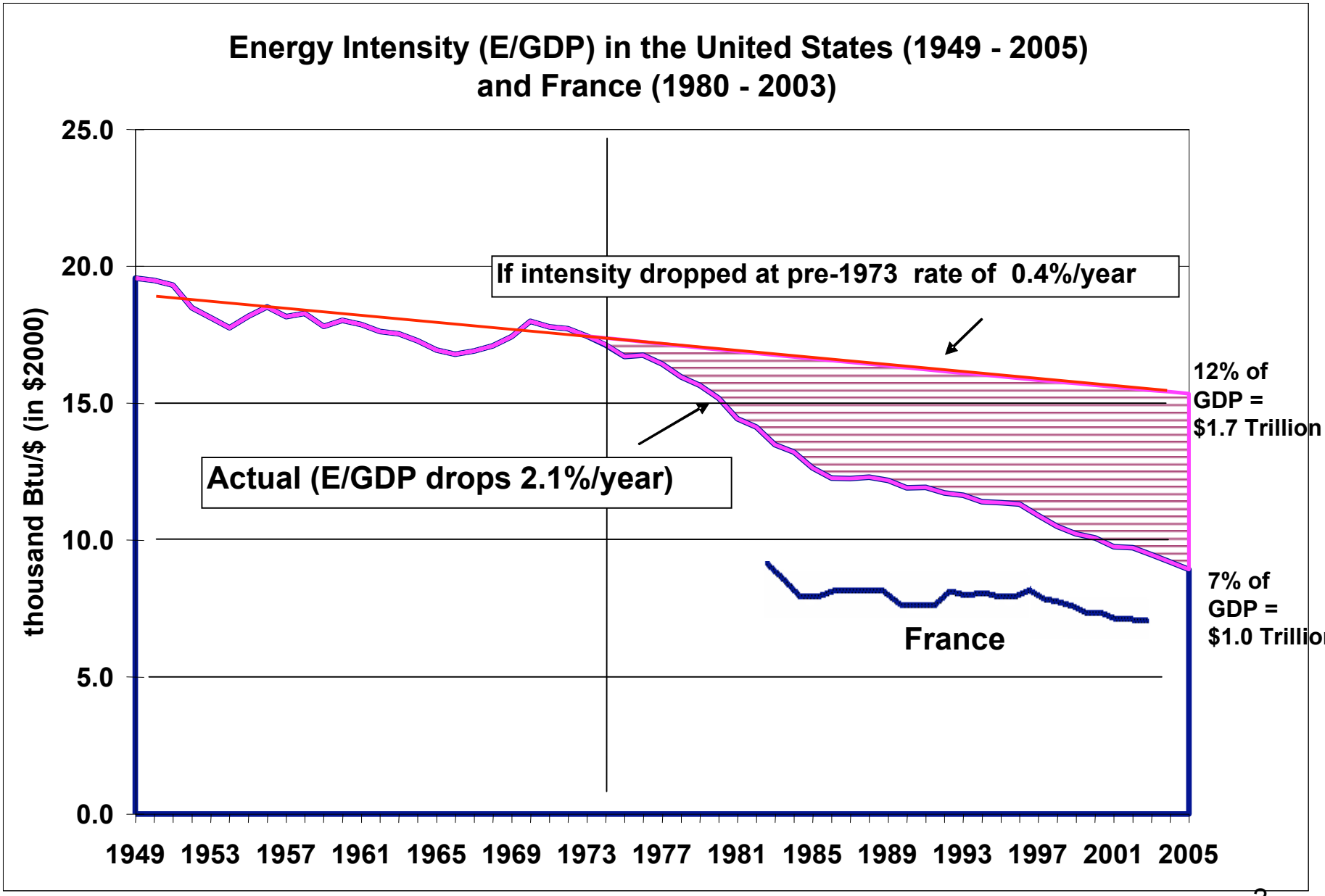
Energy End-Use Efficiency

Physics of Sustainable Energy
U. C. Berkeley
March 1, 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"


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
7% of GDP = $1.0 Trillion

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 Fluorescent 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

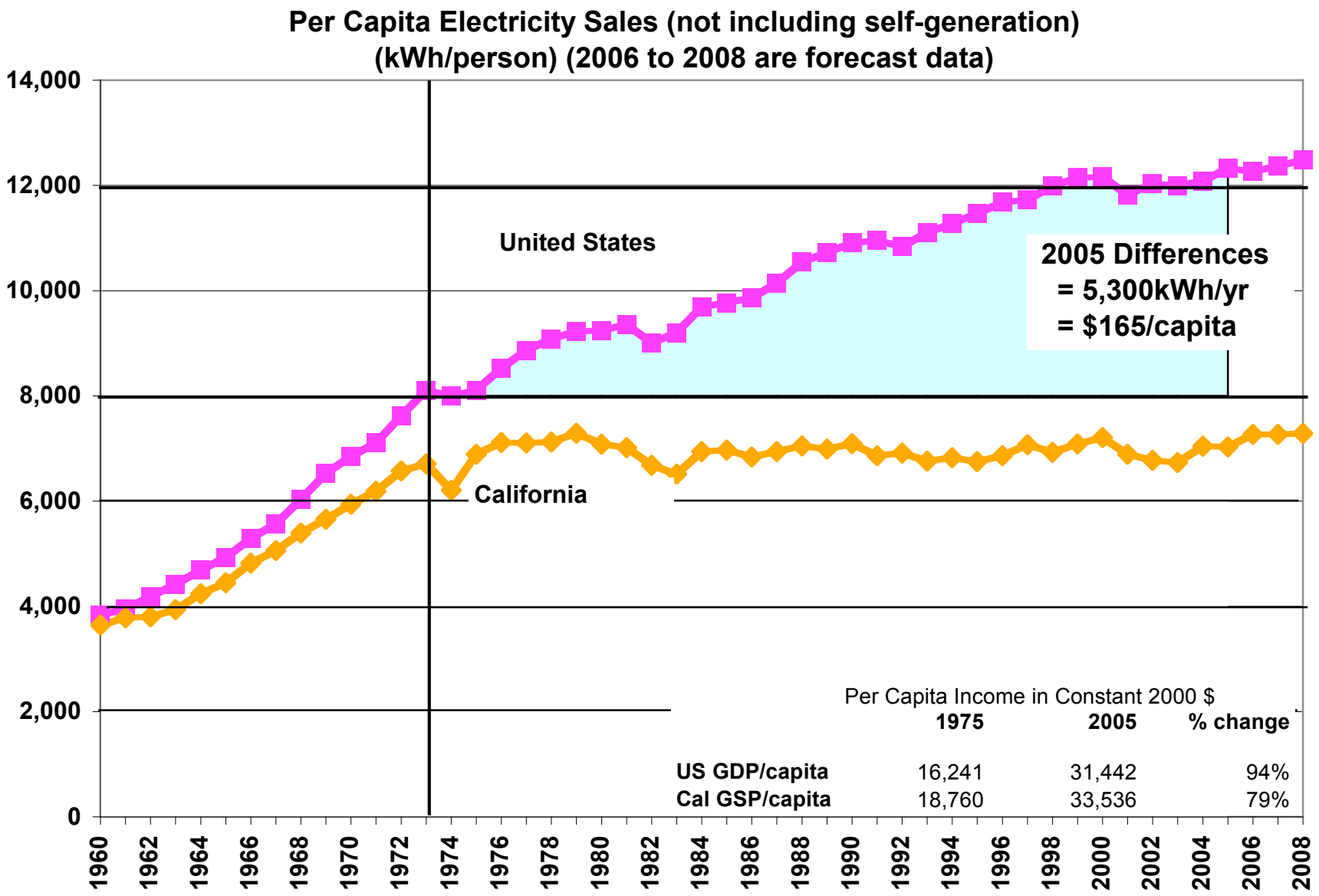
- The California Public Utilities Commission (CPUC) was formed in 1890 to regulate natural monopolies, like railroads, and later electric and gas utilities.
- The California Energy Commission (CEC) was formed in 1974 to regulate the environmental side of energy production and use.
- Now the two agencies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

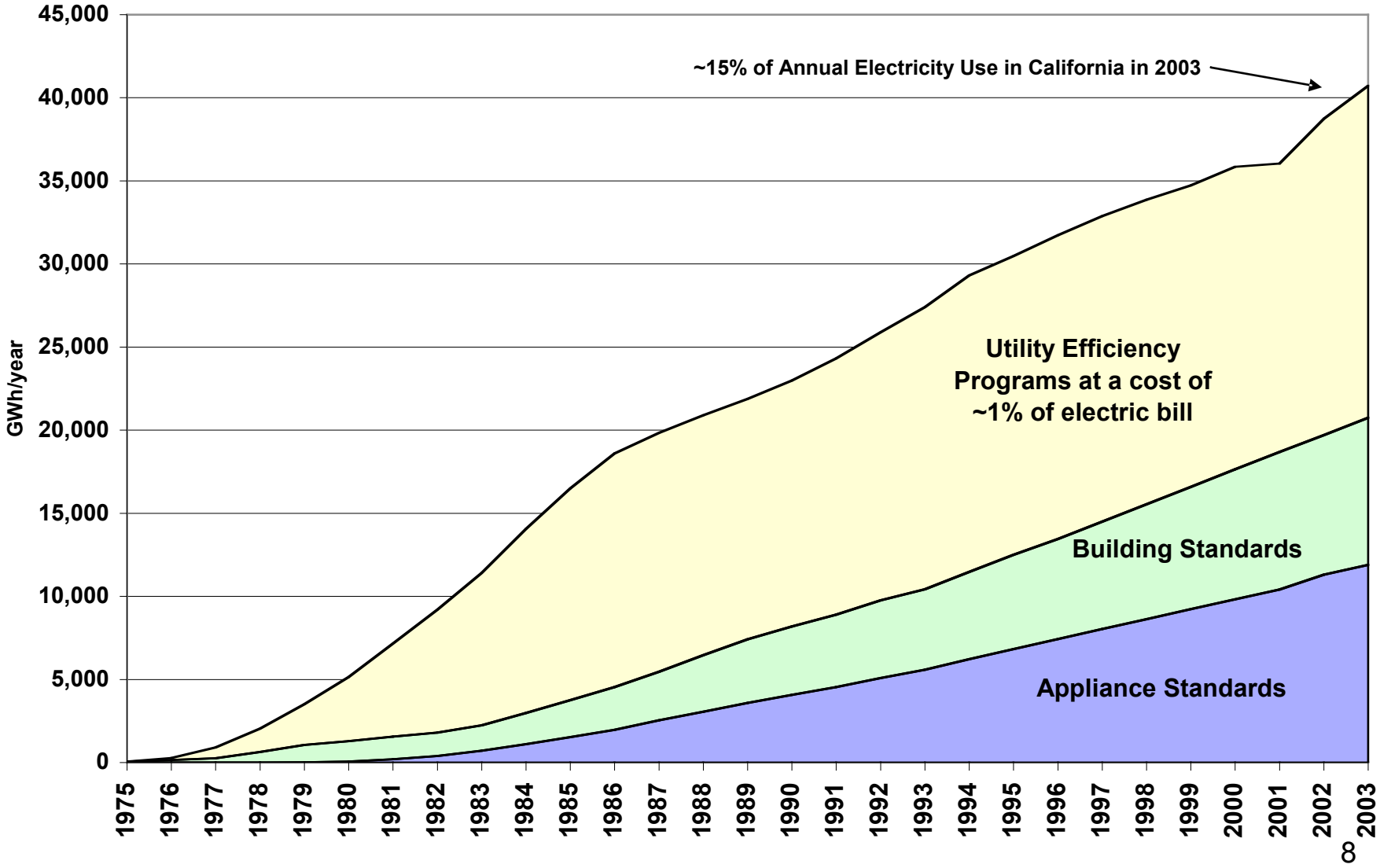
How US and California differ by Sector

US and Cal compared in 2005 Per Capita Electricity Consumption

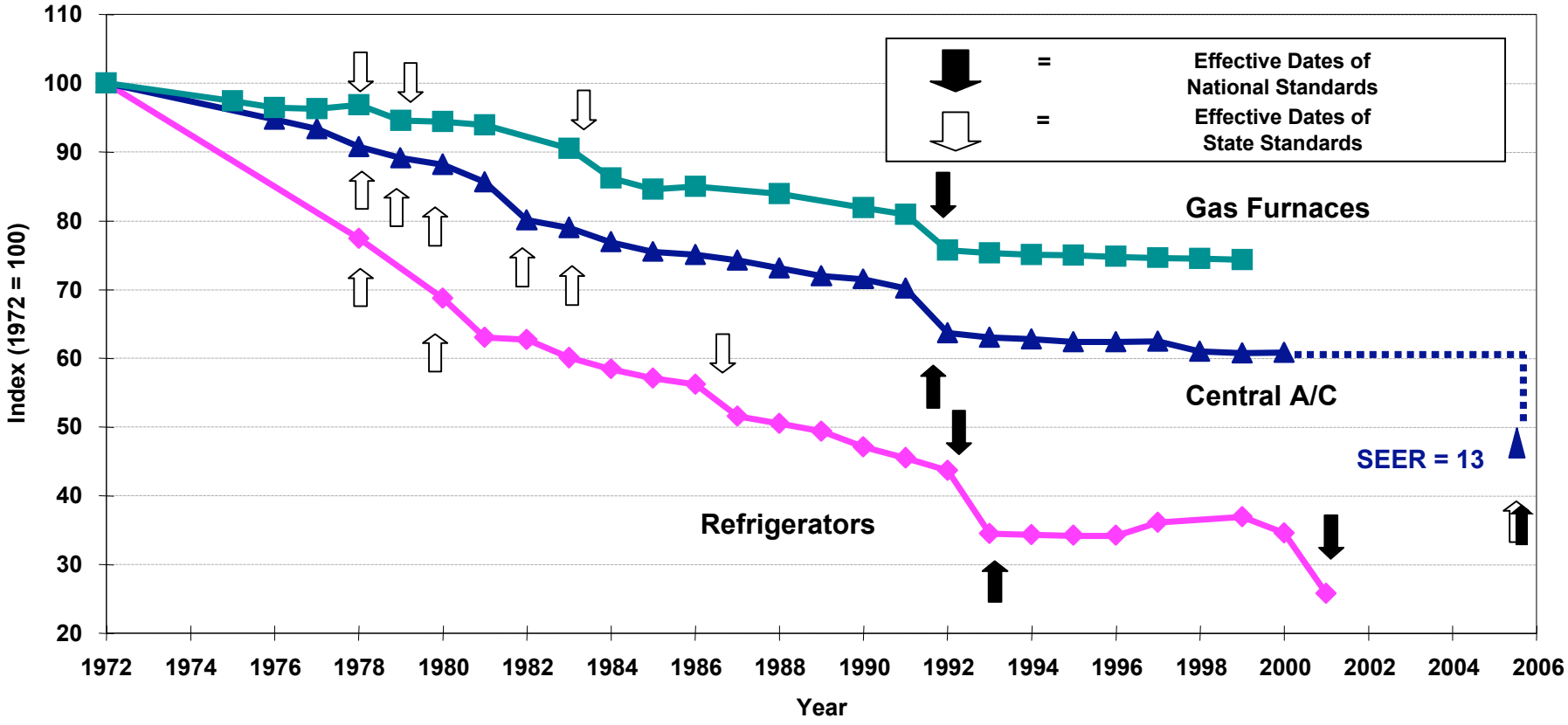
	United States (kWh/person)	California (kWh/person)	Difference (kWh/person)	% of Difference
Residential	4,586	2,369	2,216	42%
Commercial	4,302	3,253	1,048	20%
Industrial	3,438	1,391	2,048	39%
Total	**12,326**	**7,013**	**5,312**	**100%**

For a thorough discussion of differences, see Deconstructing the 'Rosenfeld Curve', Anant Sudarshan and James Sweeney, Stanford University, to be published in the Energy Journal (2008)

Annual Energy Savings from Efficiency Programs and Standards



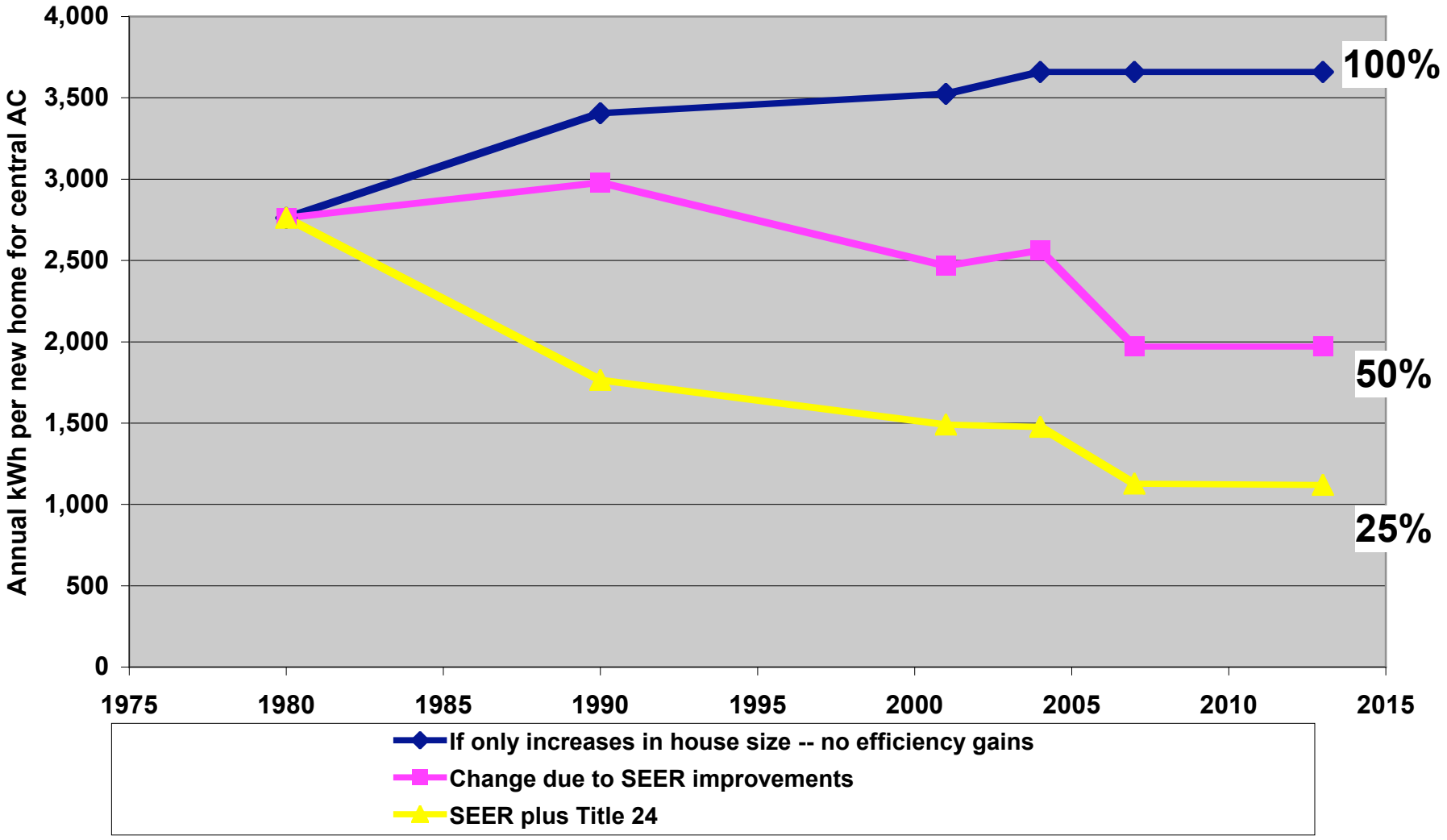
Impact of Standards on Efficiency of 3 Appliances



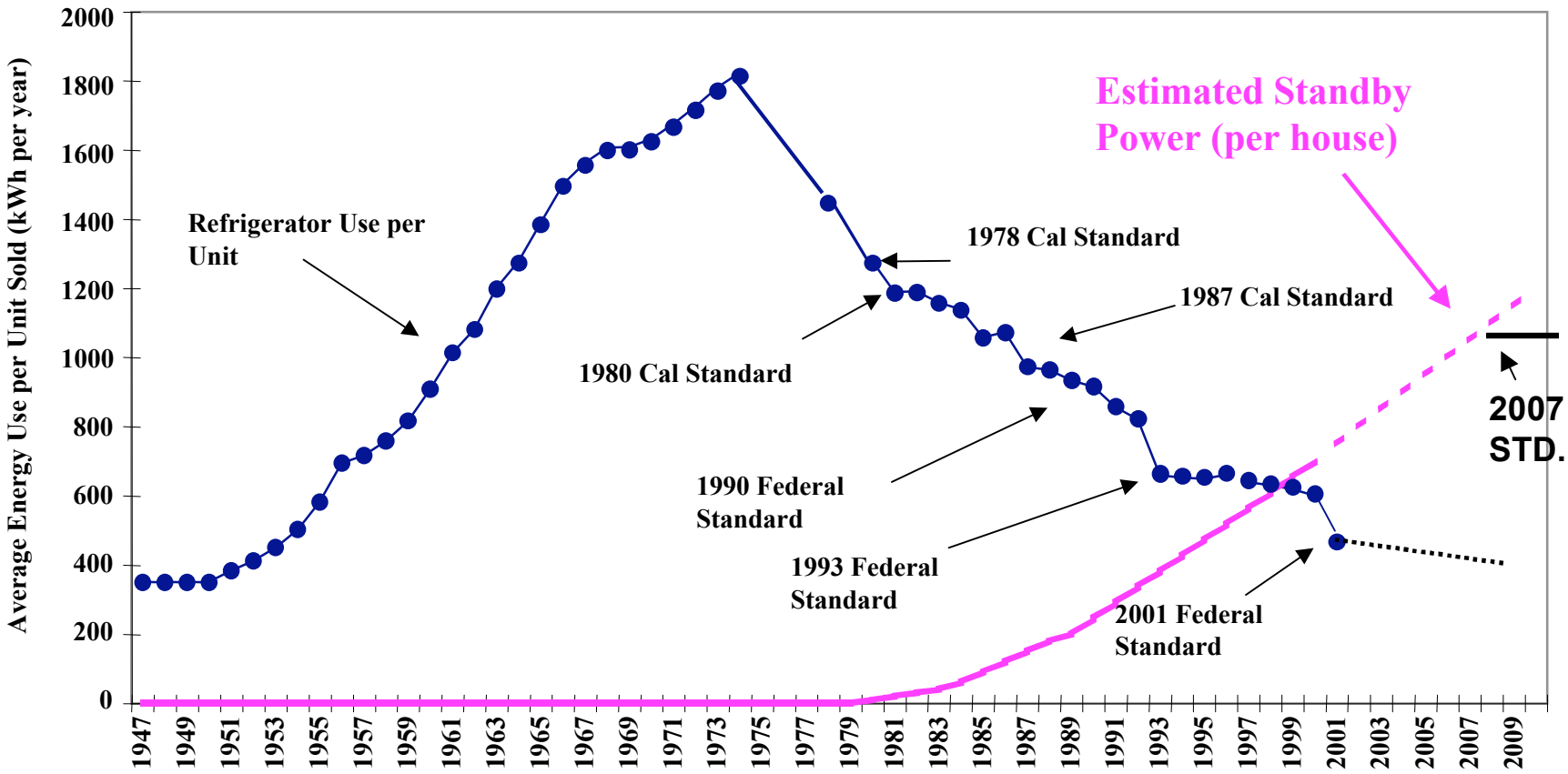
Source: S. Nadel, ACEEE,

in ECEEE 2003 Summer Study, www.eceee.org

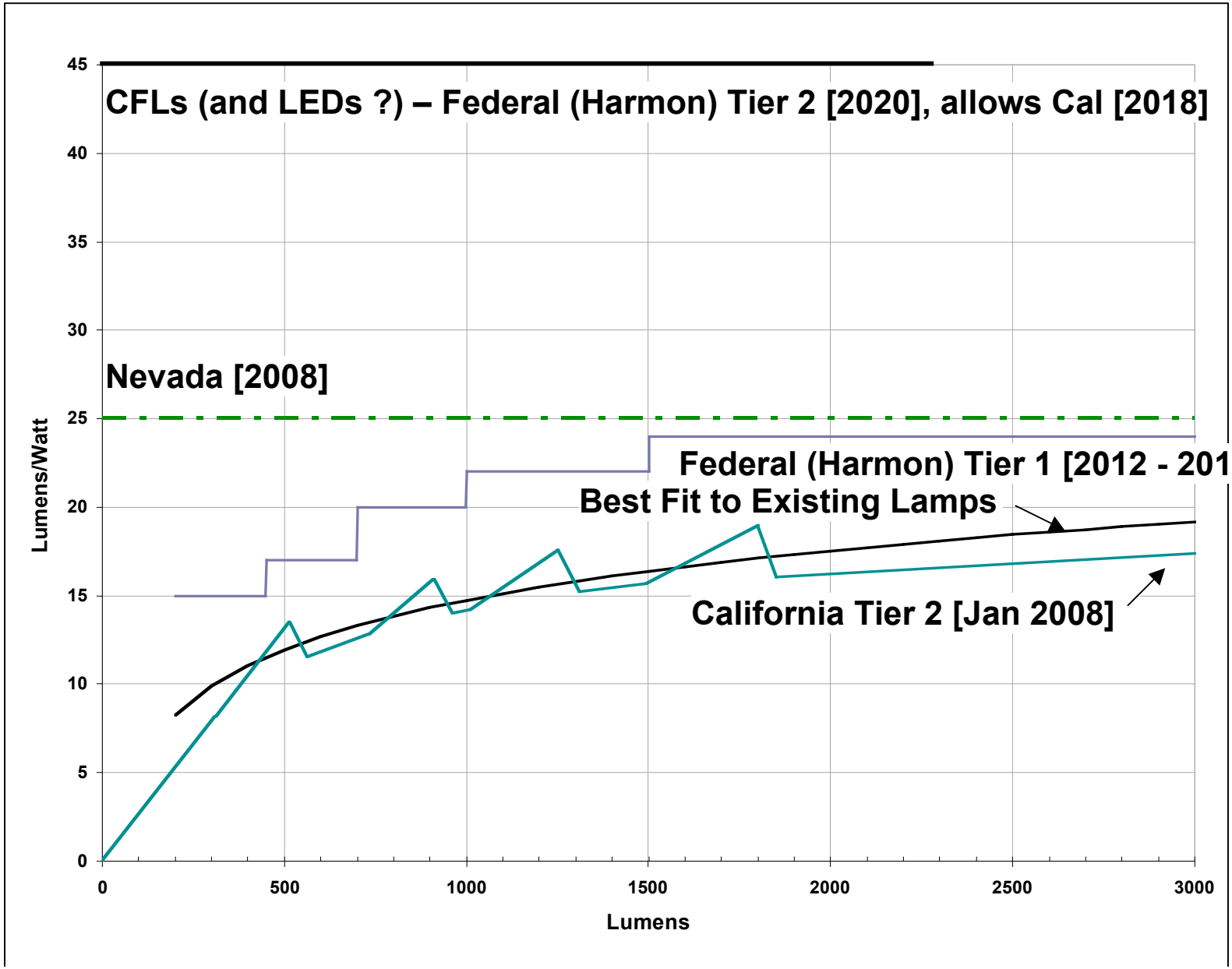
Air Conditioning Energy Use in Single Family Homes in PG&E
The effect of AC Standards (SEER) and Title 24 standards



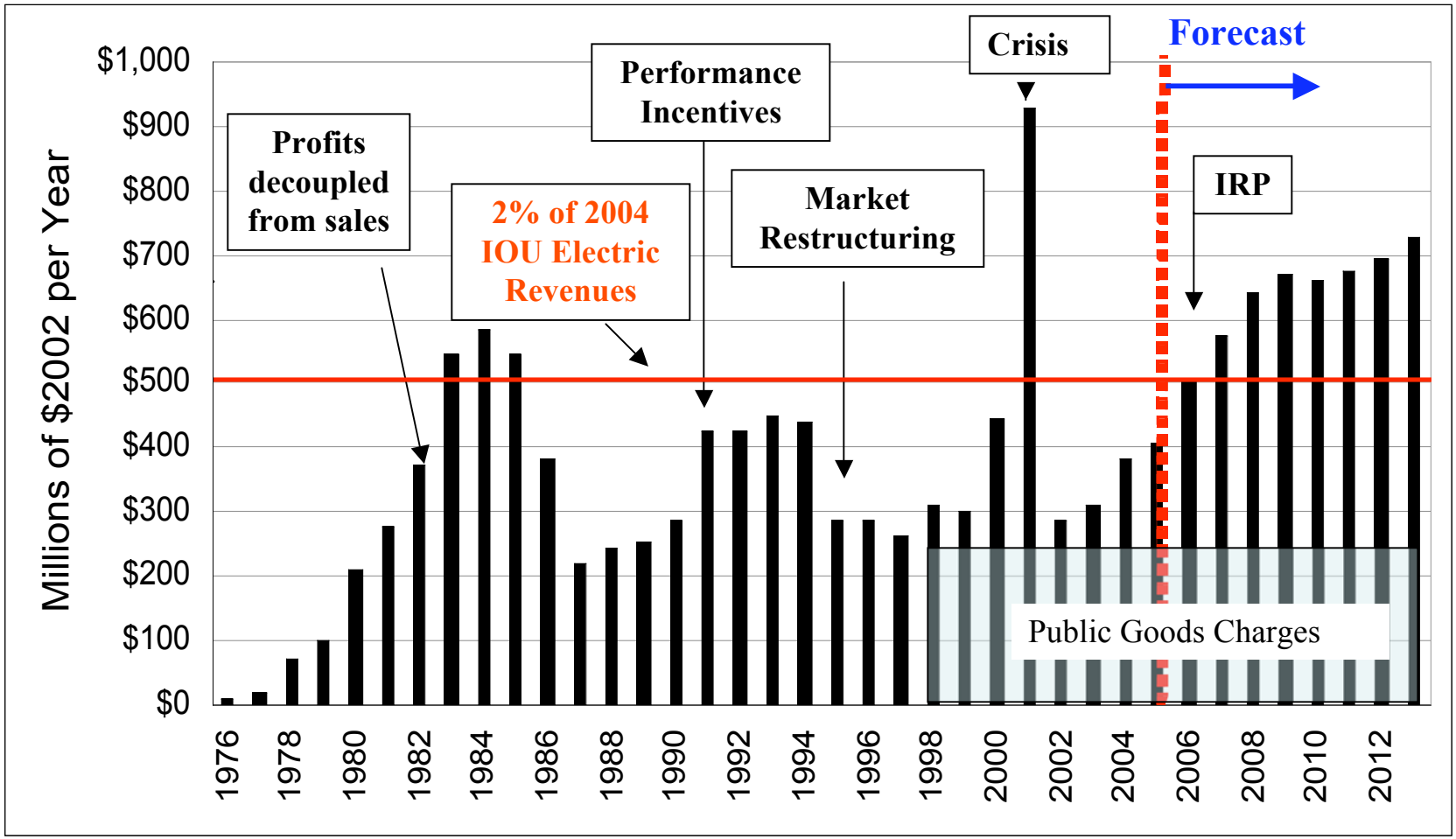
United States Refrigerator Use, repeated, to compare with Estimated Household Standby Use v. Time



Improving and Phasing-Out Incandescent Lamps



California IOU's Investment in Energy Efficiency



Cool Urban Surfaces and Global Warming

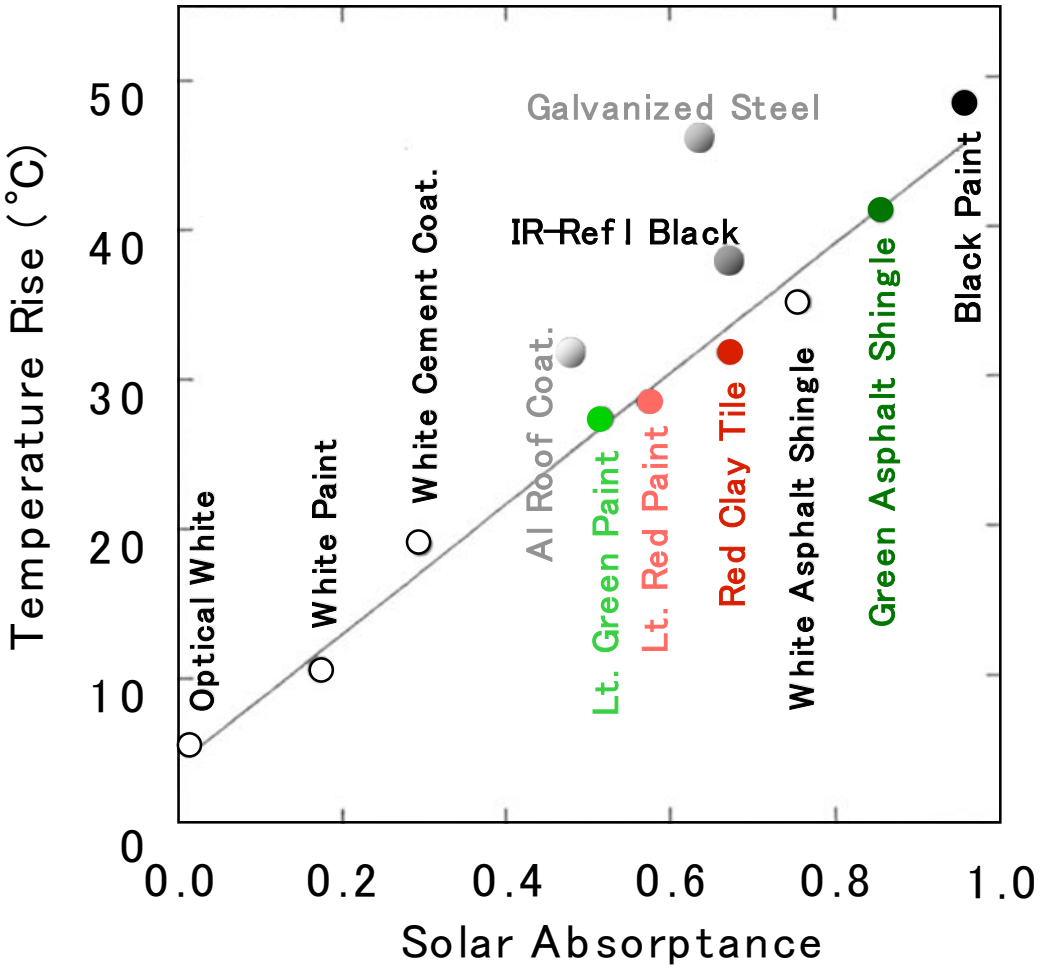
Hashem Akbari

Heat Island Group
Lawrence Berkeley National Laboratory

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

International Workshop on Countermeasures to Urban Heat Islands August 3 - 4, 2006; Tokyo, Japan

Temperature Rise of Various Materials in Sunlight



Direct and Indirect Effects of Light-Colored Surfaces

- **Direct Effect**
  - **Light-colored roofs** reflect solar radiation, reduce air-conditioning use
- **Indirect Effect**
  - Light-colored surfaces in a neighborhood alter surface energy balance; result in lower ambient temperature

and in Santorini, Greece

Cool Roof Technologies

Old

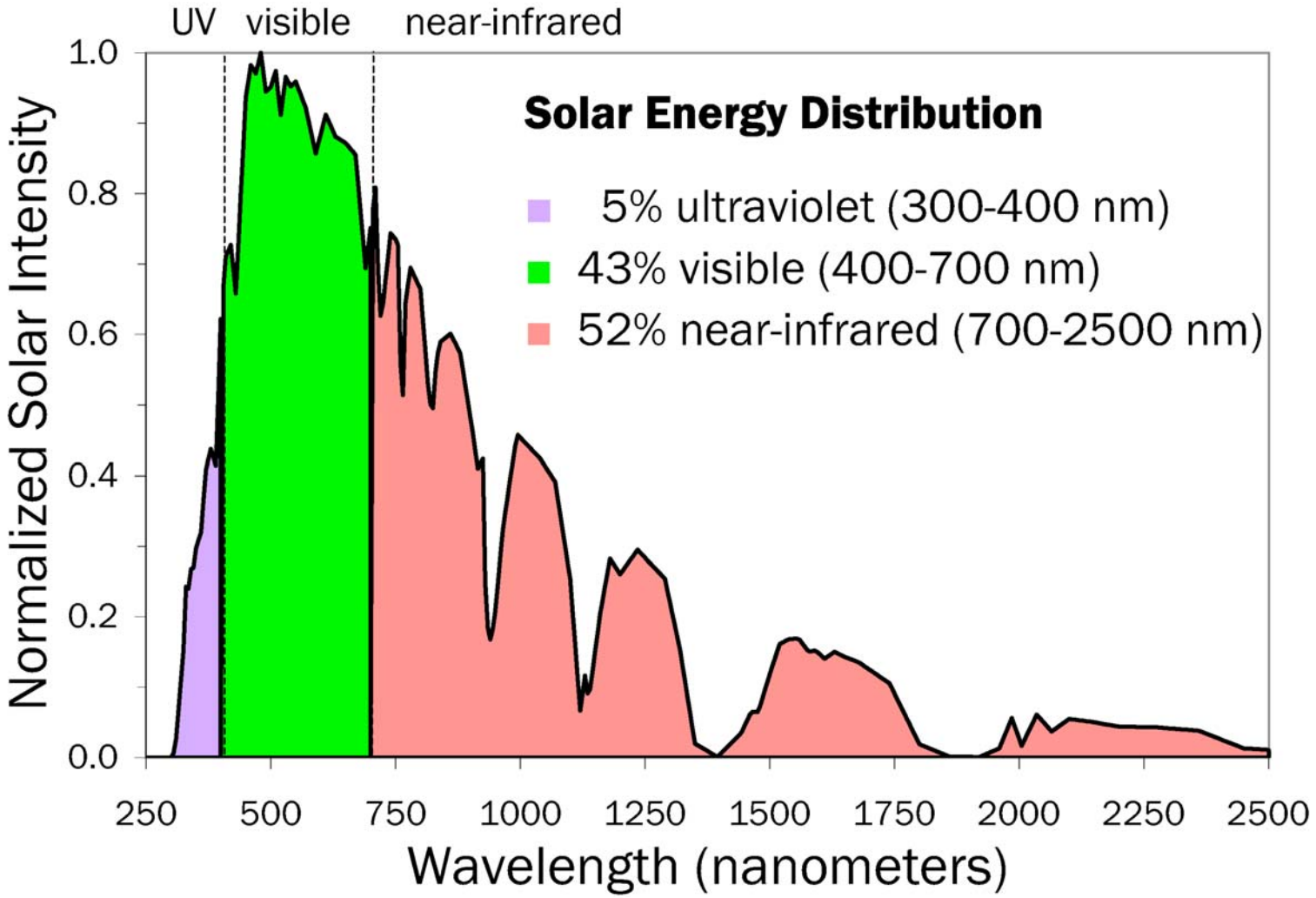
flat, white

pitched, white

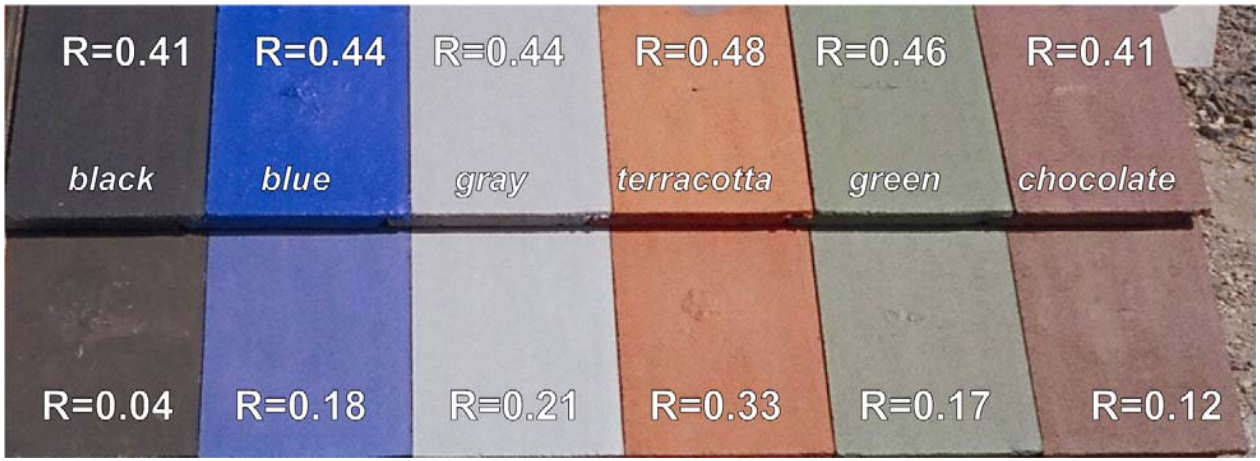
New

pitched, cool & colored

Cool Colors Reflect Invisible Near-Infrared Sunlight



Cool and Standard Color-Matched Concrete Tiles



Courtesy American Rooftile Coatings

cool

standard

ΔR=0.37 **ΔR=0.26** **ΔR=0.23** **ΔR=0.15** **ΔR=0.29** **ΔR=0.29**

- Can increase solar reflectance by up to 0.5
- Gain greatest for dark colors

Cool Roofs Standards

- Building standards for reflective roofs
  - American Society of Heating and Air-conditioning Engineers (ASHRAE): New commercial and residential buildings
  - **Many states: California, Georgia, Florida, Hawaii, …**
- Air quality standards (qualitative but not quantitative credit)
  - South Coast AQMD
  - S.F. Bay Area AQMD
  - EPA's SIP (State Implementation Plans)

From Cool Color Roofs to Cool Color Cars

- **Toyota experiment (surface temperature 18F cooler)**
- **Ford, BMW, and Fiat are also working on the technology**

Cool Surfaces also Cool the Globe

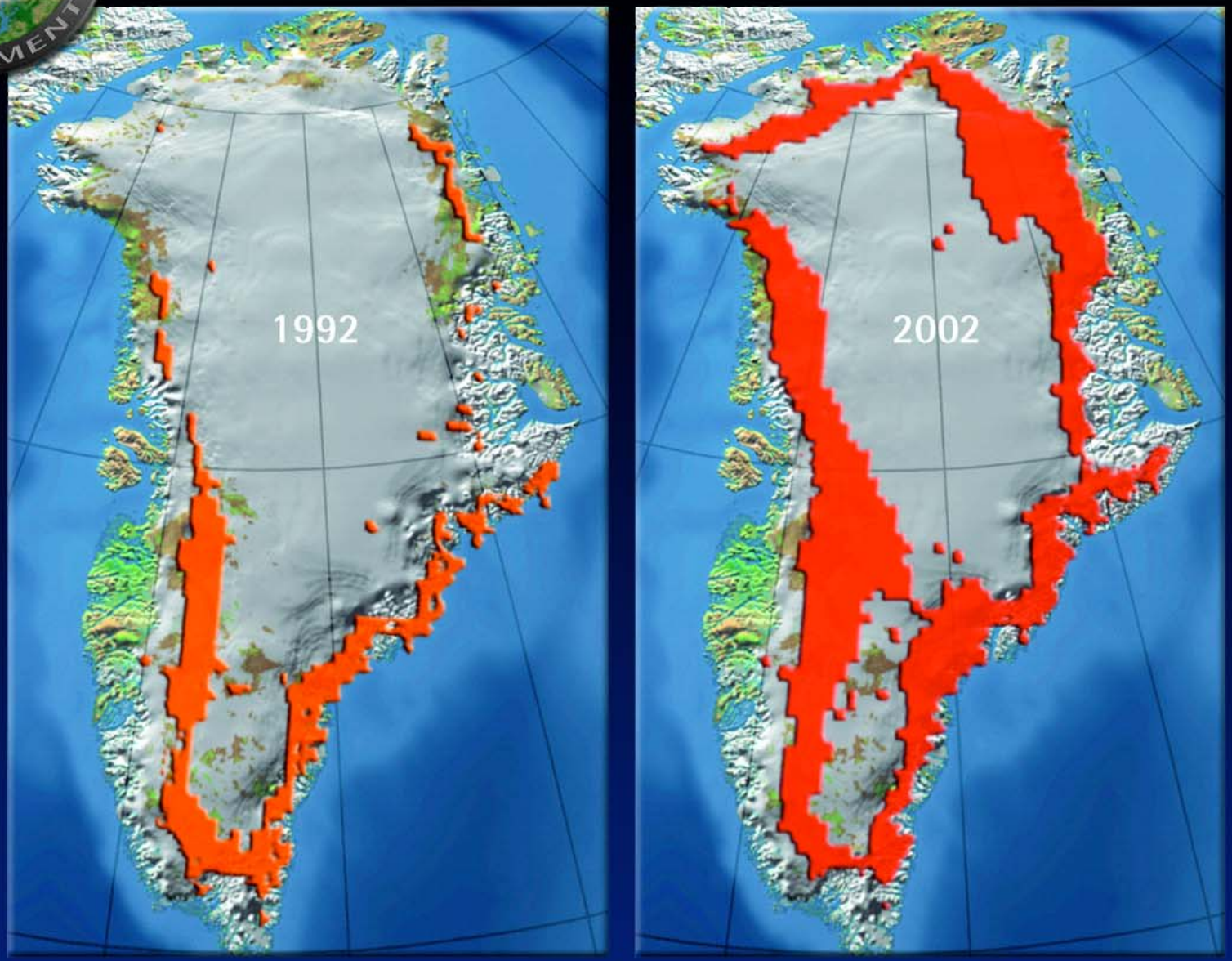
- Cool roof standards are designed to reduce a/c demand, save money, and save emissions. In Los Angeles they will eventually save ~$100,000 per *hour*.
- But higher albedo surfaces (roofs and pavements) directly cool the world (0.01 K) quite independent of avoided CO_2. So we discuss the effect of cool surfaces for tropical, and temperate cities, and show that
- Each 25m^2 (250 square feet) of cooler roof offsets 1 ton of CO_2 each 35 m^2 (350 square feet) of cooler pavement offsets another ton.

Dense Urban Areas are 1% of Land

- Area of the Earth = 511×10^{12} 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]
- **1% of land is 1.5 x 10^12 m2 = area of a square of side s = 1200 km or 750 miles on a side. Roughly the area of the remaining Greenland Ice Cap (see next slide)**

IMPACTS OF A WARMING ARCTIC

Greenland Ice Sheet Melt Extent



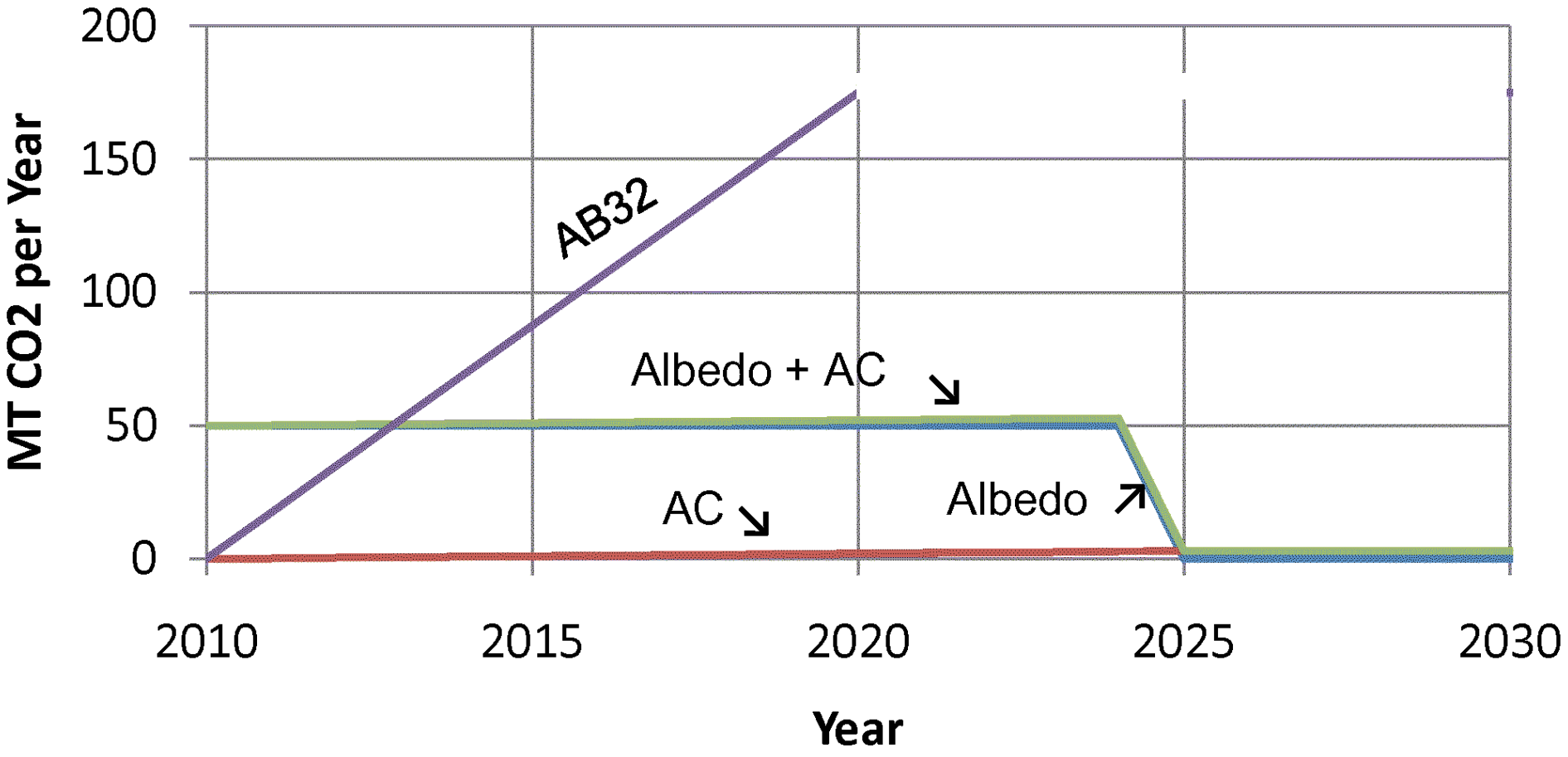
Cooler cities as a mirror

- Mirror Area = 1.5×10^{12} m^2 [5] *(0.1/0.7)[δ albedo of cities/ δ albedo of mirror]
  = 0.2×10^{12} m^2 = 200,000 km^2 {This is equivalent to an square of 460 km on the side}
  = 10% of Greenland = 50% of California

Equivalent Value of Avoided CO_2

- CO_2 currently trade at ~$25/ton
- 10Gt worth $250 billion, for changing albedo of roofs and paved surface
- Cooler roofs alone worth $125B
- Cooler roofs also save air conditioning (and provide comfort) worth ten times more
- Let developed countries offer $1 million per large city in a developing country, to trigger a cool roof/pavement program in that city

California cool urban surfaces and AB32



Reducing U.S. Greenhouse Gas Emissions: *How Much at What Cost?*

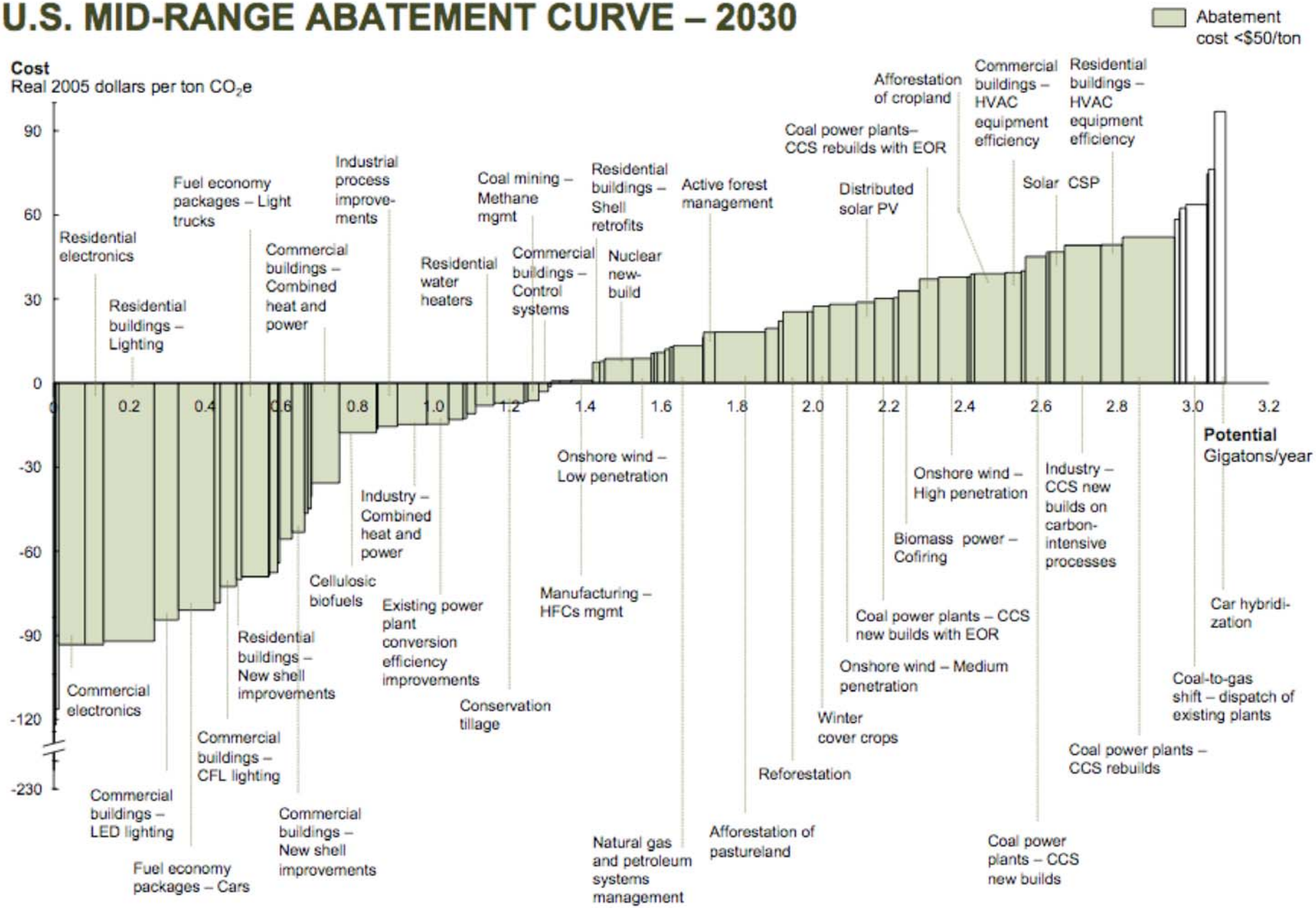
US Greenhouse Gas Abatement Mapping Initiative

December 12, 2007

McKinsey&Company

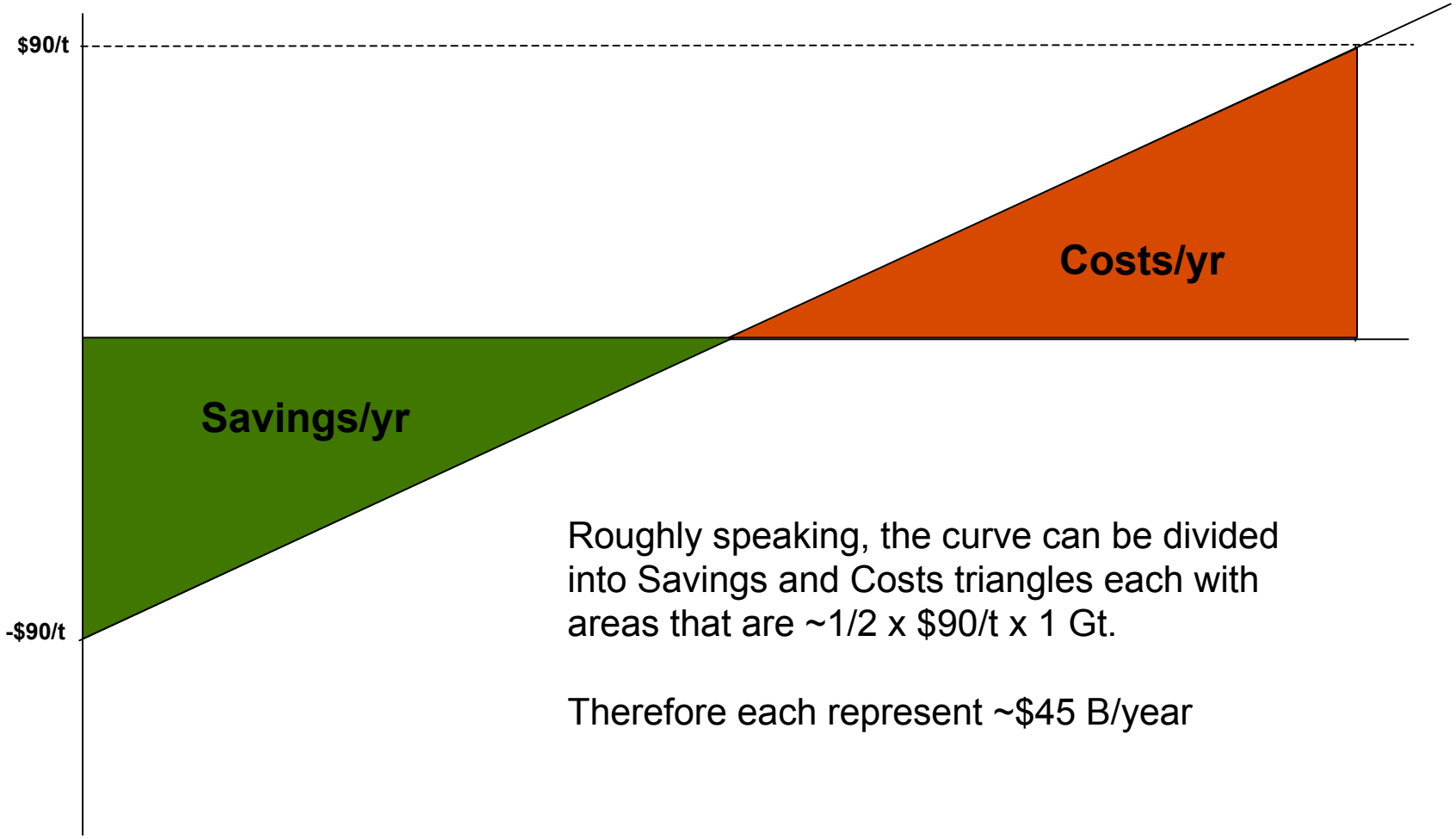
Exhibit B

U.S. MID-RANGE ABATEMENT CURVE – 2030



Source: McKinsey analysis

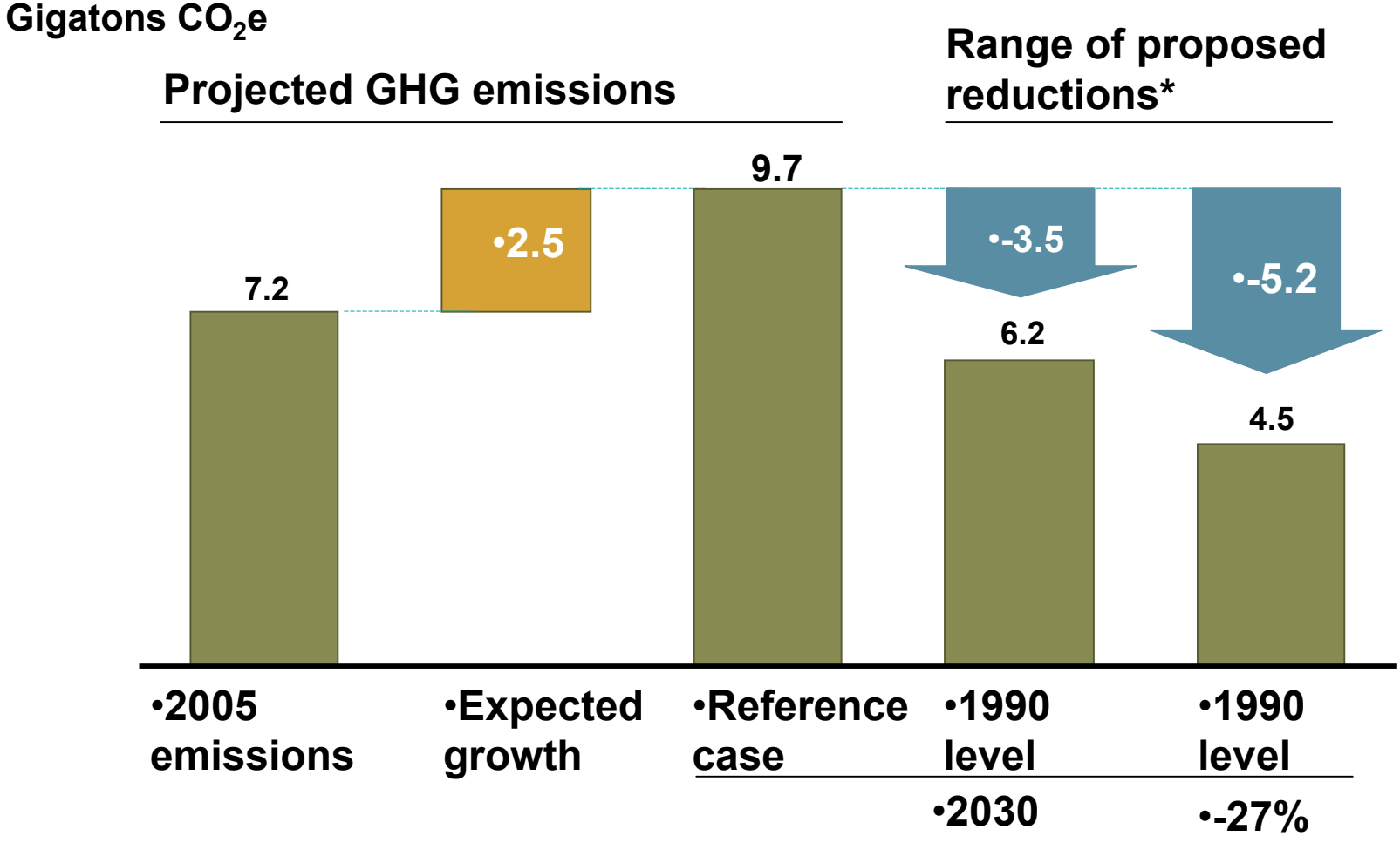
"Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?" McKinsey&Company, 2007



Roughly speaking, the curve can be divided into Savings and Costs triangles each with areas that are ~1/2 x $90/t x 1 Gt.

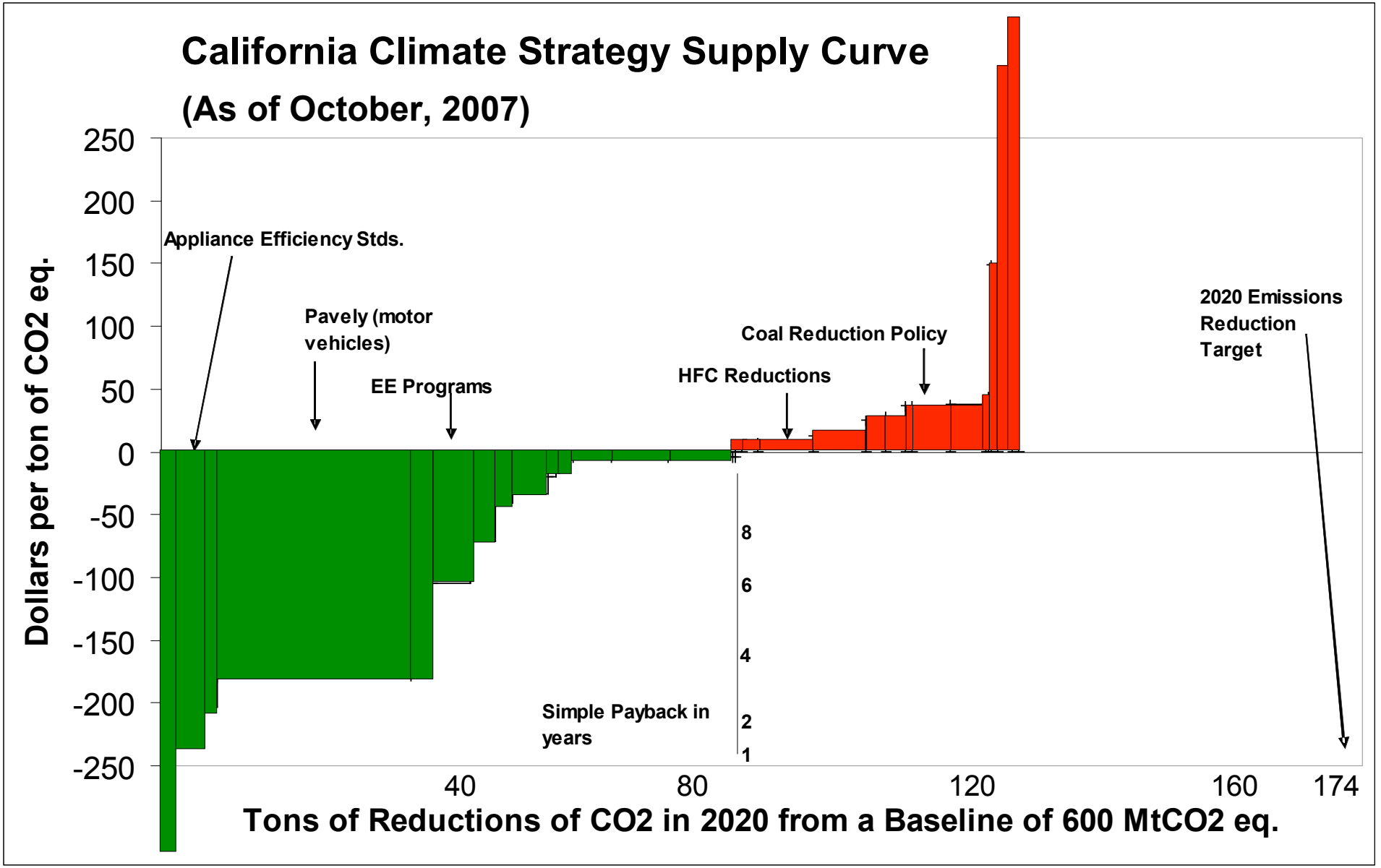
Therefore each represent ~$45 B/year

U.S. GHG emissions in 2030 are projected to exceed proposed targets being considered in Congress by a wide margin



* Based on bills introduced in Congress that address climate change and/or GHG emissions on an economy-wide basis and have quantifiable targets

Source: U.S. EIA Annual Energy Outlook (2007) "Reference case," U.S. EPA; Pew Center On Global Climate Change; McKinsey analysis



Source: http://www.climatechange.ca.gov/events/2007-09-14_workshop/final_report/2007-10-15_MACROECONOMIC_ANALYSIS.PDF

McKinsey Quarterly

A **cost curve** for greenhouse gas reduction

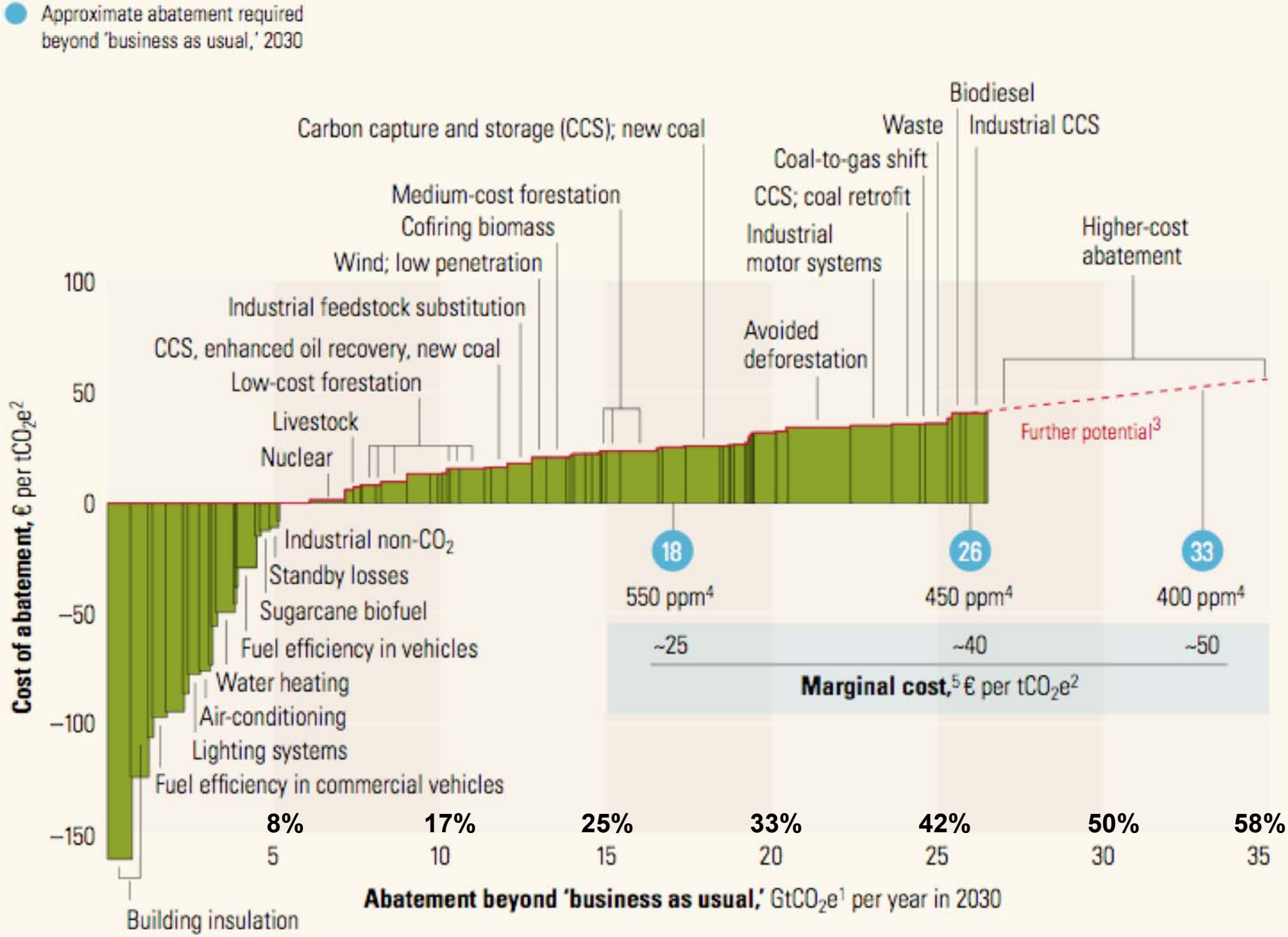
With a Worldwide Perspective

A global study of the size and cost of measures to reduce greenhouse gas emissions yields important insights for businesses and policy makers.

Per-Anders Enkvist, Tomas Nauclér, and Jerker Rosander

http://www.mckinseyquarterly.com/Energy_Resources_Materials/A_cost_curve_for_greenhouse_gas_reduction_abstract

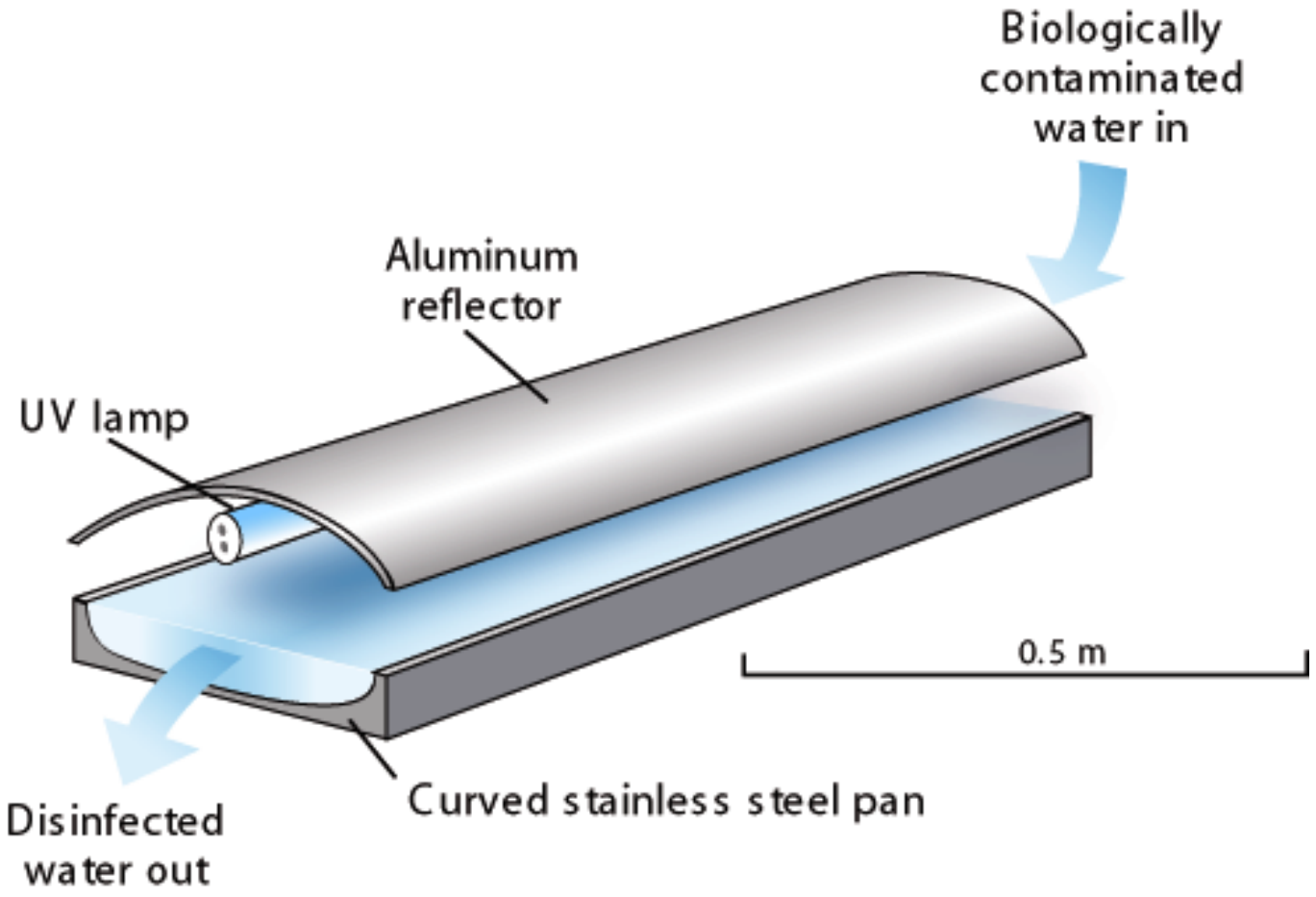
Global cost curve for greenhouse gas abatement measures beyond 'business as usual'; greenhouse gases measured in $GtCO_2e$[1]



Two Technologies for the Developing World to Improve Quality of Life but also delay Climate Change.

- Ultraviolet Water Purification avoids the need to boil water
- LED flashlights and task lights, with rechargeable batteries, avoid the need to burn kerosene (in lanterns) or candles or wood.

UV Water Purification for Health, but avoids boiling



Typical interior layout of the WaterHealth Community System Installation in Kothapeta Andhra Pradesh, India.

Source: Dr. Ashok Gadgil, LBNL

How to Save 40 MtCO2 eq. per year

1. UV Water Purification– An alternative to boiling
- Worldwide 3 Billion people have access only to polluted water
- 1.2 Billion boil this; the remainder must use polluted water
  - Many get sick and children die
- Boiling water emits an avoidable **20 MtCO2 eq.** per year
  - Primarily fire wood is used for this
  - With heat content = 2 million barrels of petroleum per day

2. Switching from Kerosene Lighting to LED rechargeable Flashlights
- 2 Billion people off of electricity grid use kerosene lanterns
- Rechargeable LED flashlights now cost less than $20
- Worldwide this will avoid another **20 MtCO2 eq.** per year

The total of **40 MtCO2 eq. per year** = **1%** of reduction target in the building sector, as estimated earlier in talk by “Design To Win”

Switching from Kerosene Lanterns to Rechargeable LEDs

Commercially available LEDs
- 0.1 to 1 watt
- Lumens/watts > 100 better than kerosene lanterns
- Much better directionality adds to this advantage

Evan Mills
Energy Analysis Department
Lawrence Berkeley National Laboratory
Emills@lbl.gov
+ 1 510 486-6784
http://www.ifc.org/led

Rechargeable LED Flashlights and Task Lights Already Available