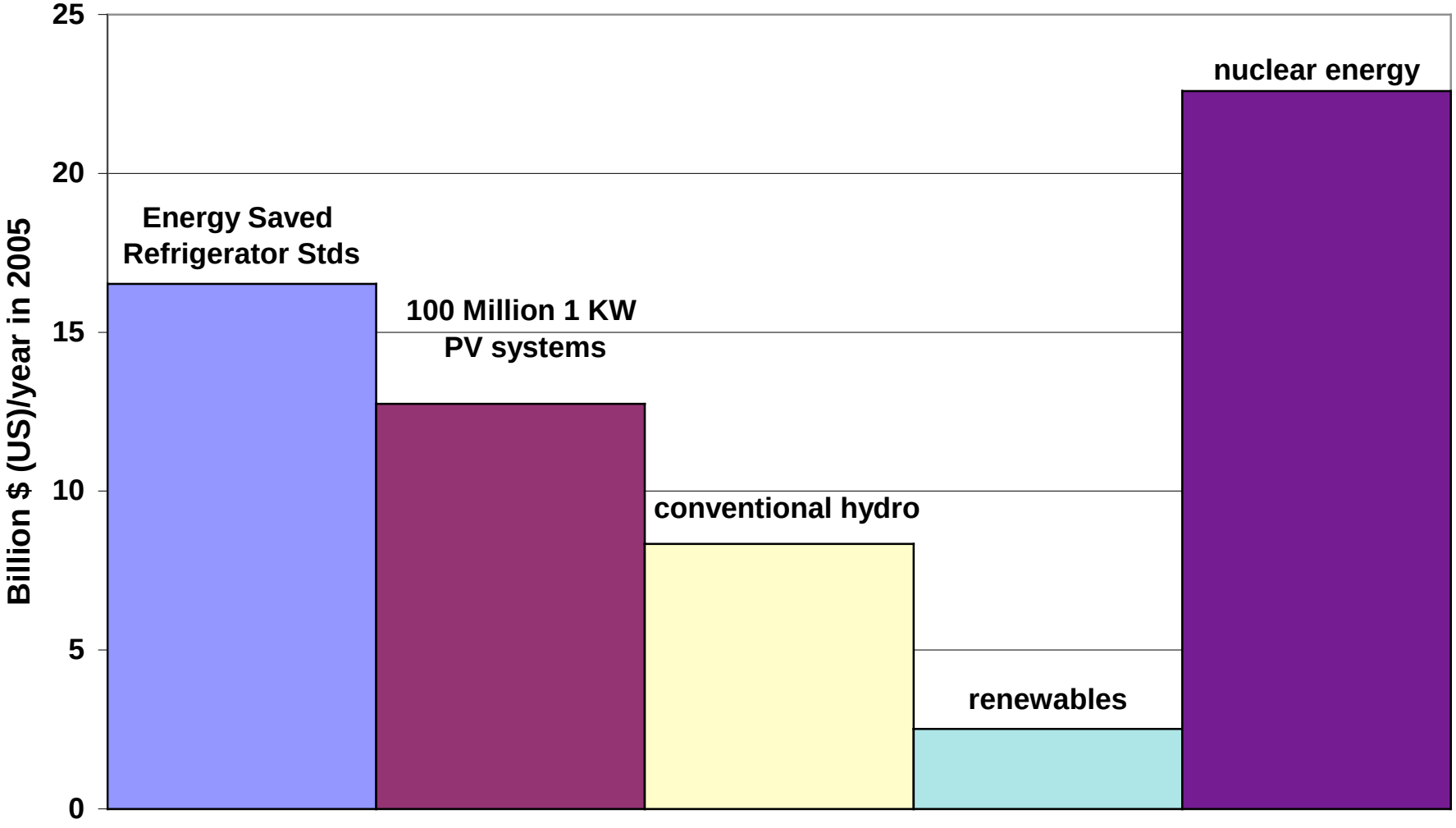

Source: David Goldstein

## Annual Energy Saved vs. Several Sources of Supply In the United States

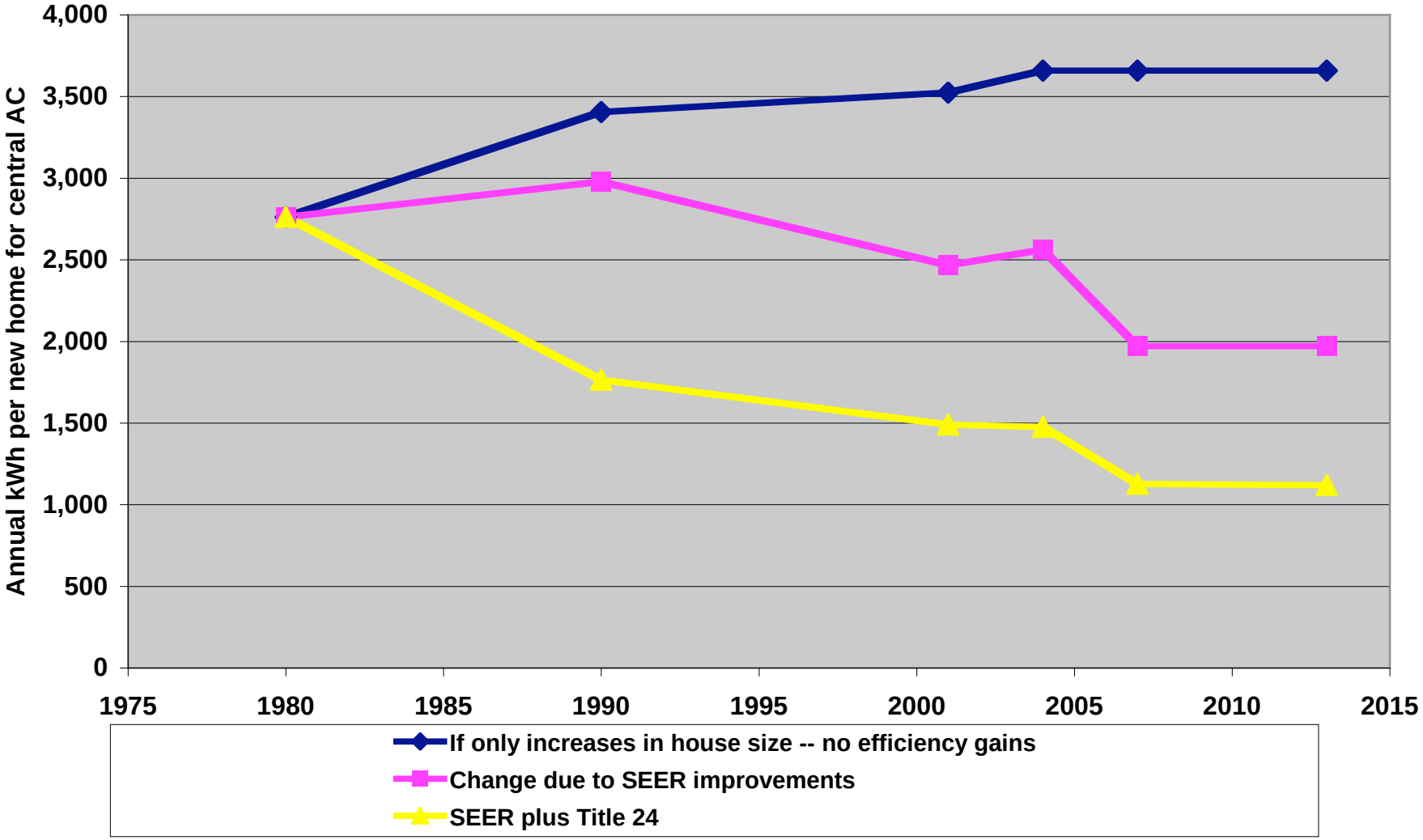


## In the United States

## 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)

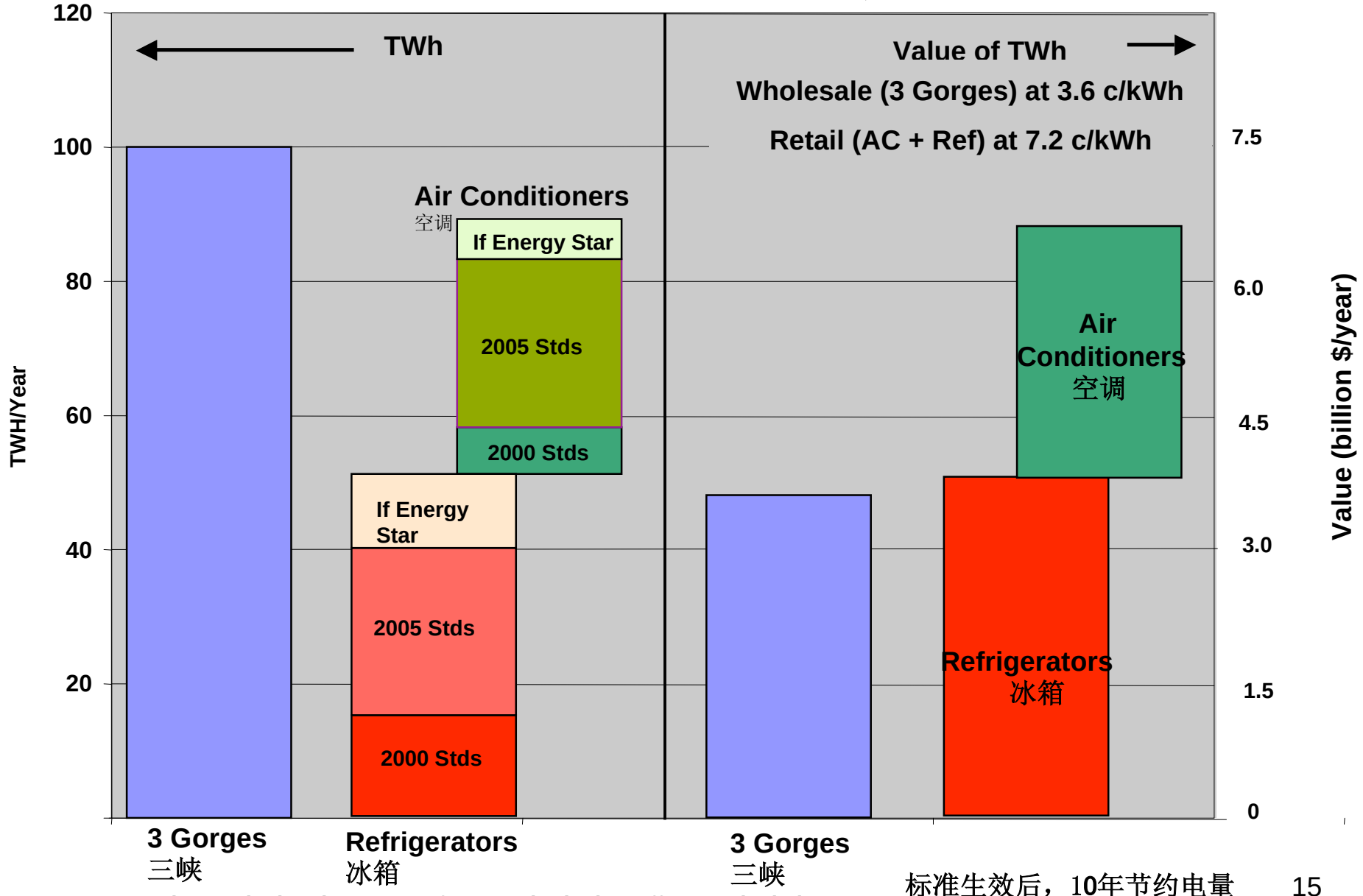


## Air Conditioning Energy Use in Single Family Homes in PG&E
## The effect of AC Standards (SEER) and Title 24 standards



## Comparison of 3 Gorges to Refrigerator and AC Efficiency Improvements

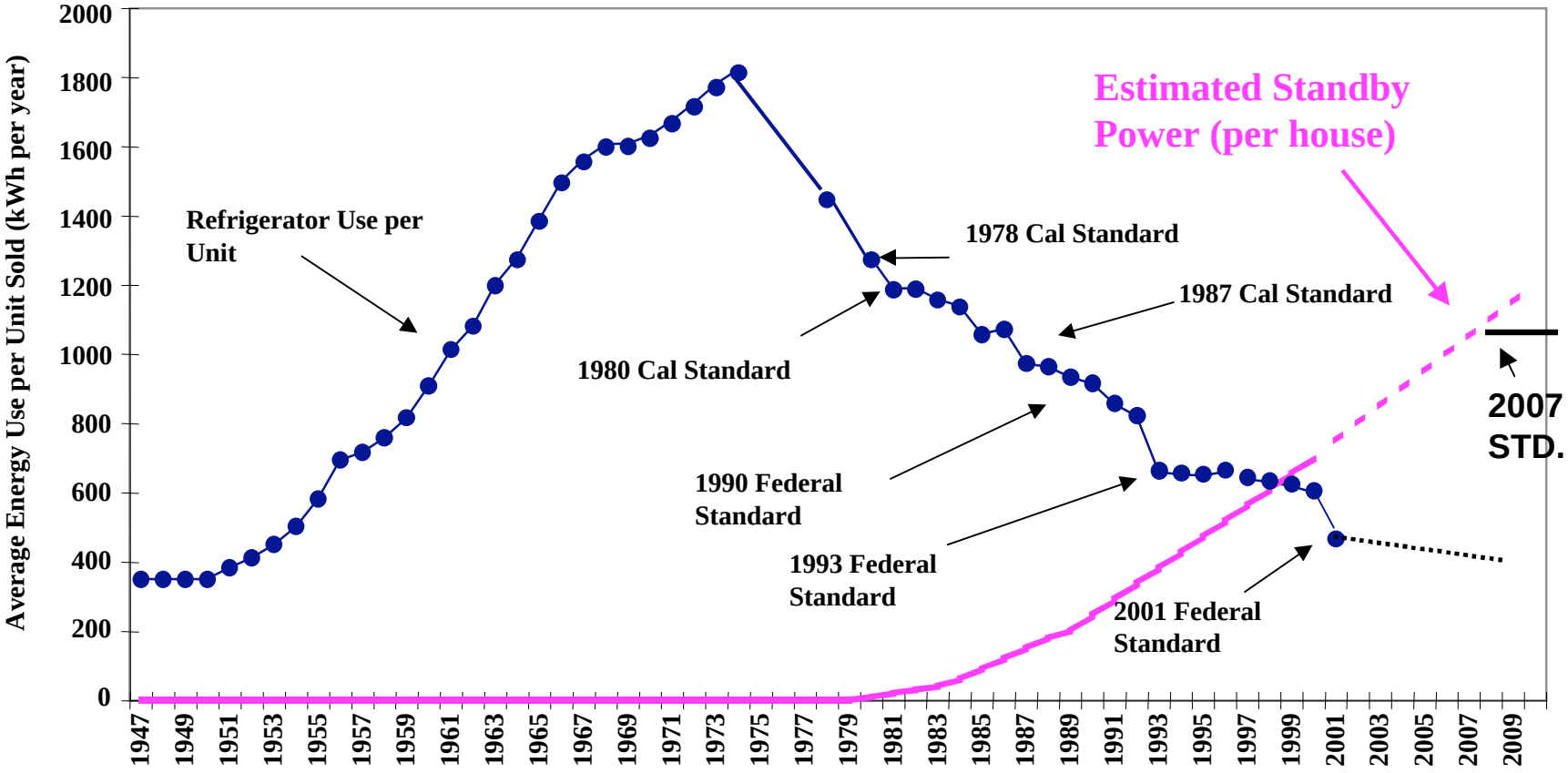
## 三峡电量与电冰箱、空调能效对比



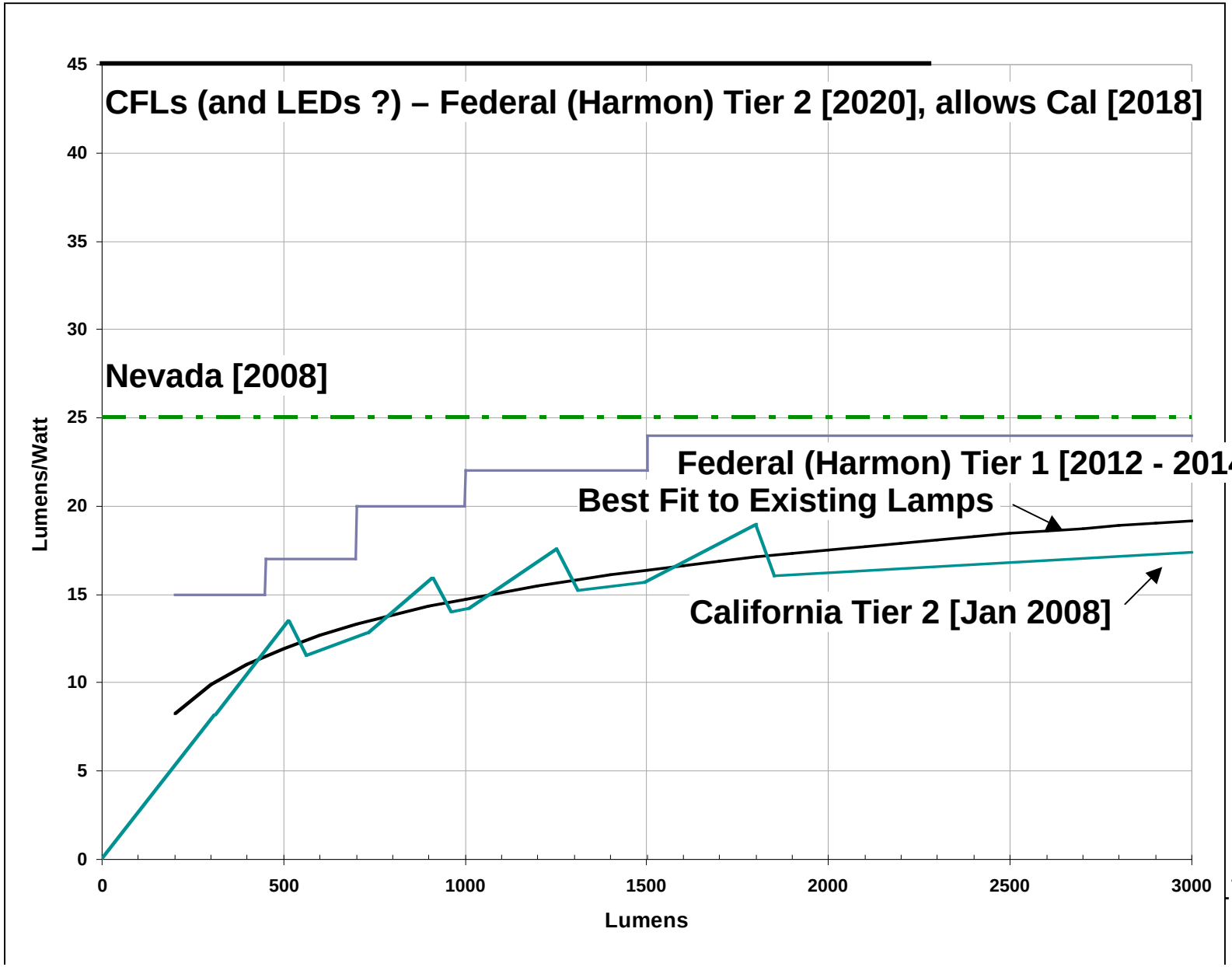

Savings calculated 10 years after standard takes effect. Calculations provided by David Fridley, LBNL

标准生效后，10年节约电量

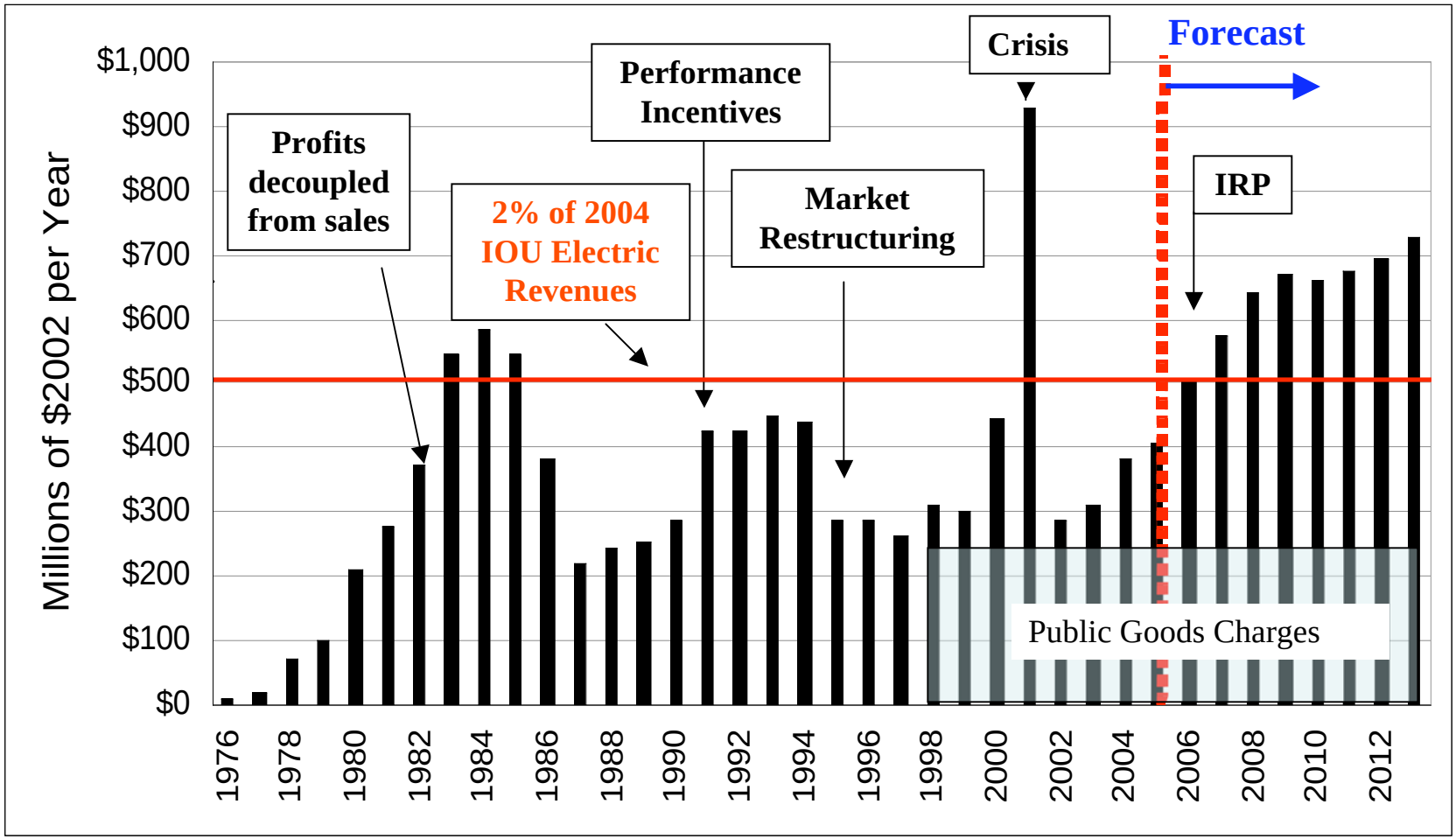
# United States Refrigerator Use, repeated, to compare with Estimated Household Standby Use v. Time



# Improving and Phasing-Out Incandescent Lamps



# California IOU's Investment in Energy Efficiency



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

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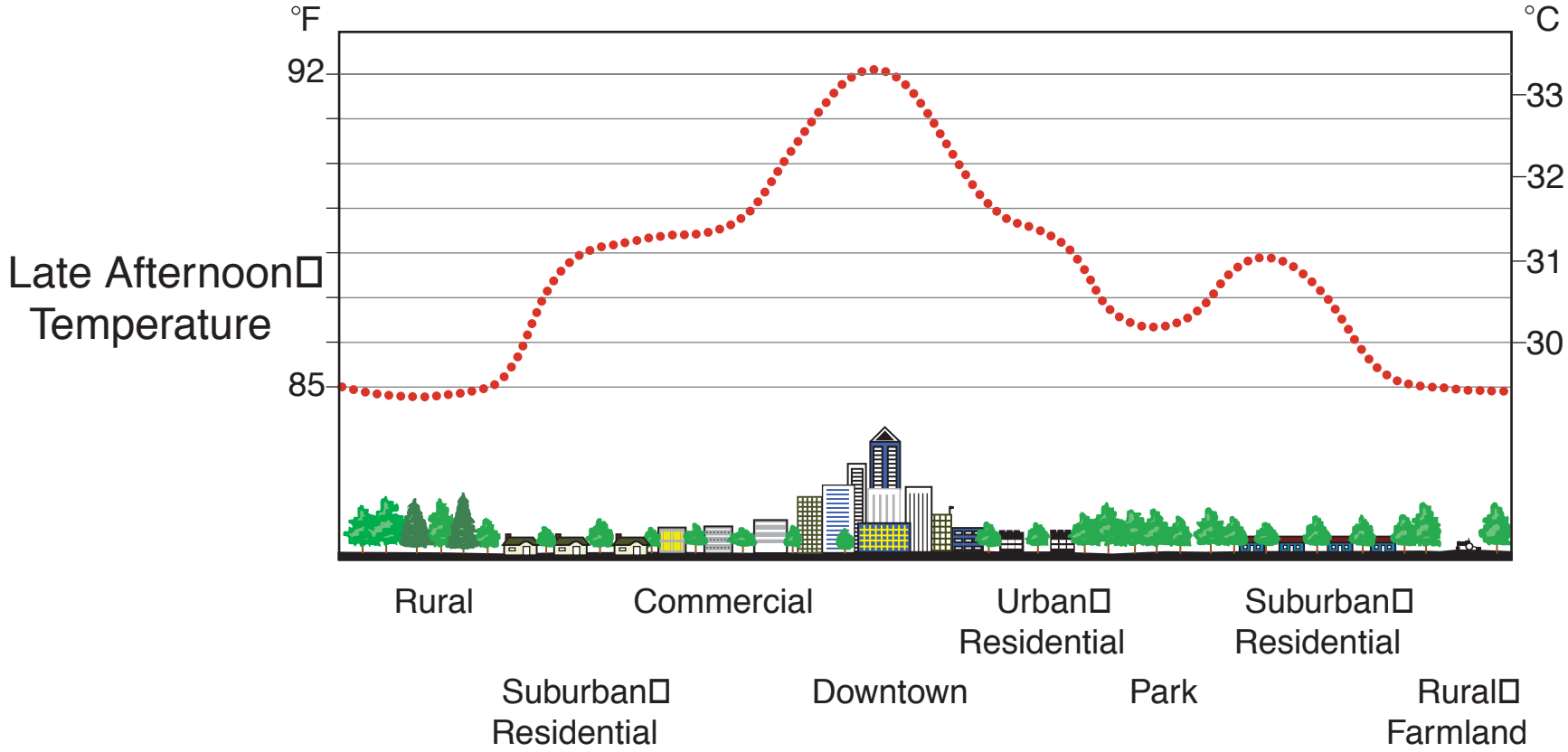
Heat Island Group

Ernest Orlando Lawrence Berkeley National Laboratory

Tel: 510-486-4287
E_mail: H_Akbari@LBL.gov
http://HeatIsland.LBL.gov

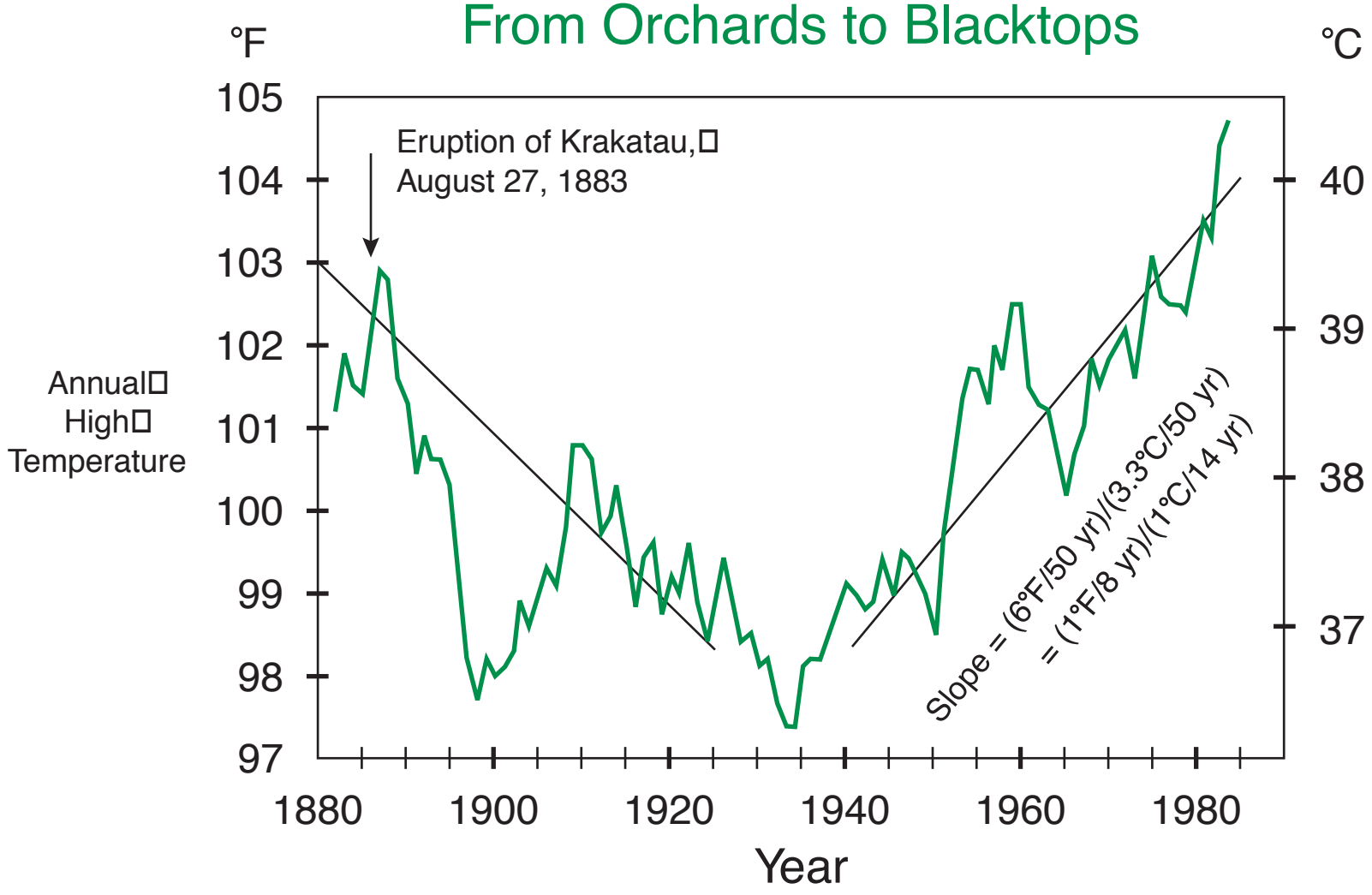
# What Is a Heat Island?

## Sketch of an Urban Heat-Island Profile

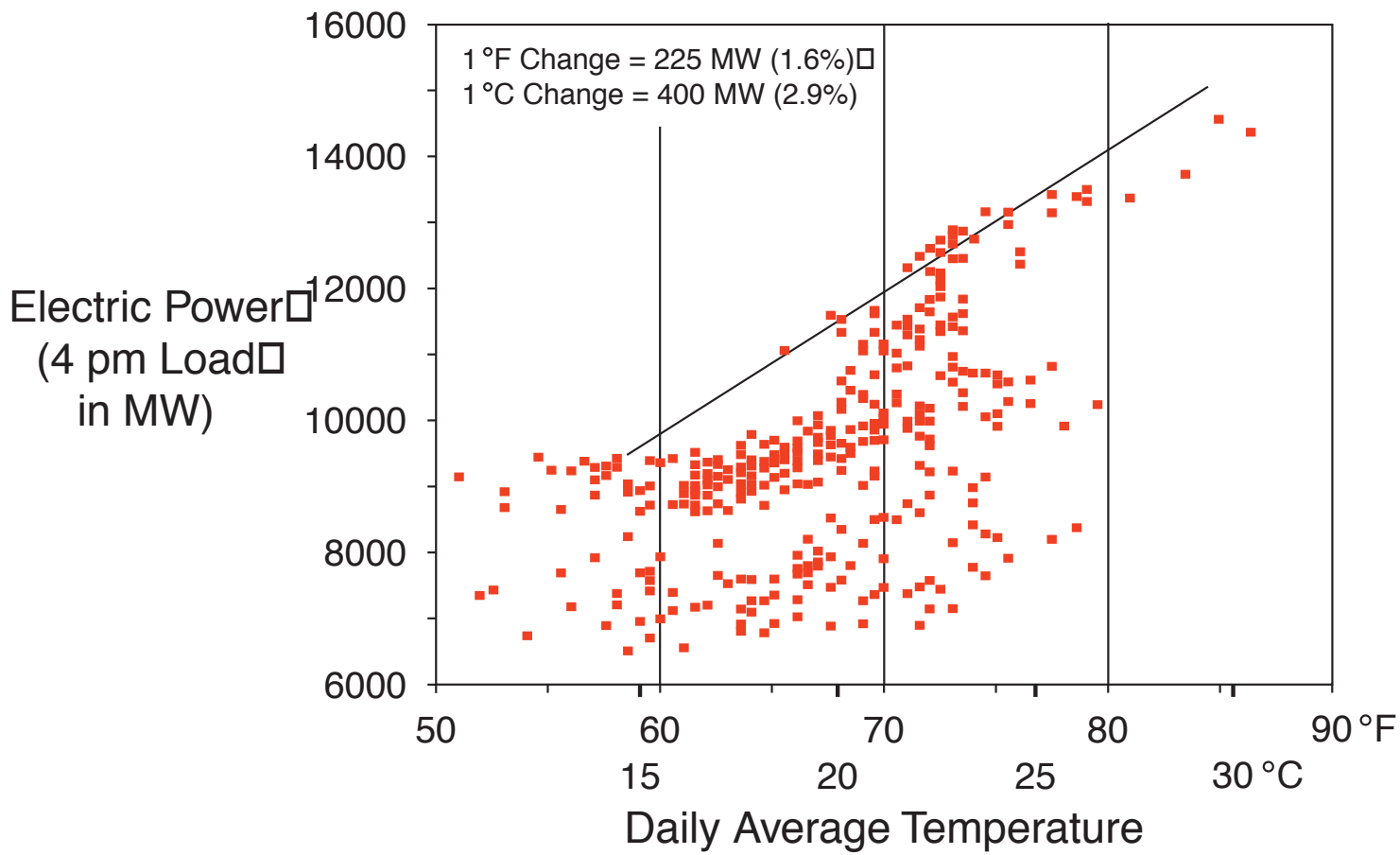


# Temperature Trends in Downtown Los Angeles

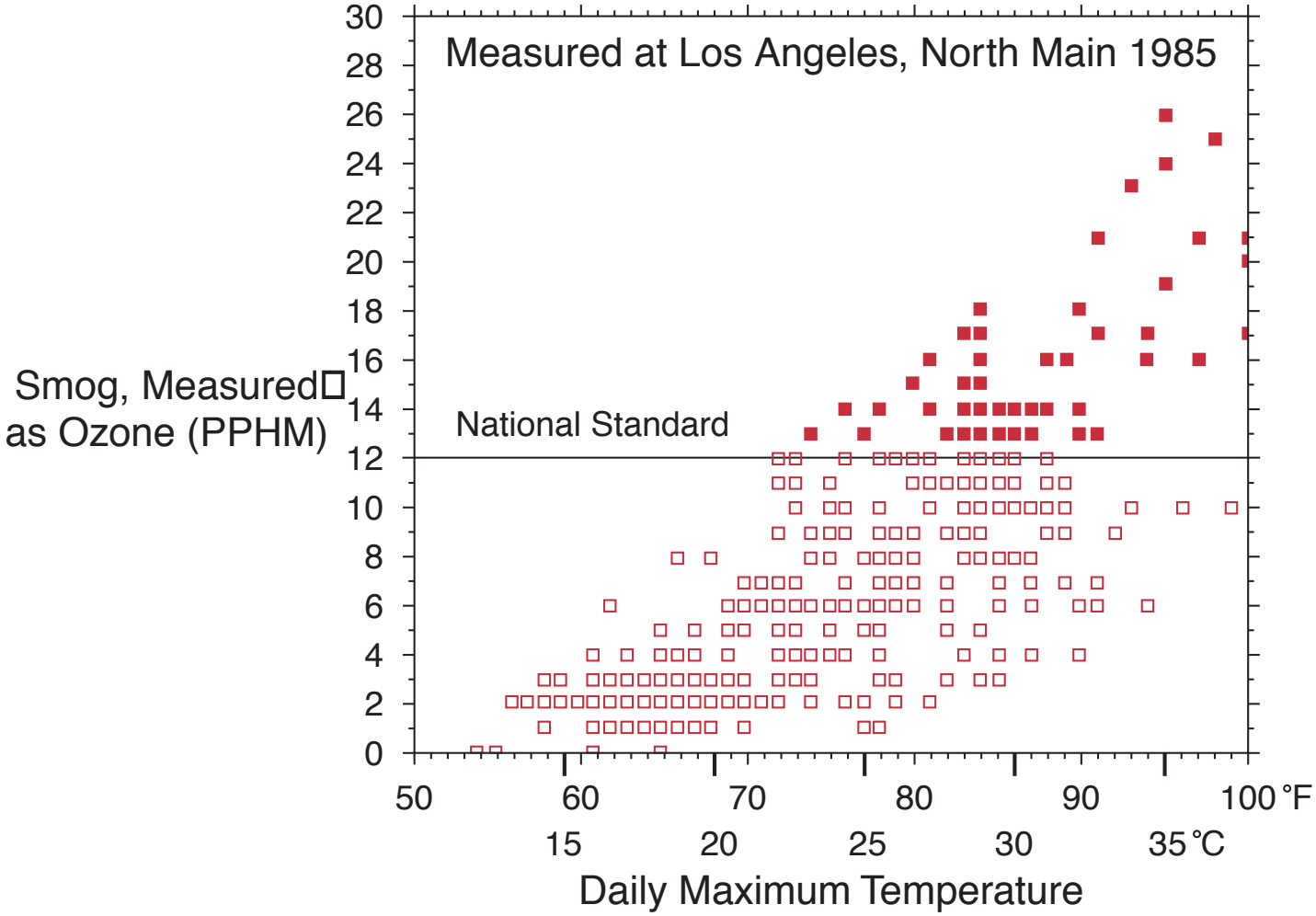
## From Orchards to Blacktops



# Effect of Temperature Rise on Southern California Edison Peak Load (1988)



# Effect of Temperature Rise on Peak Ozone Concentration

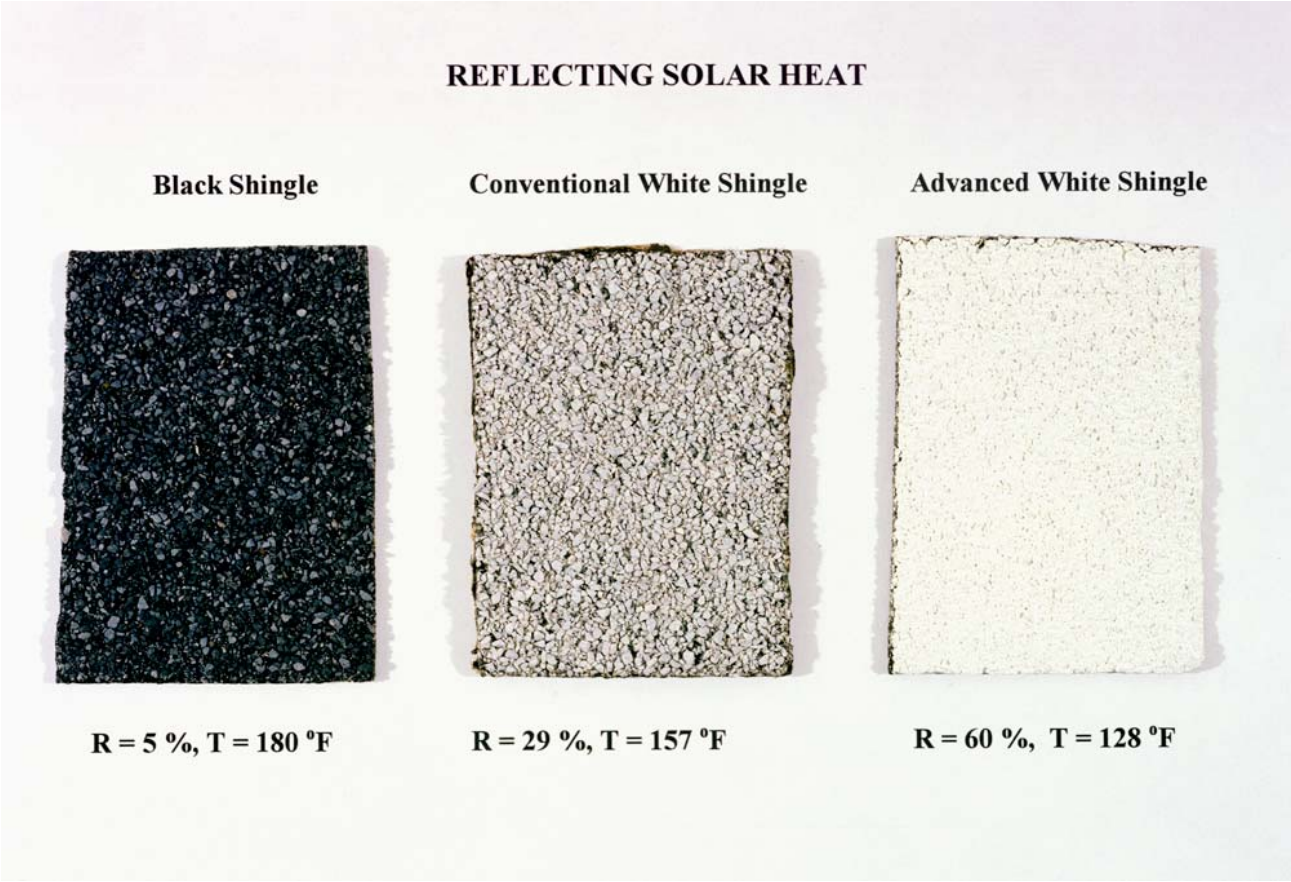


# Mitigation Measures: Light-Colored Surfaces and Trees

- **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



# White is ‘cool’ in Bermuda

# and in Santorini, Greece

# Cool Roof Technologies

**Old**

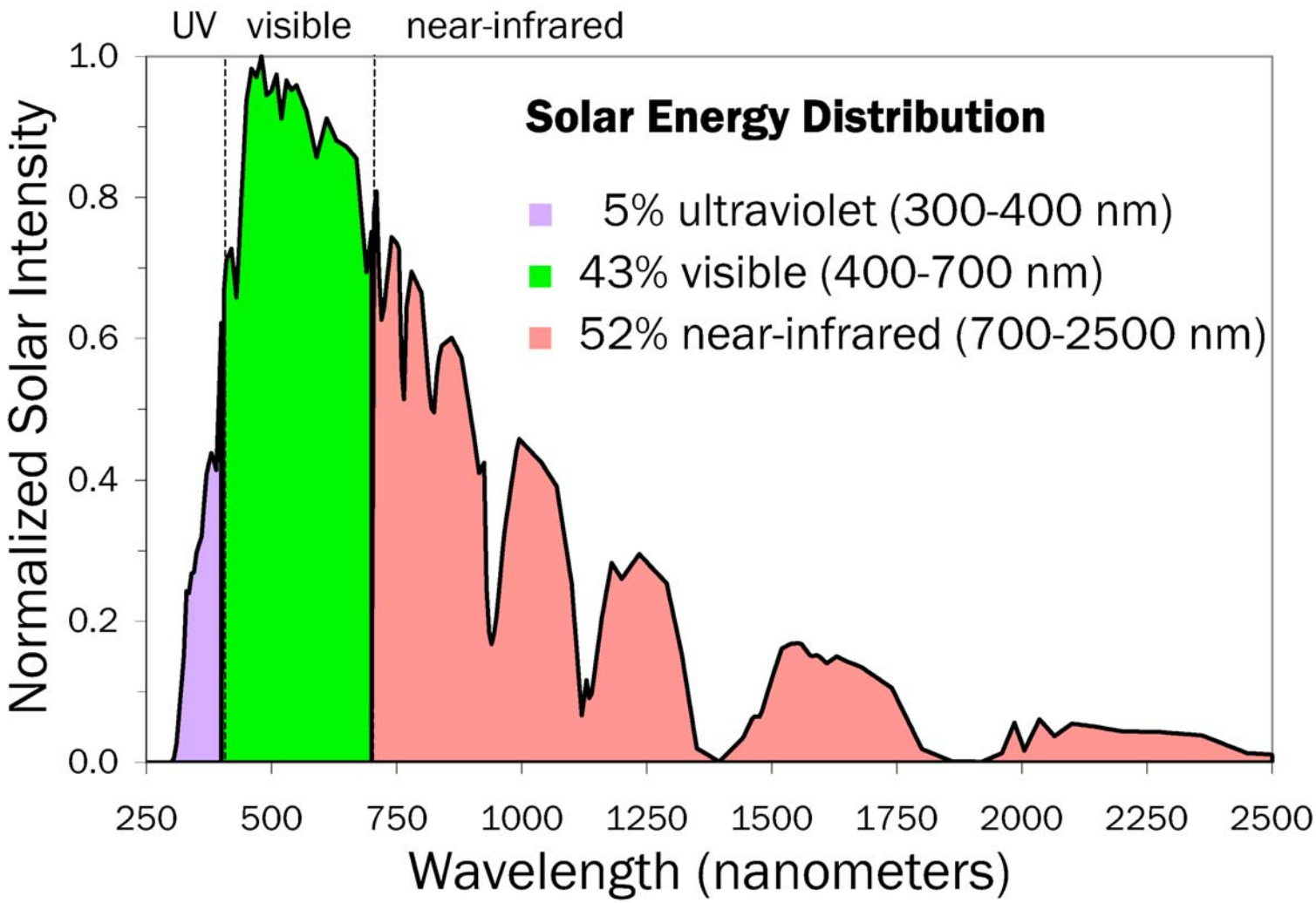
flat, white

pitched, white

**New**

pitched, cool & colored

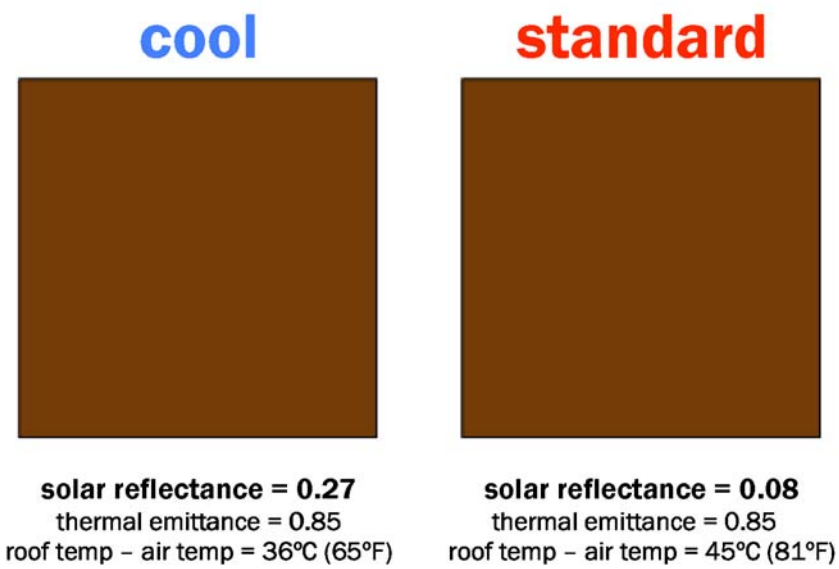
# Cool Colors Reflect Invisible Near-Infrared Sunlight

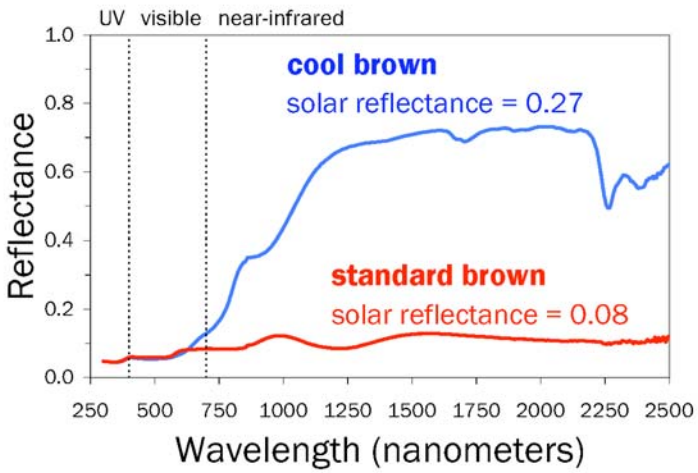


# Cool and Standard Brown Metal Roofing Panels

- Solar reflectance ~ 0.2 higher
- Afternoon surface temperature ~ 10ºC lower

Courtesy BASF Coatings



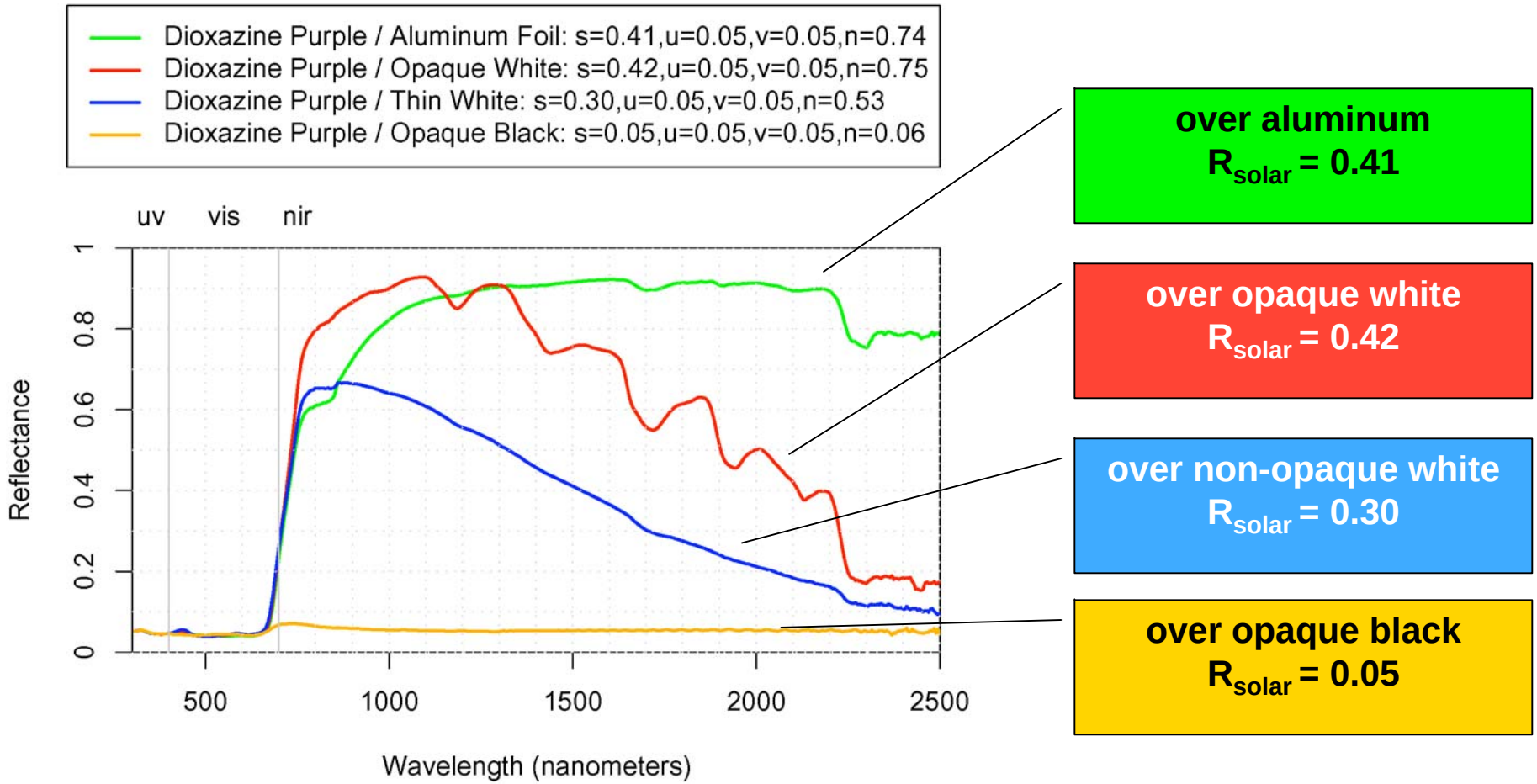



# Example: Dioxazine Purple Over Various Undercoats

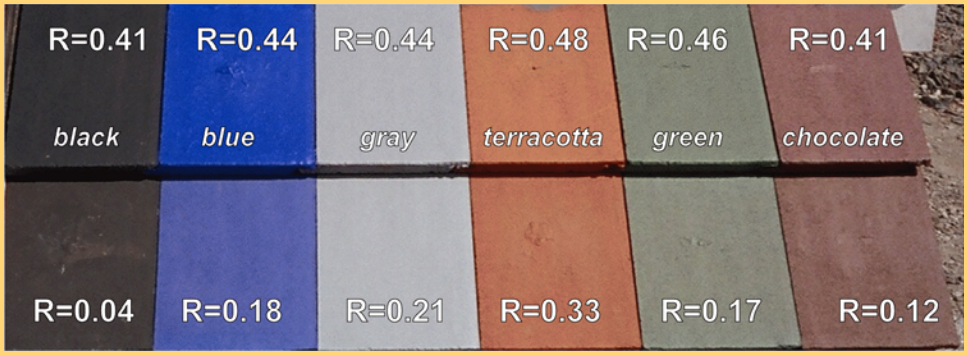
- Two-layer system
  - top coat: thin layer of dioxazine purple (14-27 μm)
  - undercoat or substrate:
    aluminum foil (~ 25 μm)
    opaque white paint (~1000 μm)
    non-opaque white paint (~ 25 μm)
    opaque black paint (~ 25 μm)

**purple over aluminum foil** | **purple over opaque white paint** | **purple over non-opaque white paint** | **purple over opaque black paint**

# Dioxazine Purple Reflectances



# Designing Cool Colored Roofing

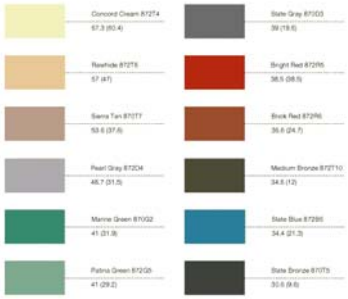



| | | | | | | |
|---|---|---|---|---|---|---|
| **cool concrete tile R ≥0.40** | R=0.41 | R=0.44 | R=0.44 | R=0.48 | R=0.46 | R=0.41 |
| **standard concrete tile (same color)** | R=0.04 | R=0.18 | R=0.21 | R=0.33 | R=0.17 | R=0.12 |
| **solar reflectance gain =** | **+0.37** | **+0.26** | **+0.23** | **+0.15** | **+0.29** | **+0.29** |

**Courtesy American Rooftile Coatings**

**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**

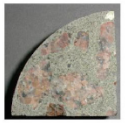
**Courtesy Elk Corporation**

# Cool is Cool: From Cool Color Roofs to Cool Color Cars and Cool Jackets

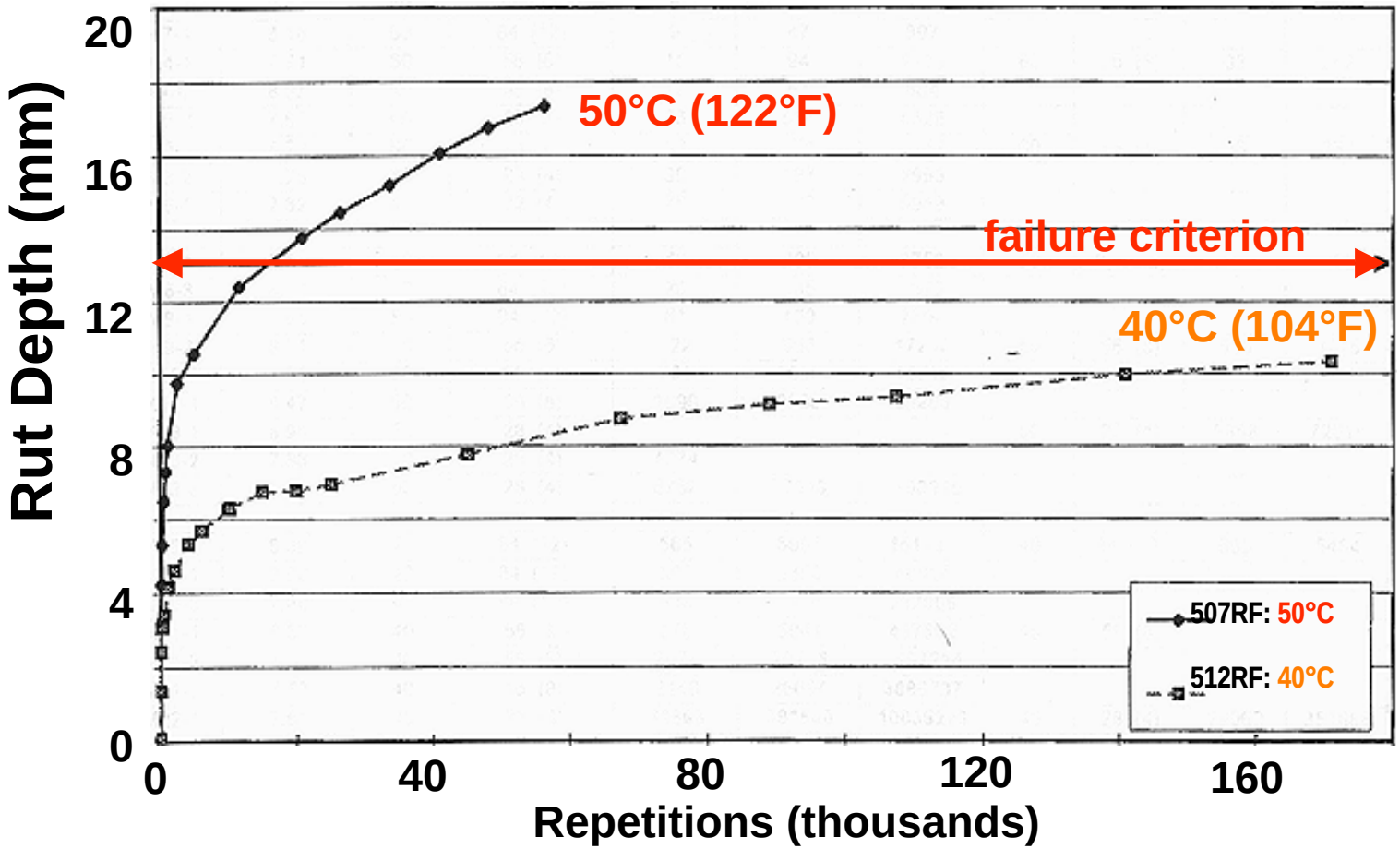
- Toyota experiment (surface temperature 10K cooler)
- Ford is also working on the technology

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

# Development of Cool Paving Materials:
## *Longer story than we have time*

| *Concrete* | **(a)** Unexposed | **(b)** Weathered | **(c)** Weathered, wetted | **(d)** Soiled | **(e)** Abraded | **(f)** Formed |
|---|---|---|---|---|---|---|
| **C1:S1:R2** gray cement/ riverbed sand/ granite rock | ρ=0.44 | ρ=0.34 | ρ=0.14 | ρ=0.43 |  ρ=0.24 | ρ=0.25 |

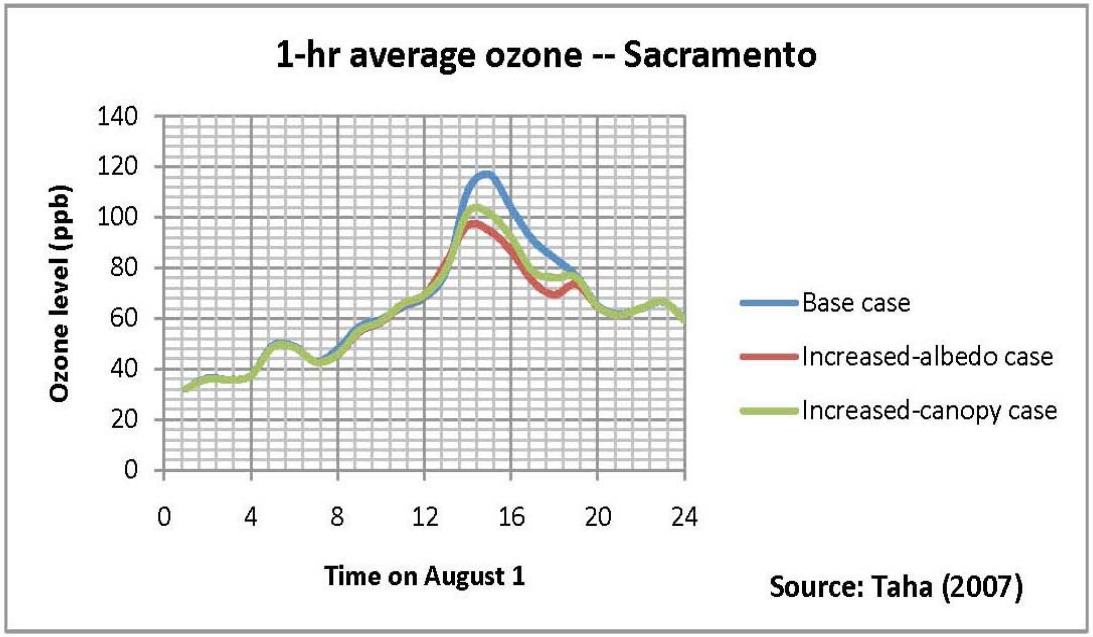
# Temperature Effect on Rutting



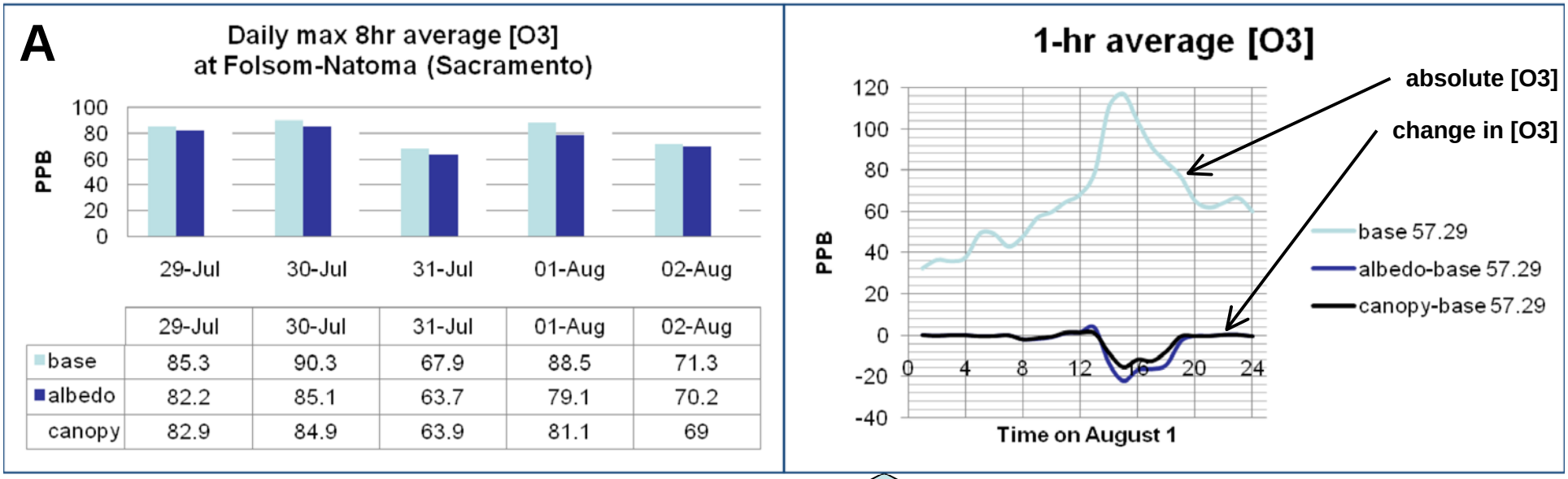

*Source: Dr. John Harvey, UC B Civil Engineering, Inst. Transpo. Studies*

# Potential air-quality improvements from UHI control

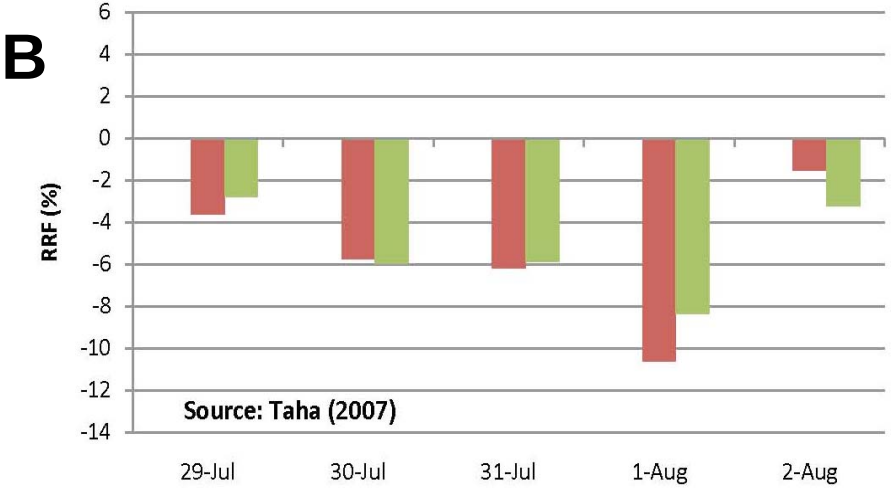
- Increased urban albedo and vegetation-canopy cover can lower urban air temperatures, which can decrease electricity use, emissions, and ozone air pollution.
- This involves modifying ~ ½ of the built up area (roofs, paved surfaces ) or adding ¼ million trees in smaller urban areas.
- Improved models 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




| | 29-Jul | 30-Jul | 31-Jul | 01-Aug | 02-Aug |
|---|---|---|---|---|---|
| base | 85.3 | 90.3 | 67.9 | 88.5 | 71.3 |
| albedo | 82.2 | 85.1 | 63.7 | 79.1 | 70.2 |
| canopy | 82.9 | 84.9 | 63.9 | 81.1 | 69 |



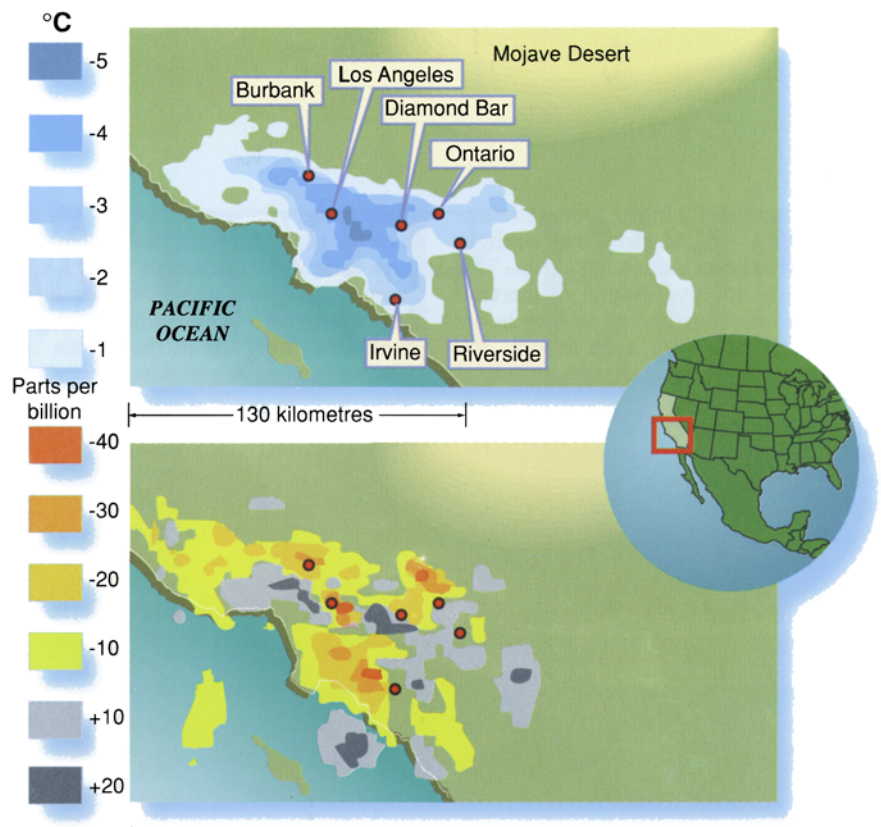

**August 1st, simulated 1-hr ozone at a location in Sacramento (eastern domain) and changes resulting from UHI control (this is an alternate view of figure on page 1).**

**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.**

# Simulated Meteorology and Air-quality Impacts in LA

Temperature Change

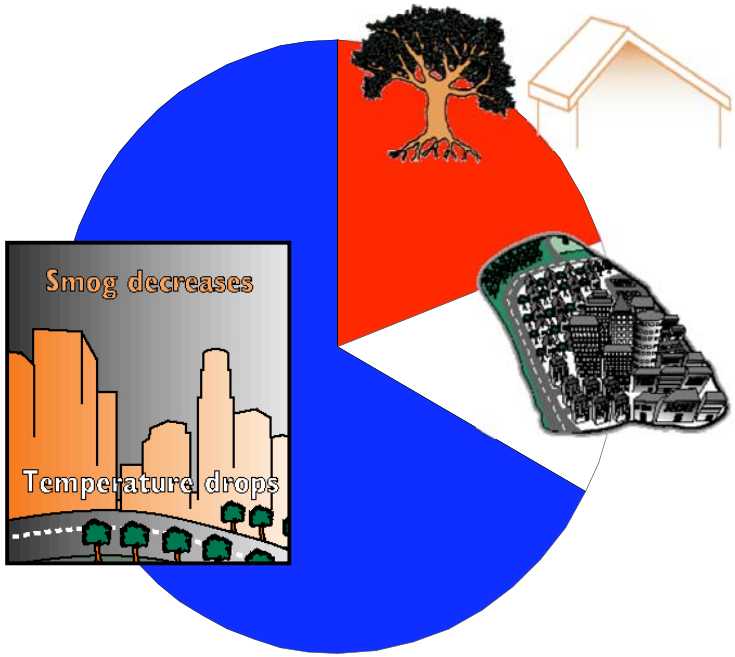
Ozone Concentration Change



# 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.

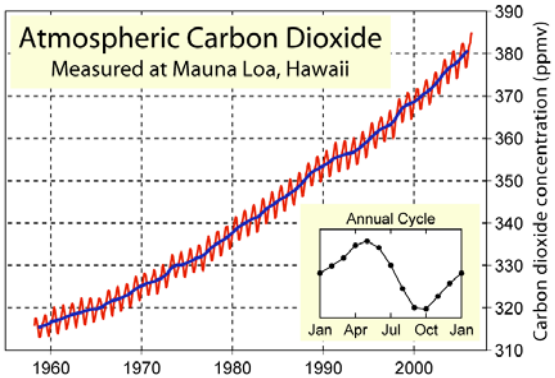
- Building standards for reflective roofs
  - American Society of Heating and Air-conditioning Engineers (ASHRAE): New commercial and residential buildings
  - California Title 24 Building Energy Standard
  - Many other states: Georgia, Florida, Hawaii, …
- Air quality standards
  - South Coast AQMD
  - 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 $CO_2$
- Annual savings in the world = $10-15B; ~ 100 M tons $CO_2$
- But higher albedo surfaces (roofs and pavements) directly cool the world (0.01 K) quite independent of avoided $CO_2$. 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
  $RF = 5.35\ ln(CO2/CO2_0)$ [W/m$^2$]
- $\delta RF = 5.35\ \delta CO2/CO2$ [W/m$^2$]
- Area of Earth = $5.08 \times 10^{14}$ [m$^2$]
- $CO_2$ in atmosphere = $3 \times 10^3$ [GT]
- Hence, RF per T of $CO_2$ ≈ **1 kW/ T $CO_2$**



# Dense Urban Areas are 1% of Land

- Area of the Earth = $5.08 \times 10^{14}$ $m^2$
- Land Area (29%) = $148 \times 10^{12}$ $m^2$ [1]
- Area of the 100 largest cities = $0.38 \times 10^{12}$ $m^2$ = 0.26% of Land Area for 670 M people
- Assuming 3B live in urban area, urban areas = [3000/670] x 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 0.25x0.25=0.063
- Paved surfaces albedo can increase by 0.15 for a net change of 0.35x0.15=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)

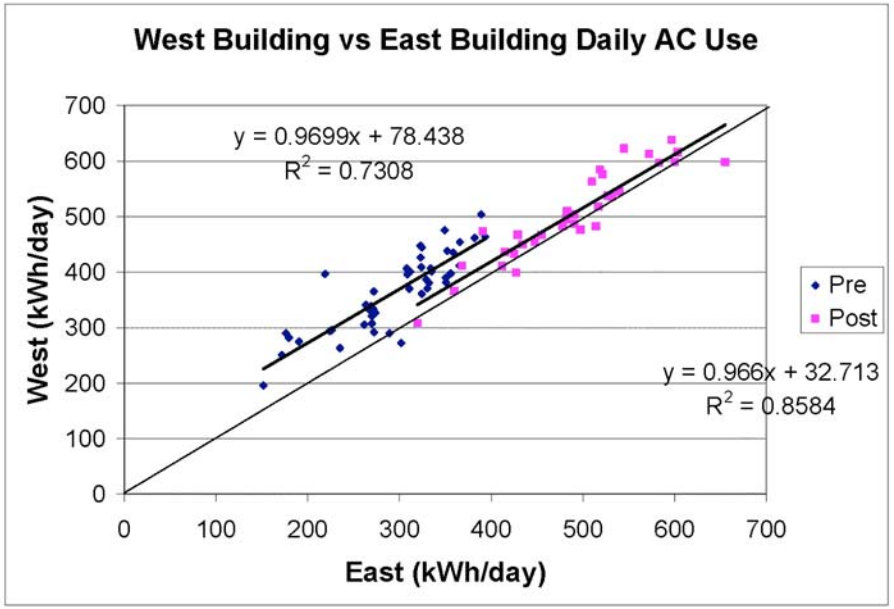
- Increasing the solar reflectance of a $m^2$ of roofs by 0.25 is equivalent to sequestering 31-57 kg $CO_2$ from atmosphere (18-32 $m^2$ of cool roof = 1 T $CO_2$ removed from atmosphere)
- Increasing the solar reflectance of a $m^2$ of paved surfaces by 0.15 is equivalent to sequestering 18-34 kg $CO_2$ from atmosphere
- World-wide equivalent atmospheric carbon reduction of reflective roofs and pavements is 22 - 40 GT $CO_2$
- Equivalent $CO_2$ emission reduction of reflective roofs and pavements = [22 – 40] /0.55 = 40 - 73 GT $CO_2$
- 40 -73 GT $CO_2$ is 1-2 years of the world 2025 emission of 37 GT $CO_2$ per year
- $CO_2$ emissions currently trade at ~$25/T; 40 – 73 GT $CO_2$ worth $1000 - $1800 billion

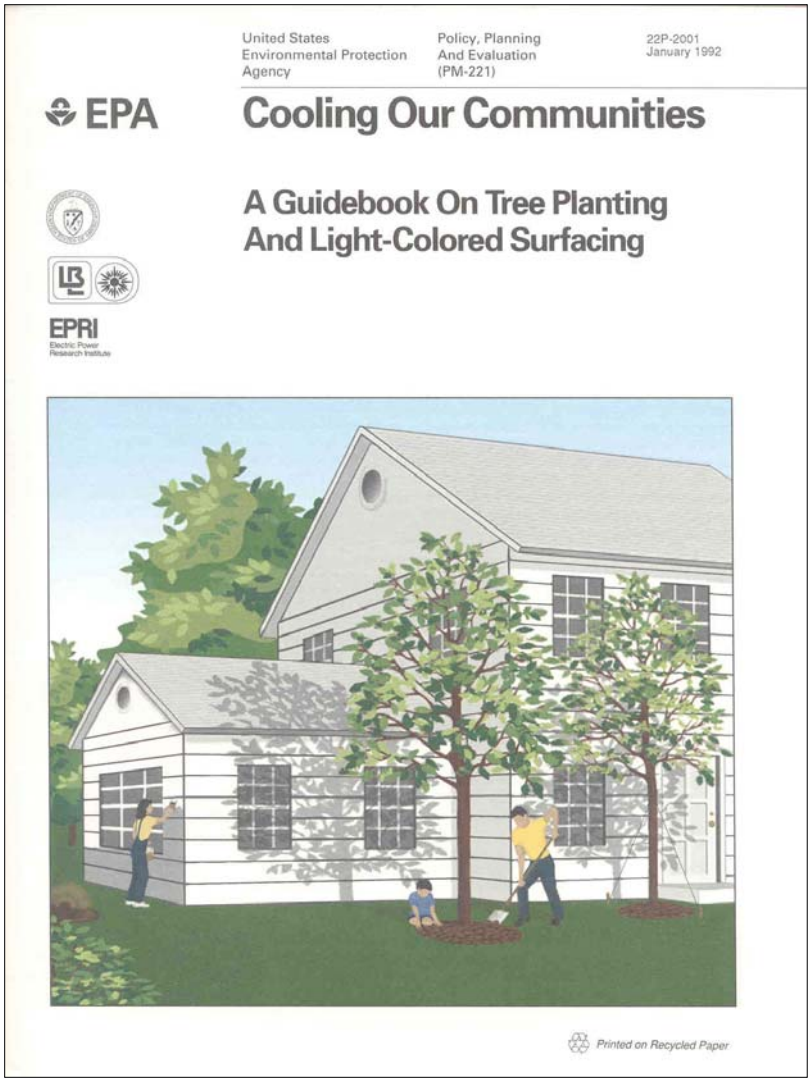
# A Global Action Plan: The Big Picture

- Develop an international to install cool roof/pavement in world's100 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