Energy Efficiency:
The first and most profitable way to delay Climate Change
The Indus Entrepreneur
July 21, 2008

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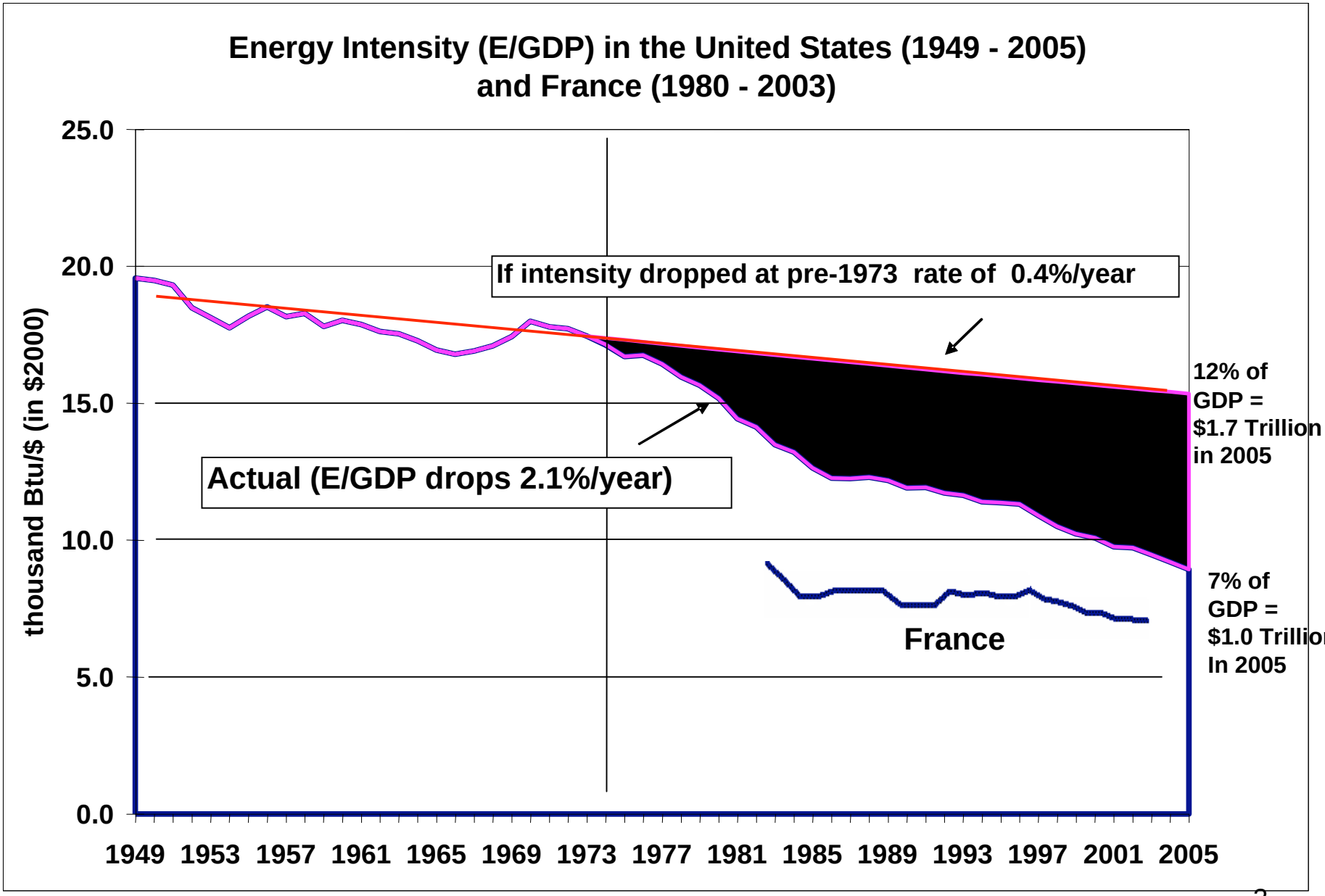
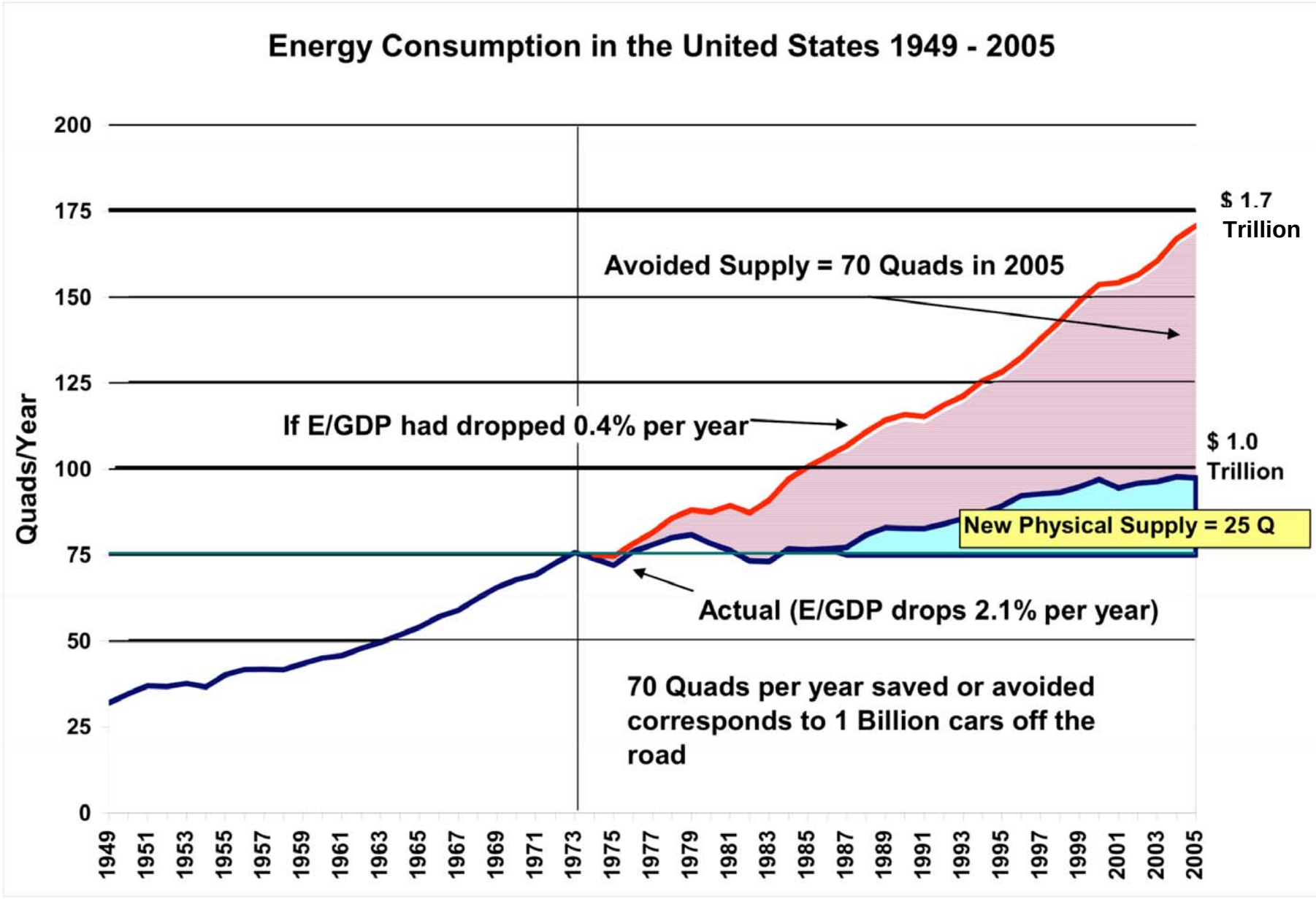
http://www.energy.ca.gov/commissioners/rosenfeld.html
or just Google “Art Rosenfeld”


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
Quads/Year
200
175
150
125
100
75
50
25
0
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
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

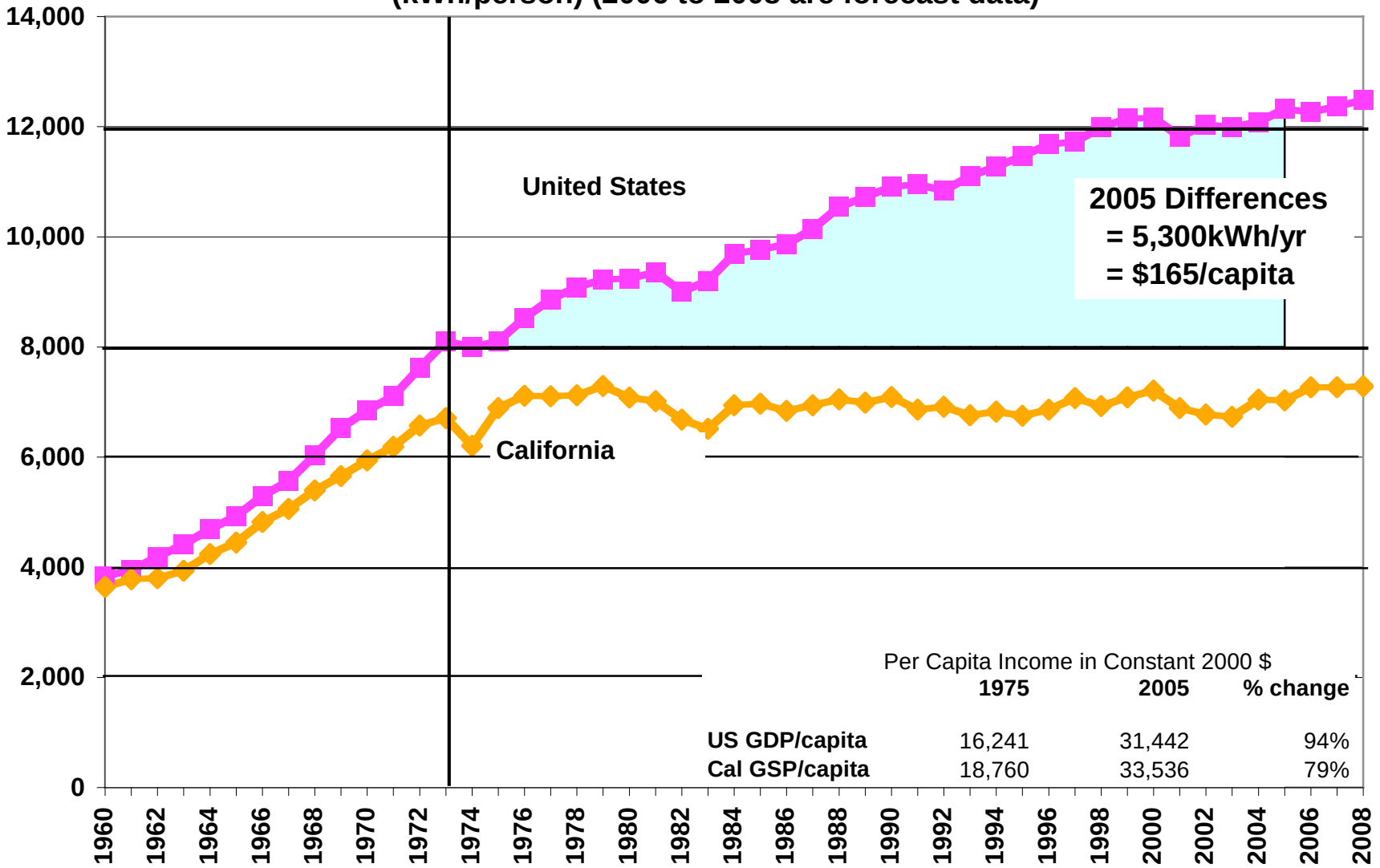
How Much of The Savings Come from Efficiency

- 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.

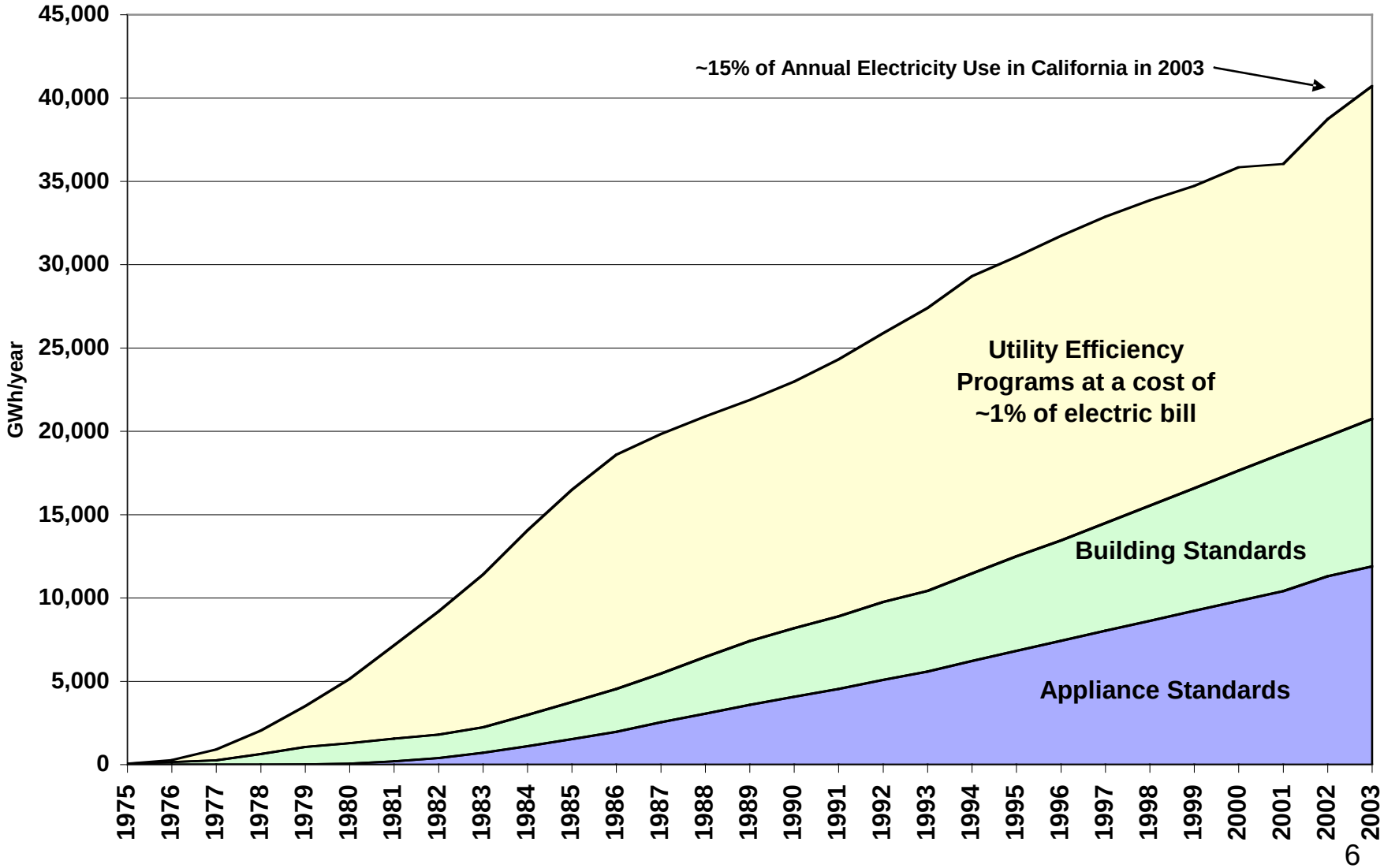
Per Capita Electricity Sales (not including self-generation) (kWh/person) (2006 to 2008 are forecast data)



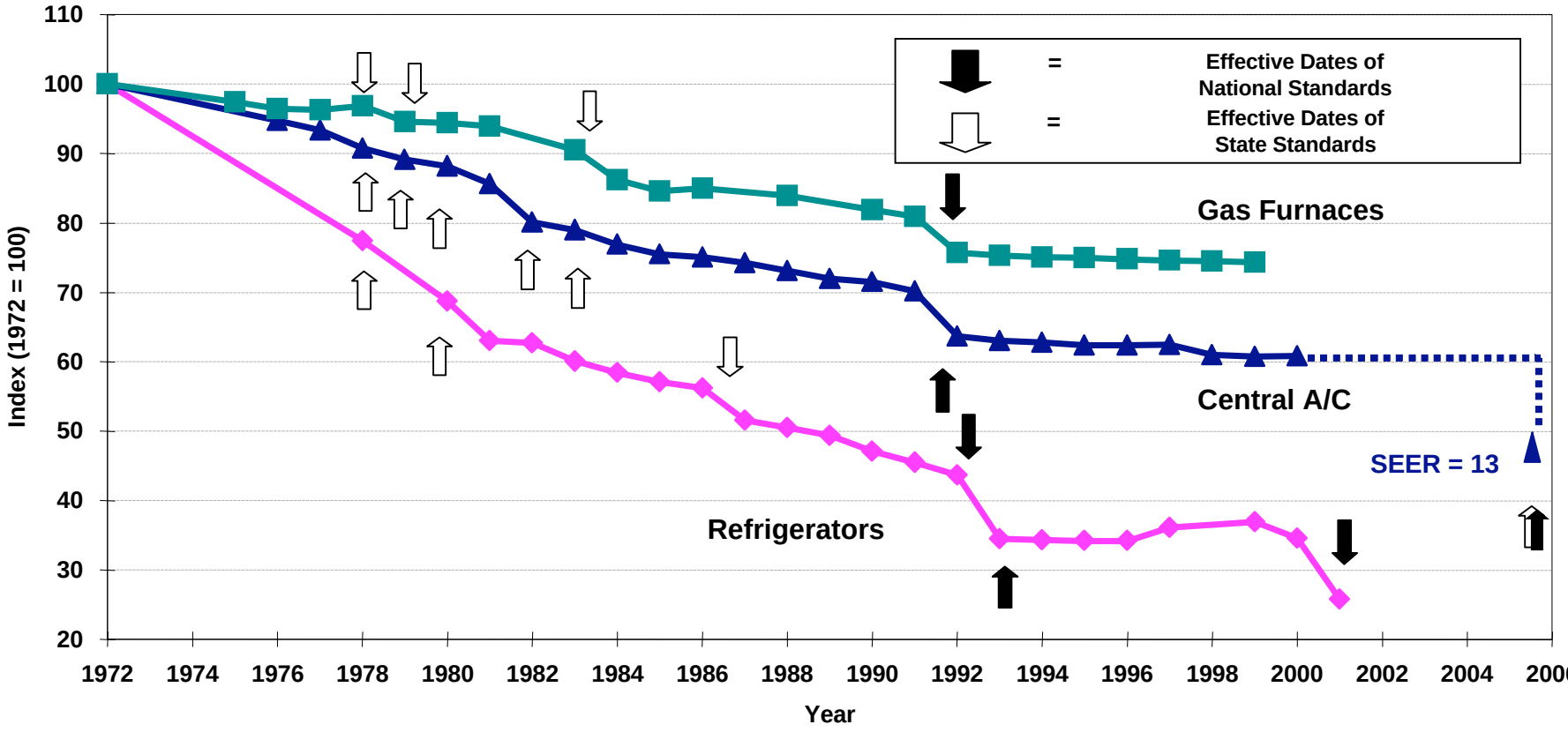
Per Capita Income in Constant 2000 $

	1975	2005	% change
US GDP/capita	16,241	31,442	94%
Cal GSP/capita	18,760	33,536	79%

Annual Energy Savings from Efficiency Programs and Standards



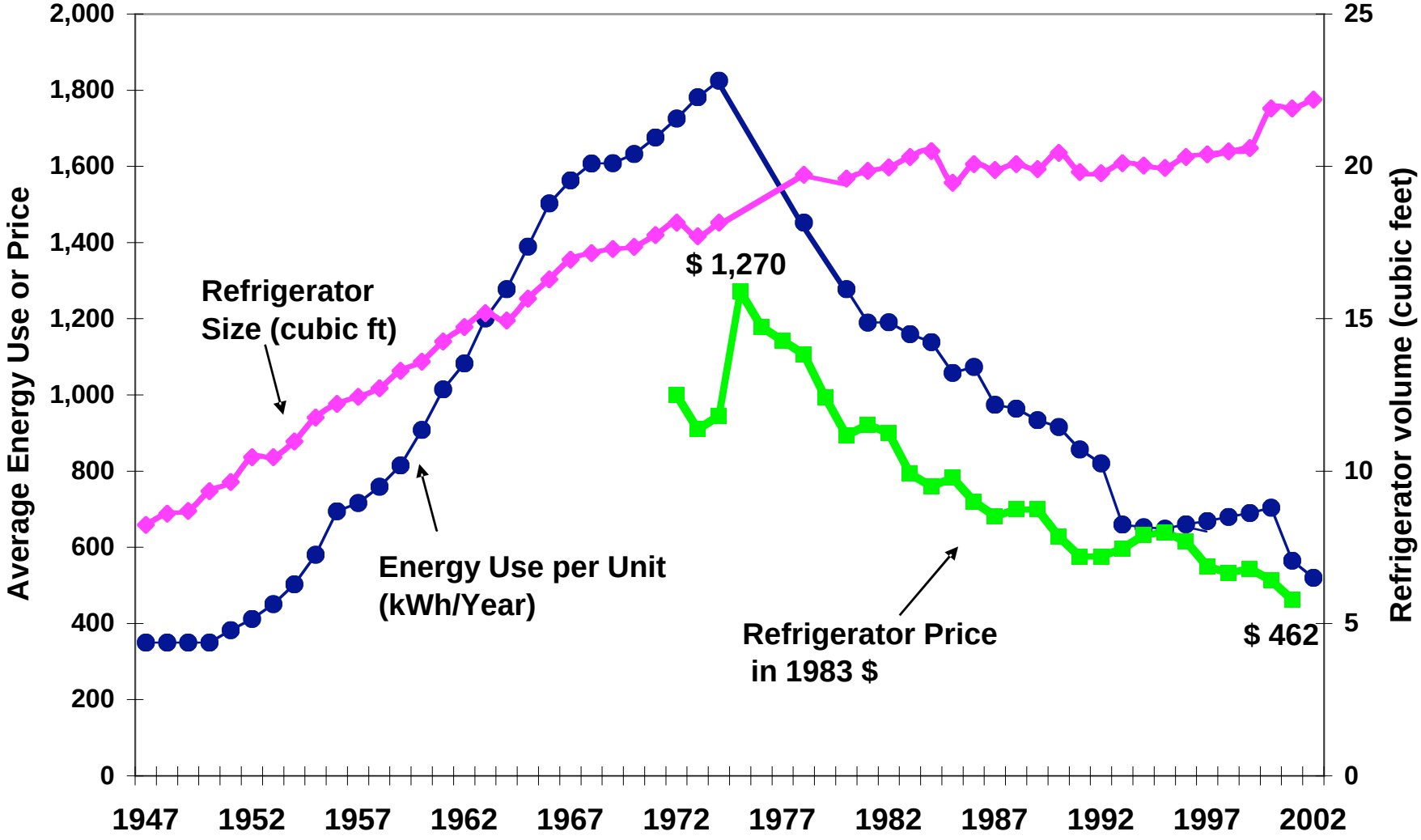
Impact of Standards on Efficiency of 3 Appliances



Source: S. Nadel, ACEEE,

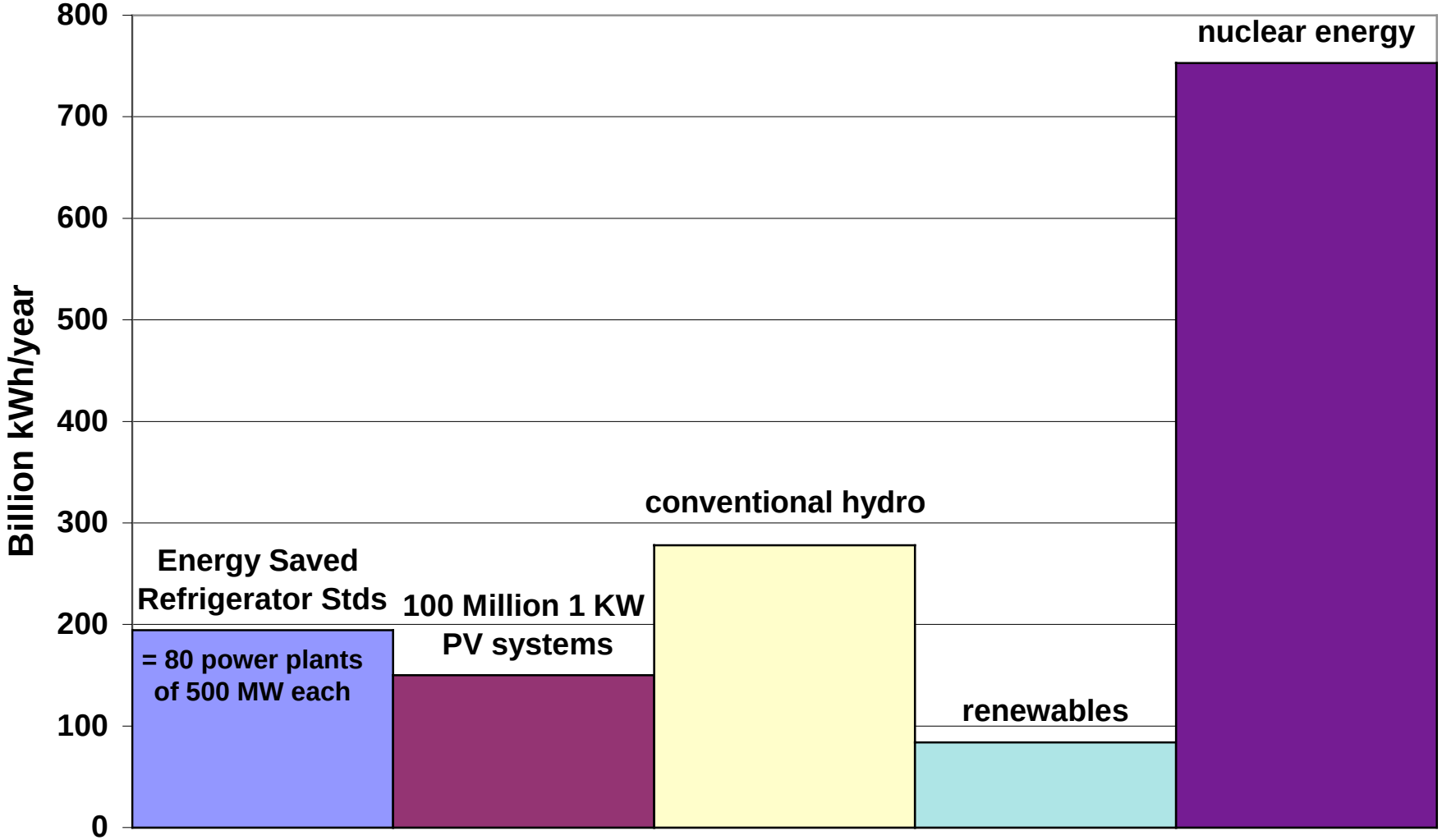
in ECEEE 2003 Summer Study, www.eceee.org

New United States Refrigerator Use v. Time and Retail Prices



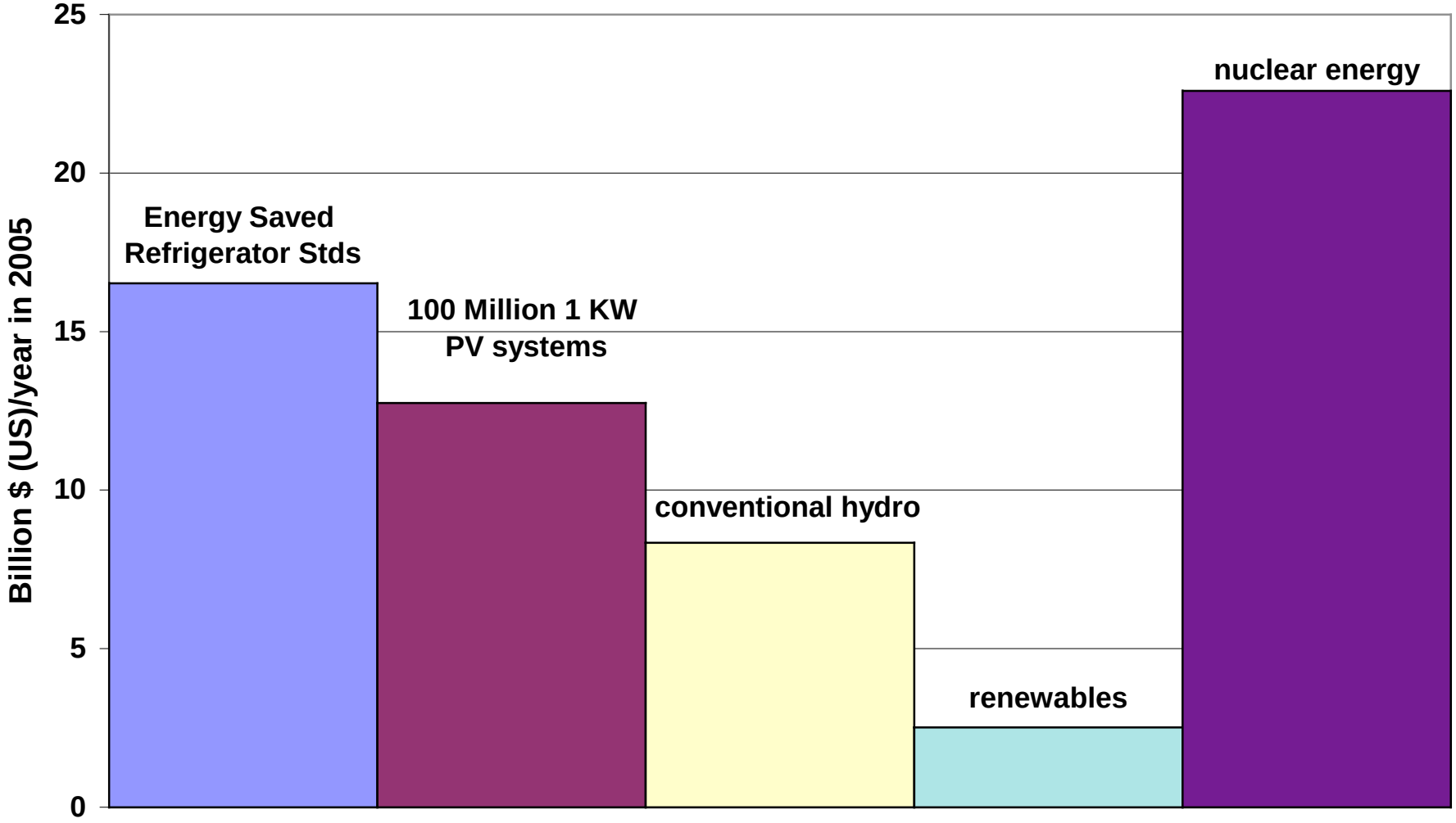
Source: David Goldstein

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

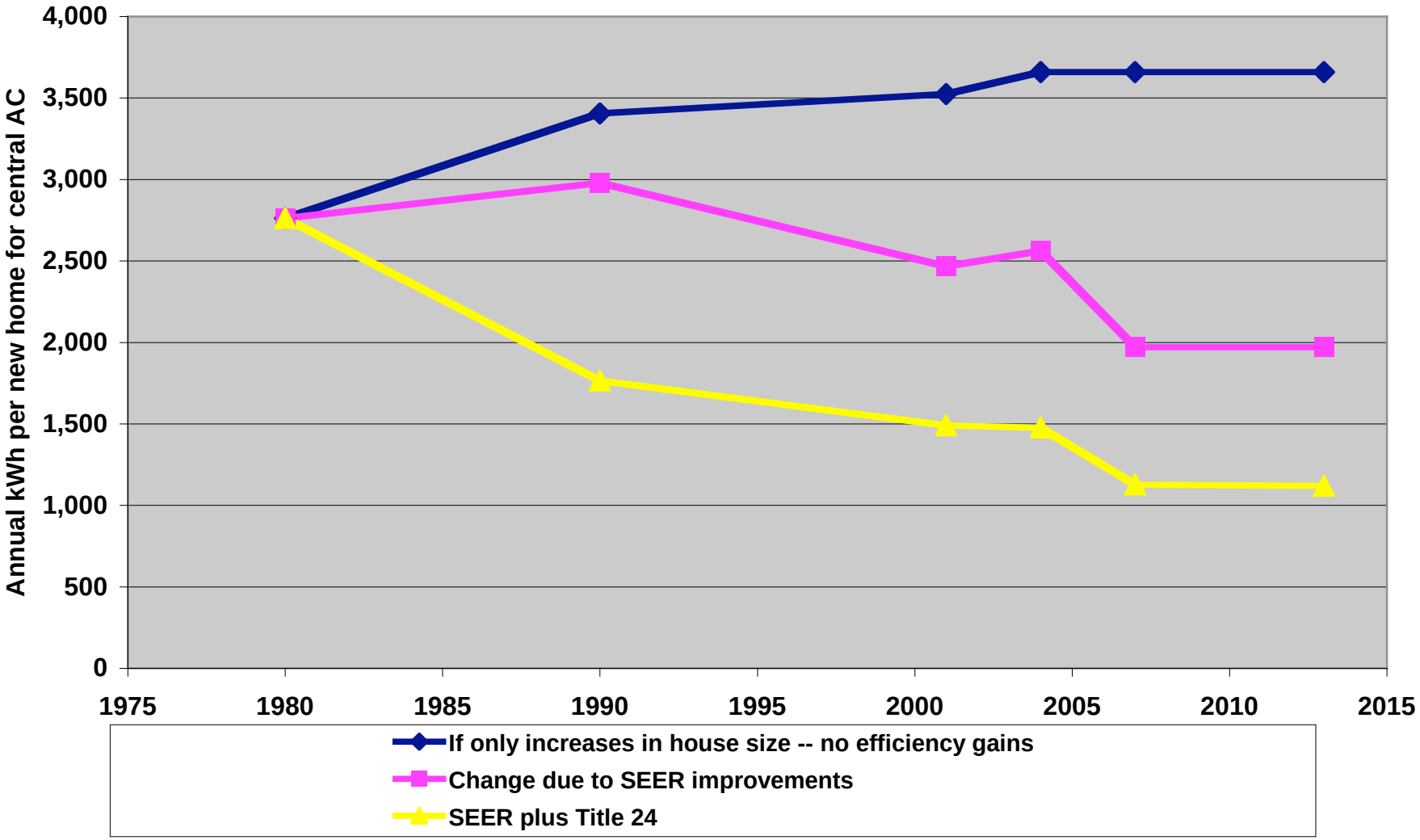


In the United States

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)

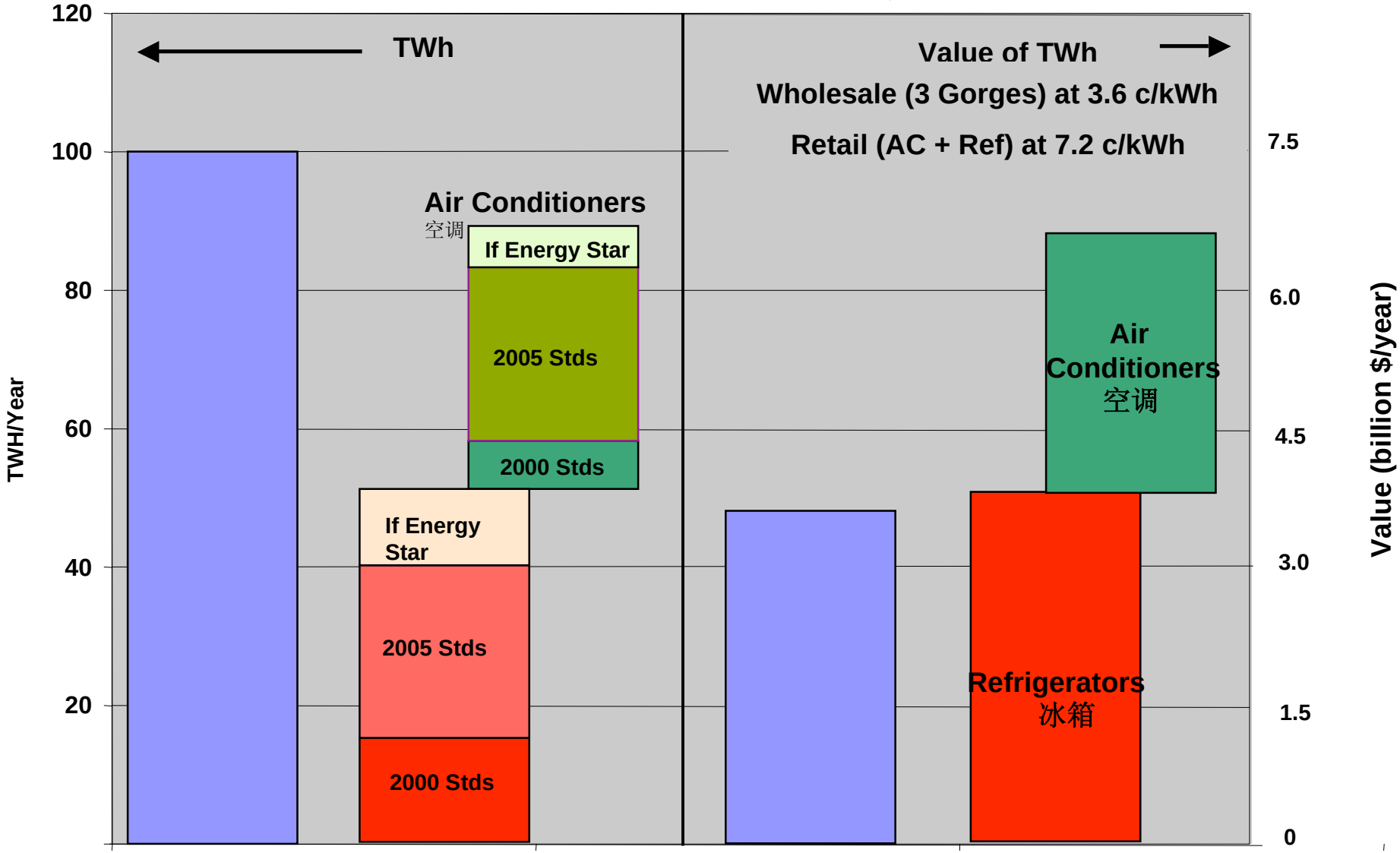


Air Conditioning Energy Use in Single Family Homes in PG&E
The effect of AC Standards (SEER) and Title 24 standards



Comparison of 3 Gorges to Refrigerator and AC Efficiency Improvements

三峡电量与电冰箱、空调能效对比

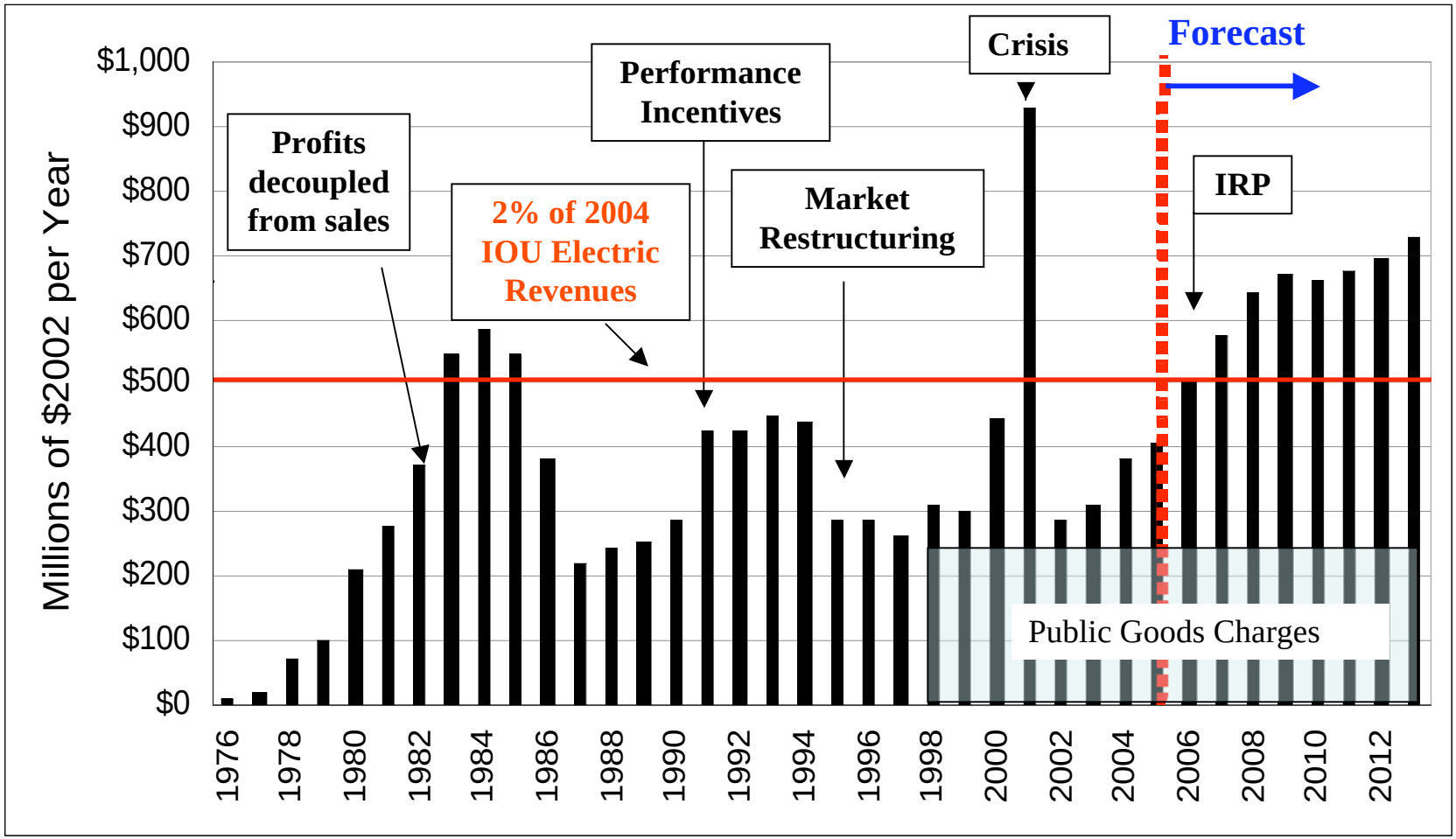


Savings calculated 10 years after standard takes effect. Calculations provided by David Fridley, LBNL

标准生效后，10年节约电量

Incandescent Lamps:
Phase out!
(by 2018)

California IOU's Investment in Energy Efficiency



Cool Roof Technologies

Old

flat, white

pitched, white

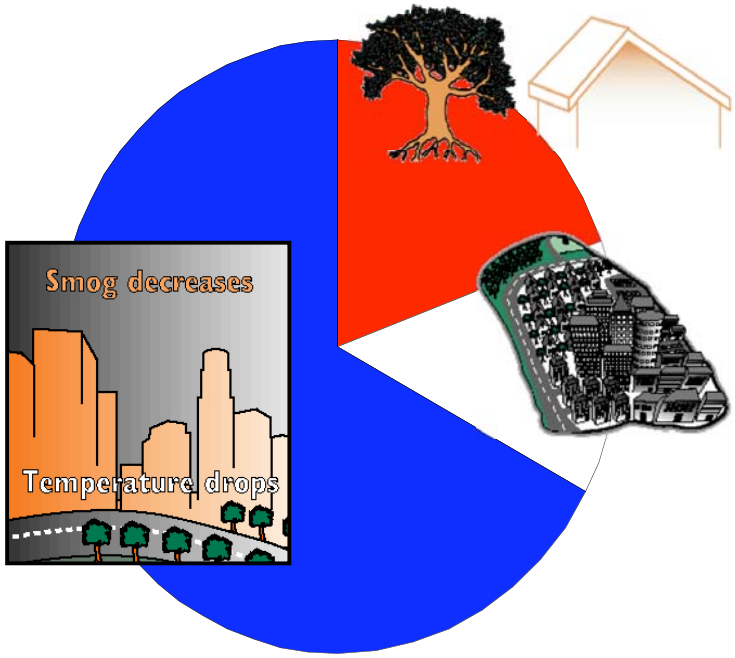
New

pitched, cool & colored

Potential Savings in LA

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

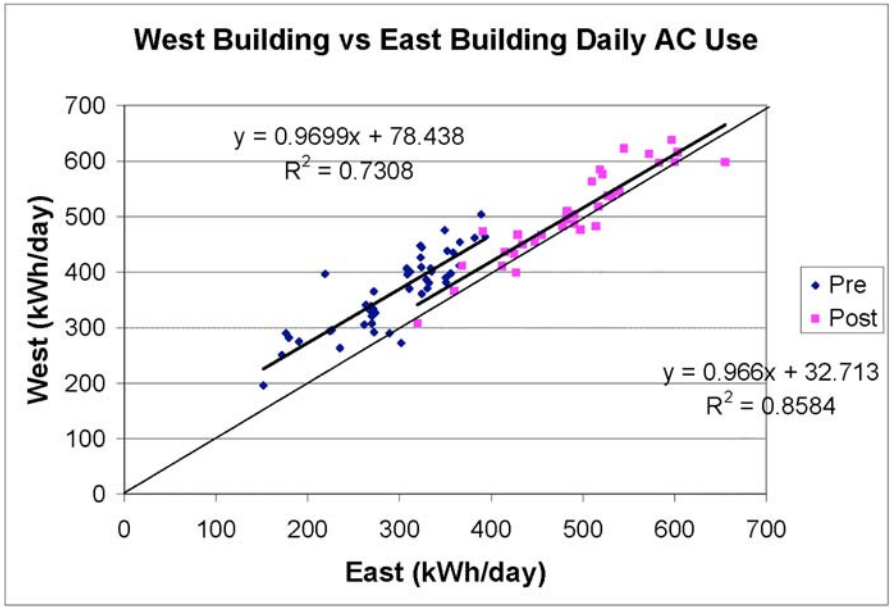
- **Estimate of national savings: $5B/year**



Cool Roof Programs around the World

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

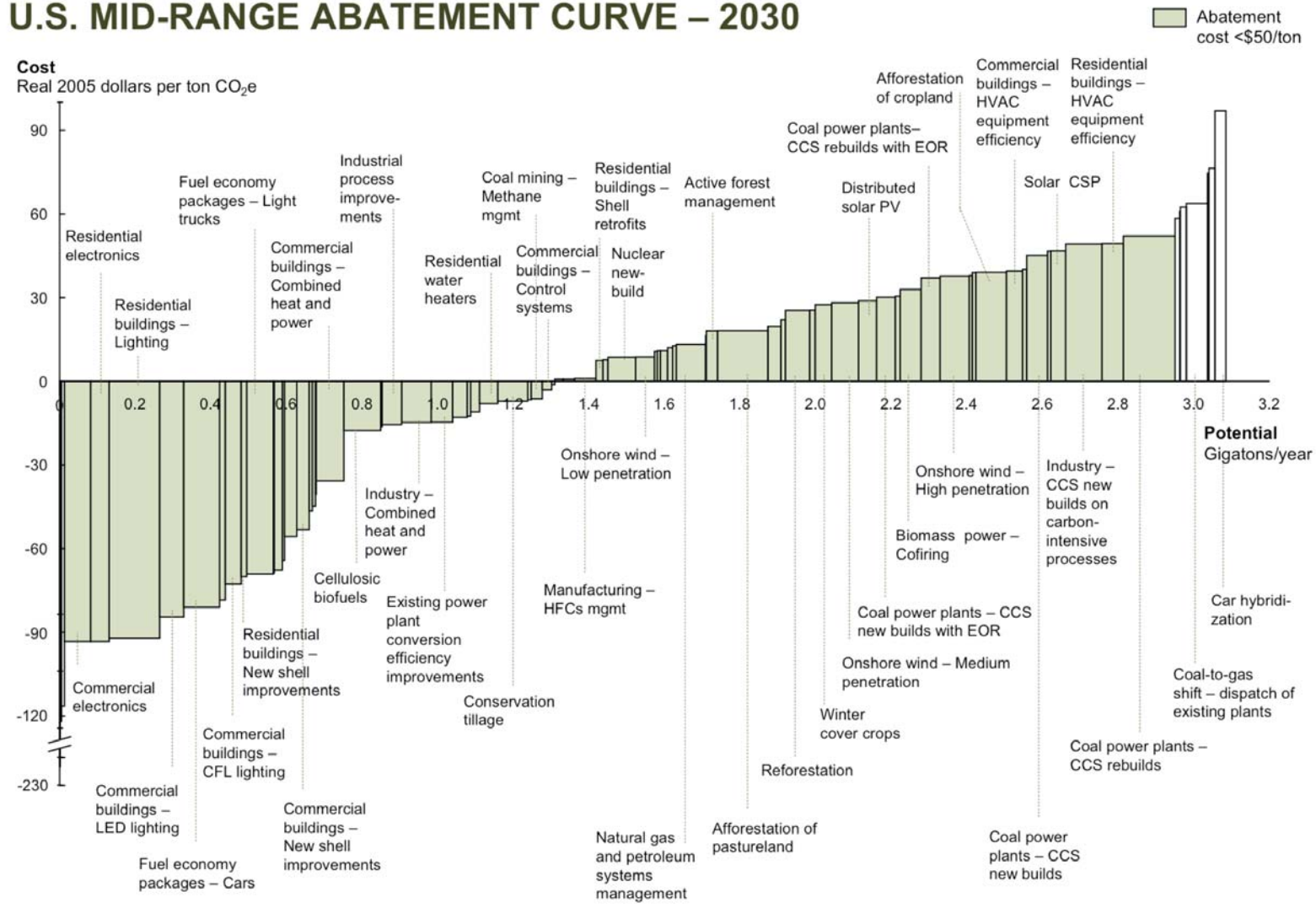
Saved 15% of Air Conditioning Energy!
Cool Cars too!



Cool Cars

- **Toyota experiment; Ford and Fiat developing**
- **18 F cooler! Better mpg and lower car purchase cost (smaller air conditioner)**

U.S. MID-RANGE ABATEMENT CURVE – 2030



Source: McKinsey analysis

The Guardian for America.

guardian.co.uk | The Observer

Time runs out for islanders on global warming's front line

Rising sea levels threaten to flood many of the islands in the fertile Ganges delta, leading to an environmental disaster and a refugee crisis for India and Bangladesh

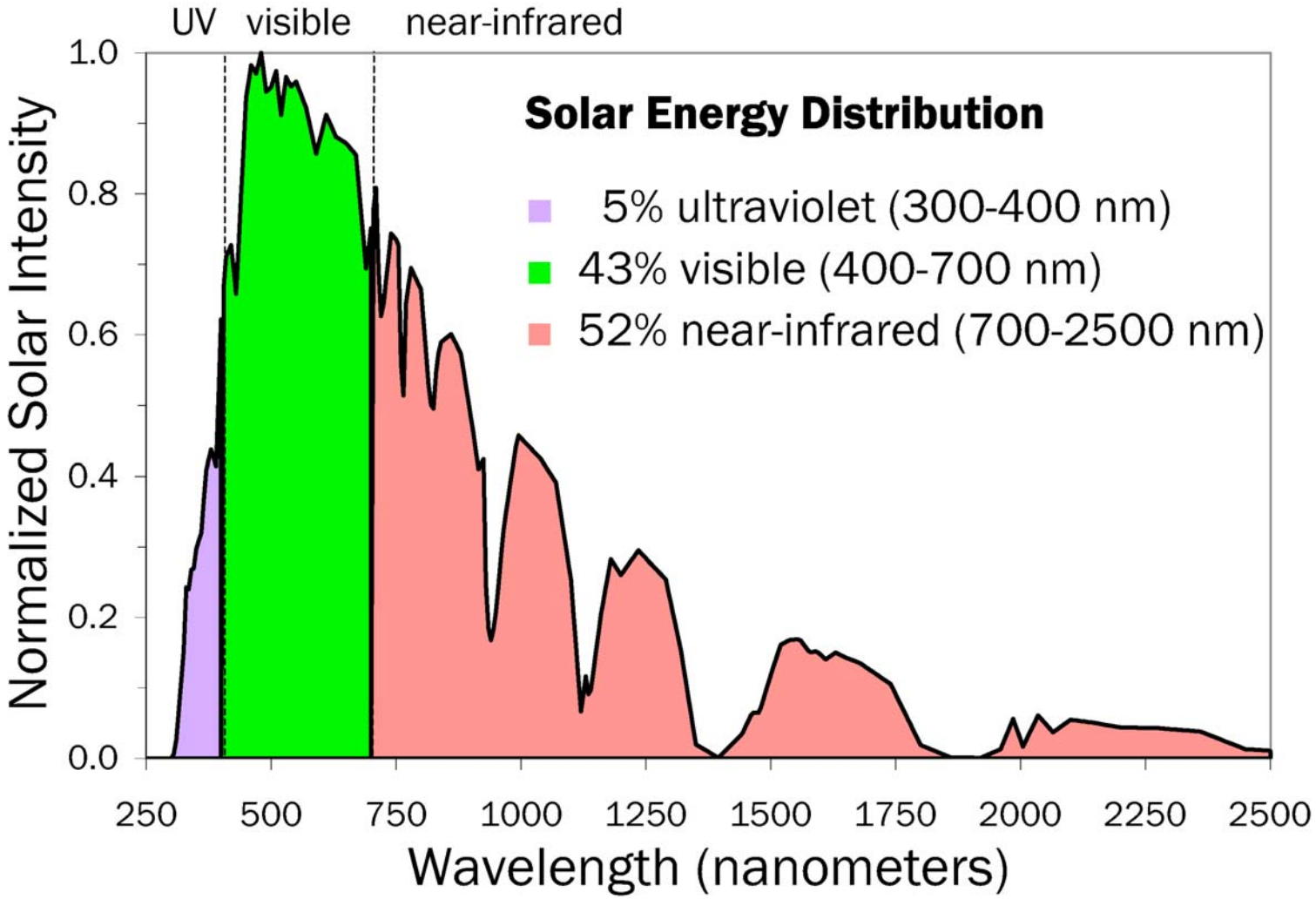
Dan McDougall in the Sundarbans
The Observer, Sunday March 30 2008

To find this story, Google "Sundarbans Refugee Camp"

The End

- All my talks are on my web page, including this one.
- Just Google “Art Rosenfeld”

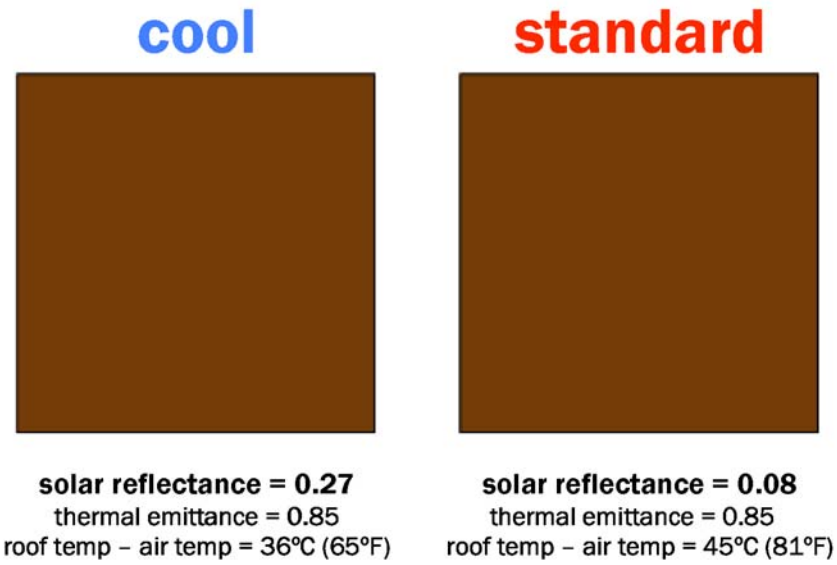
Cool Colors Reflect Invisible Near-Infrared Sunlight

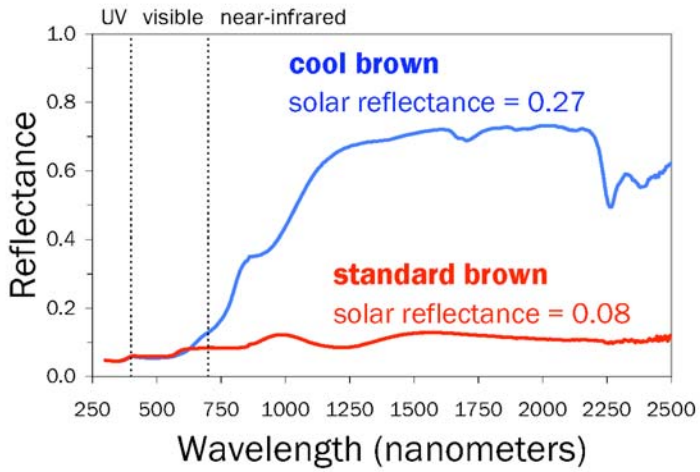


Cool and Standard Brown Metal Roofing Panels

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

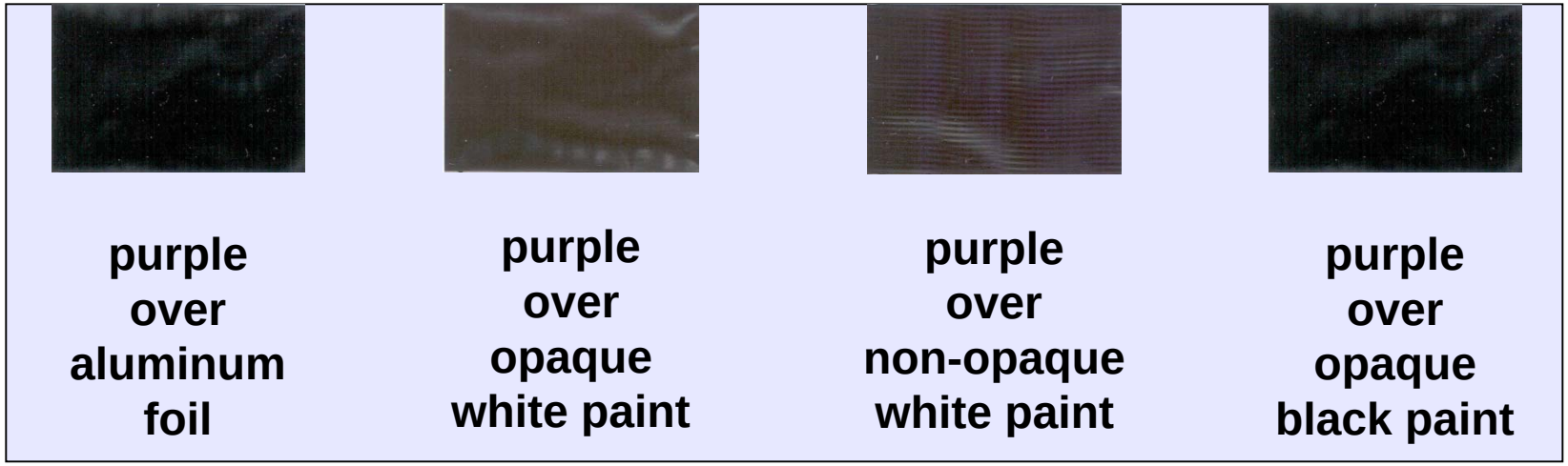
Courtesy BASF Coatings



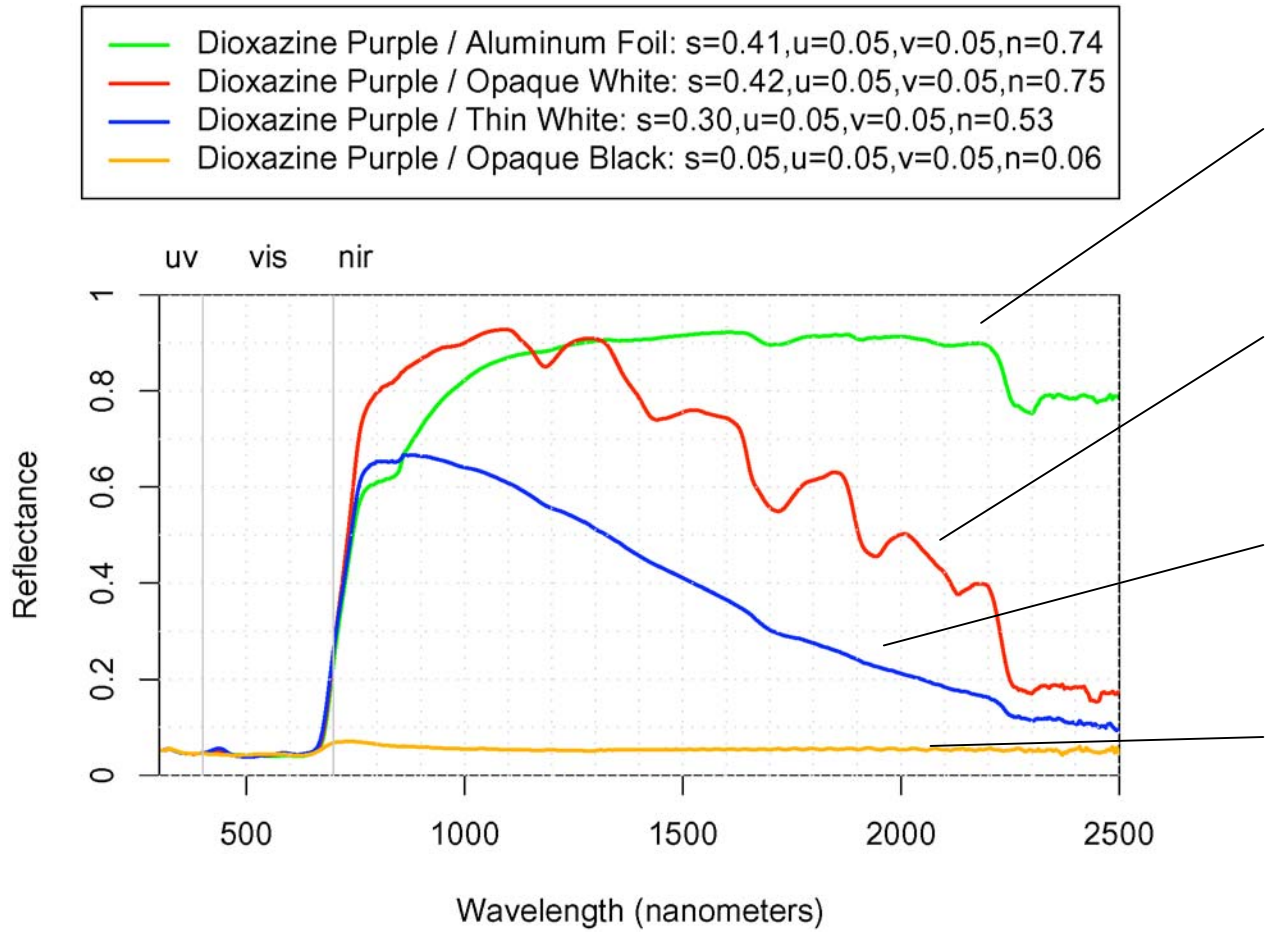


Example: Dioxazine Purple Over Various Undercoats

- 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)



Dioxazine Purple Reflectances



over aluminum
R_{solar} = 0.41

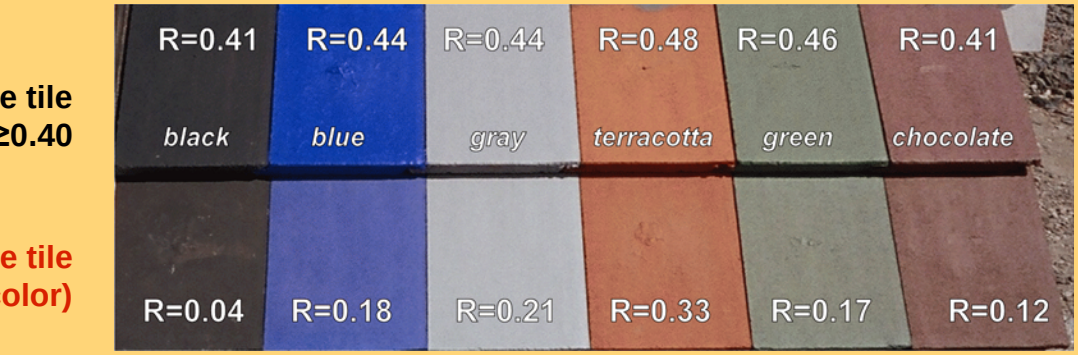
over opaque white
R_{solar} = 0.42

over non-opaque white
R_{solar} = 0.30

over opaque black
R_{solar} = 0.05

Designing Cool Colored Roofing

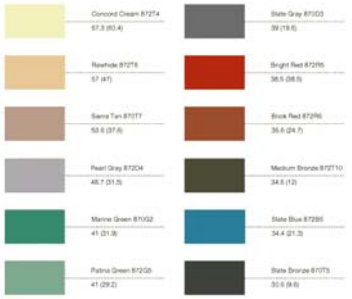
cool concrete tile R ≥0.40	R=0.41 *black*	R=0.44 *blue*	R=0.44 *gray*	R=0.48 *terracotta*	R=0.46 *green*	R=0.41 *chocolate*
standard concrete tile (same color)	R=0.04	R=0.18	R=0.21	R=0.33	R=0.17	R=0.12
solar reflectance gain =	**+0.37**	**+0.26**	**+0.23**	**+0.15**	**+0.29**	**+0.29**



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

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

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 can eventually save ~$200,000 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

Dense Urban Areas are 1% of Land

- Area of the Earth = 5.08×10^{14} m^2
- Land Area (29%) = 148×10^{12} m^2 [1]
- Area of the 100 largest cities = 0.38×10^{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]

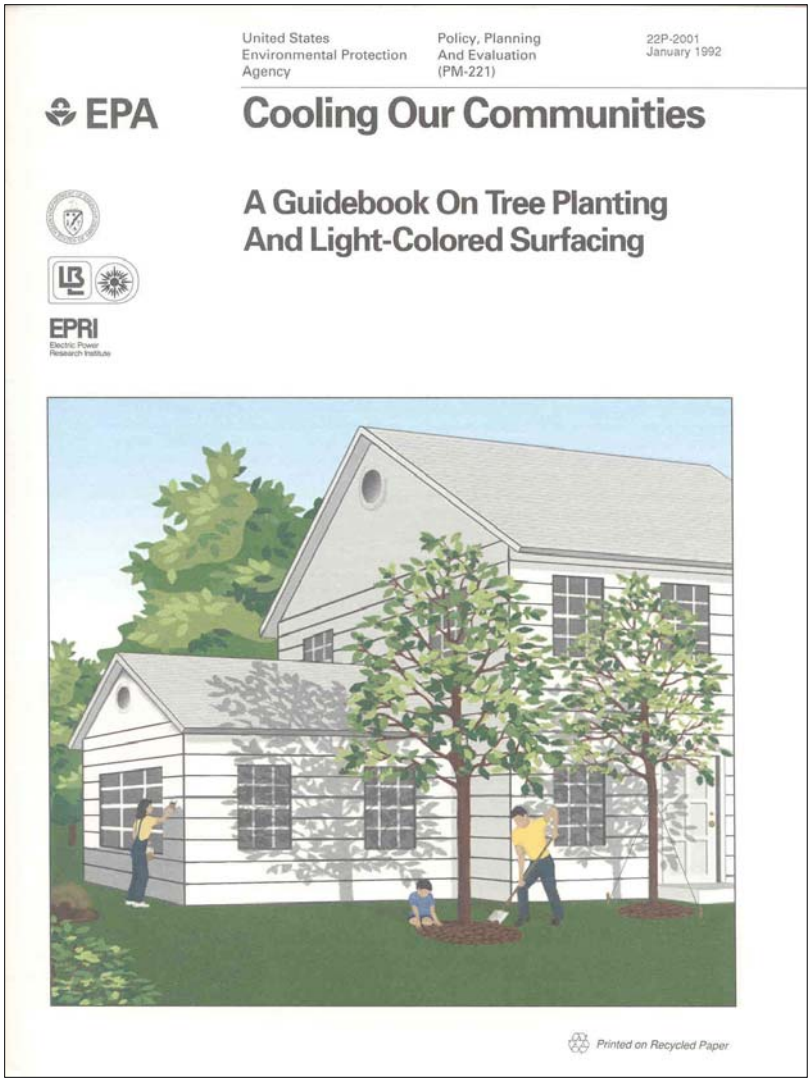
Potentials to Increase Urban Albedo is 0.1

- 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

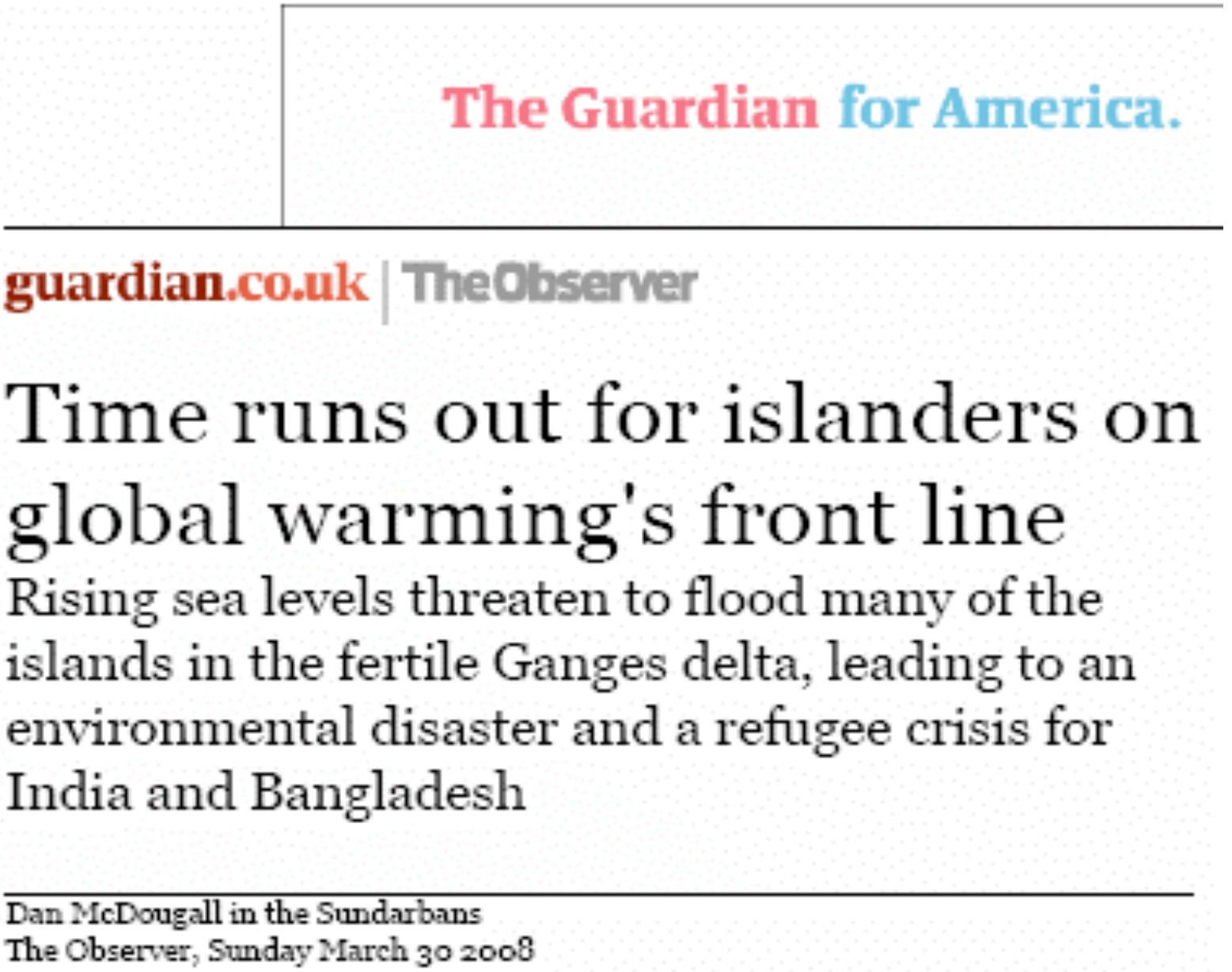
(Source: Akbari et al. 2008, submitted to Climatic Change)

- 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



Practical Guidelines

- EPA Guidebook (1992)
  - Good practical information
  - Greatest focus on trees
- EPA is working on a new edition



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