

# ***Energy End-Use Efficiency***

## ***Physics of Sustainable Energy***

***U. C. Berkeley***

***March 1, 2008***

**Arthur H. Rosenfeld, Commissioner**

**California Energy Commission**

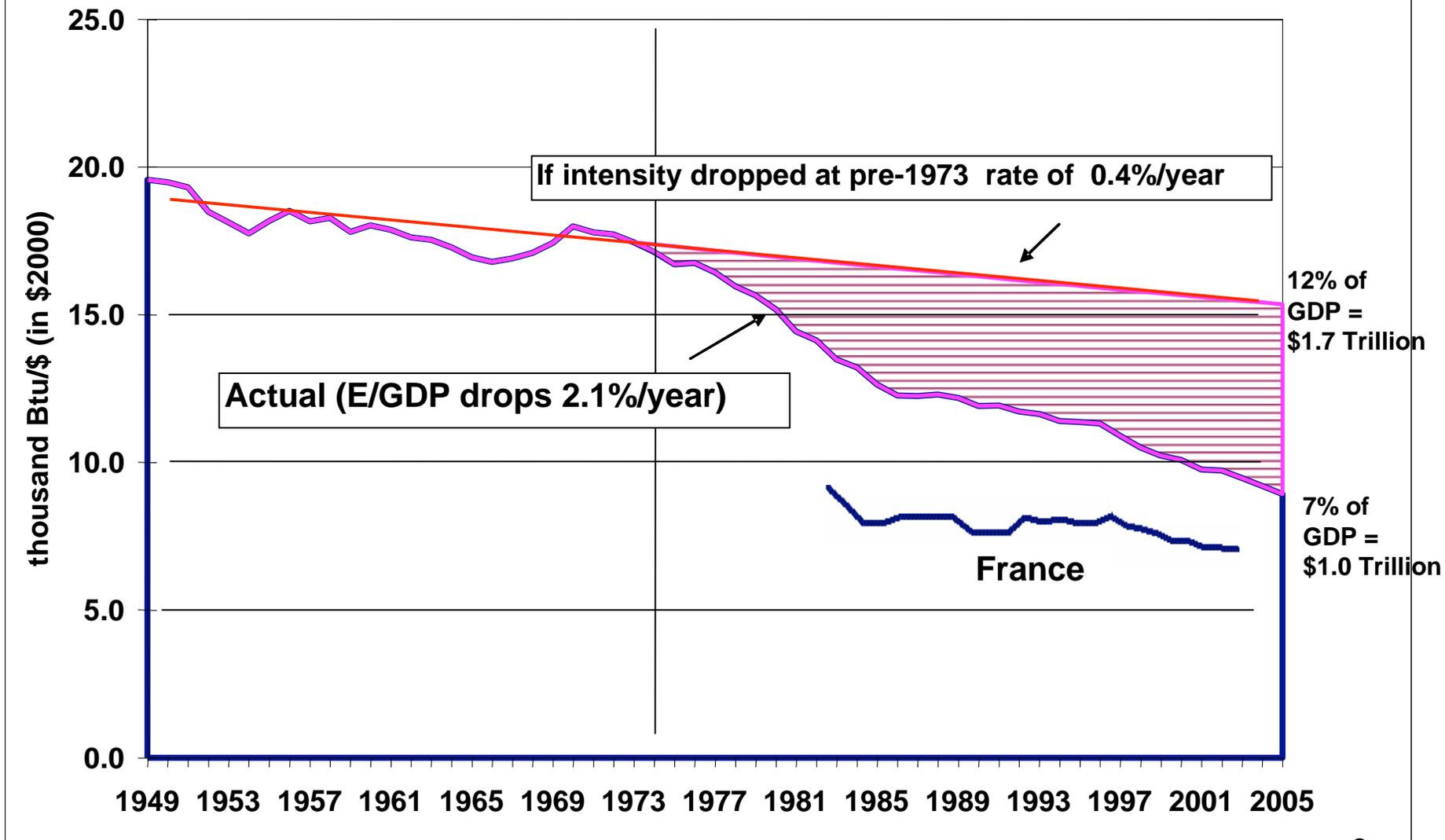
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**<http://www.energy.ca.gov/commission/commissioners/rosenfeld.html>**

**or just Google “Art Rosenfeld”**

## Energy Intensity (E/GDP) in the United States (1949 - 2005) and France (1980 - 2003)



# 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
<b>Total</b>	<b>95</b>

- Beginning in 2007 in California, reduction of “vampire” or stand-by 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.

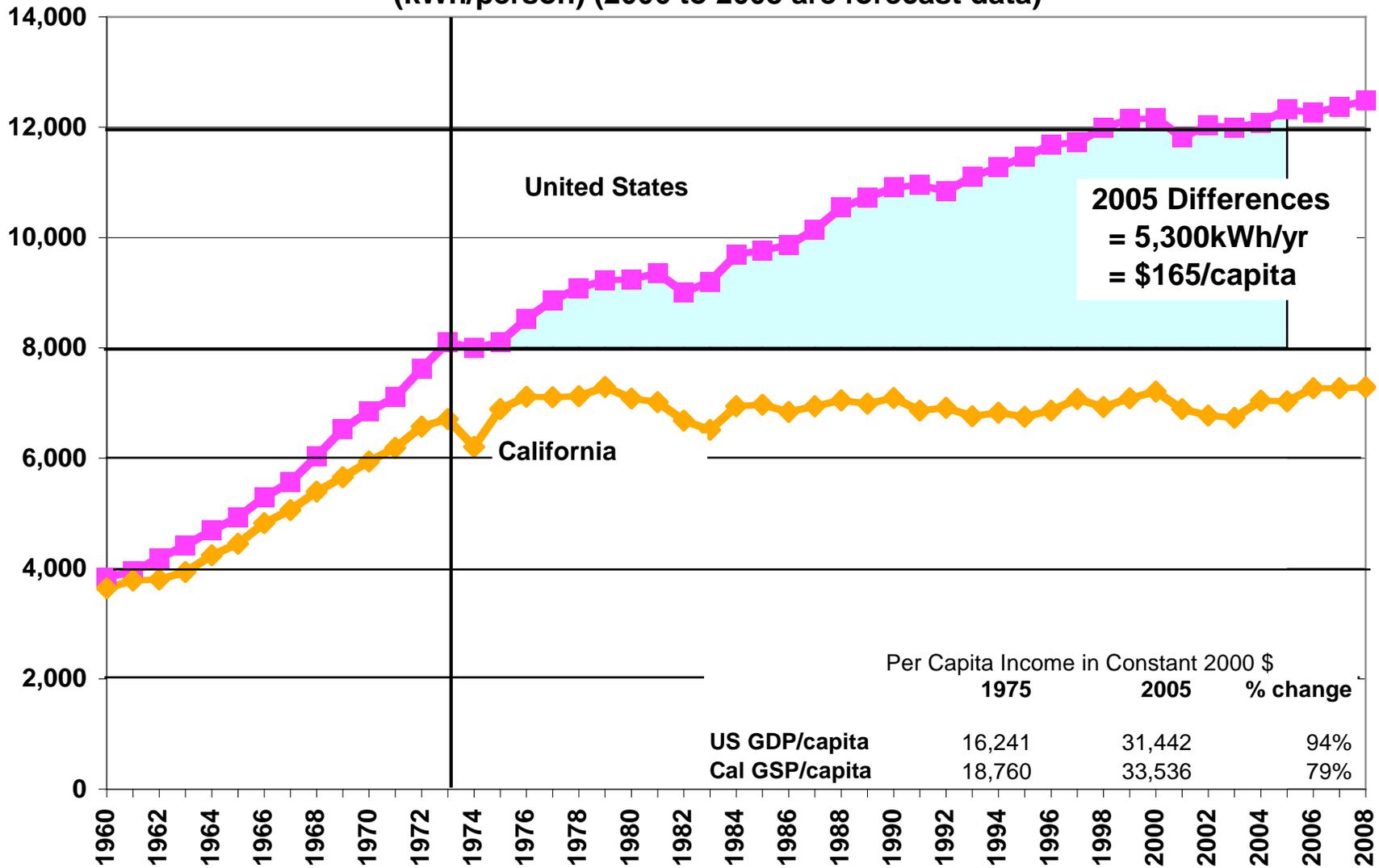
# Two Energy Agencies in California

- 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

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



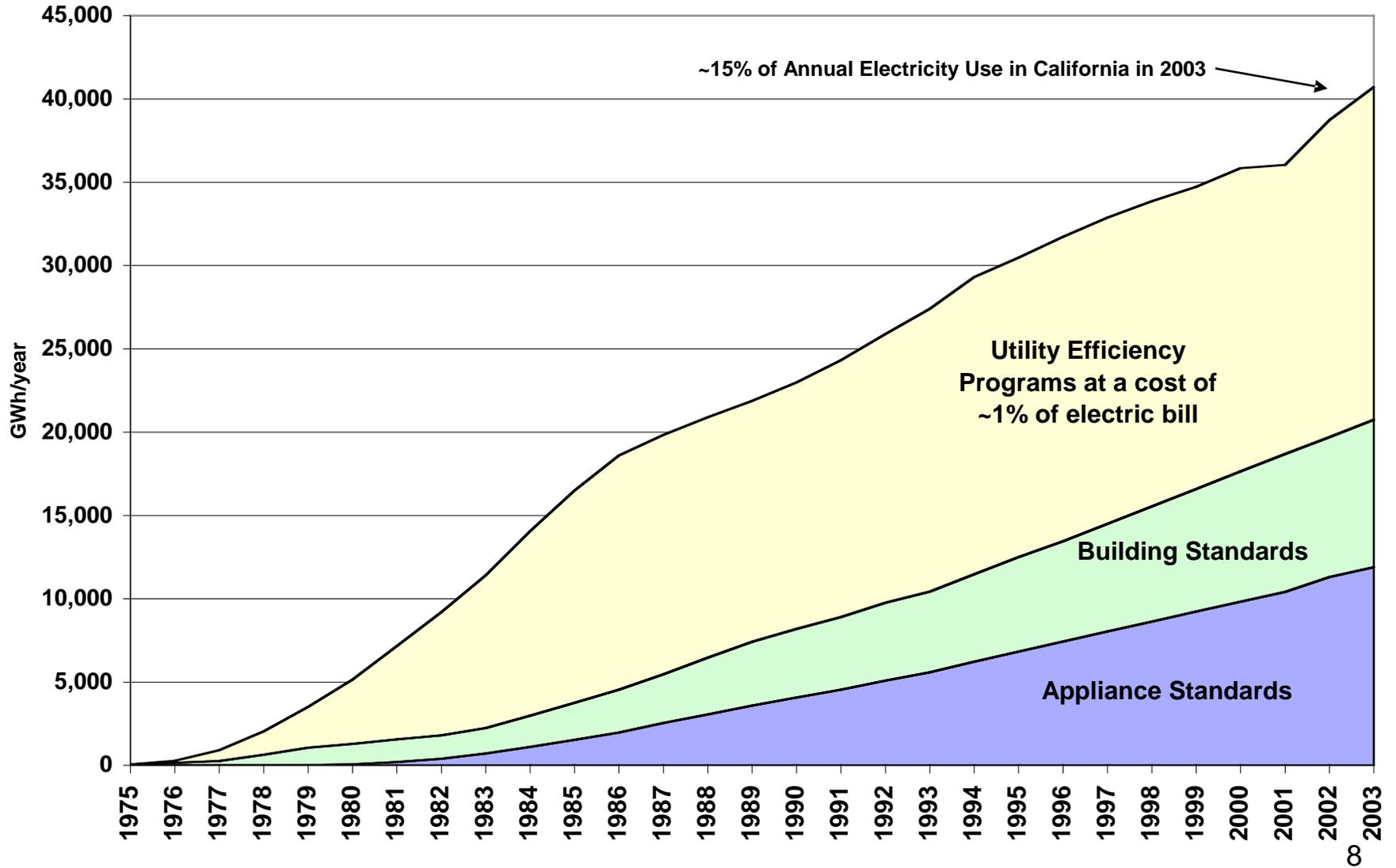
# How US and California differ by Sector

US and Cal compared in 2005 Per Capita Electricity Consumption

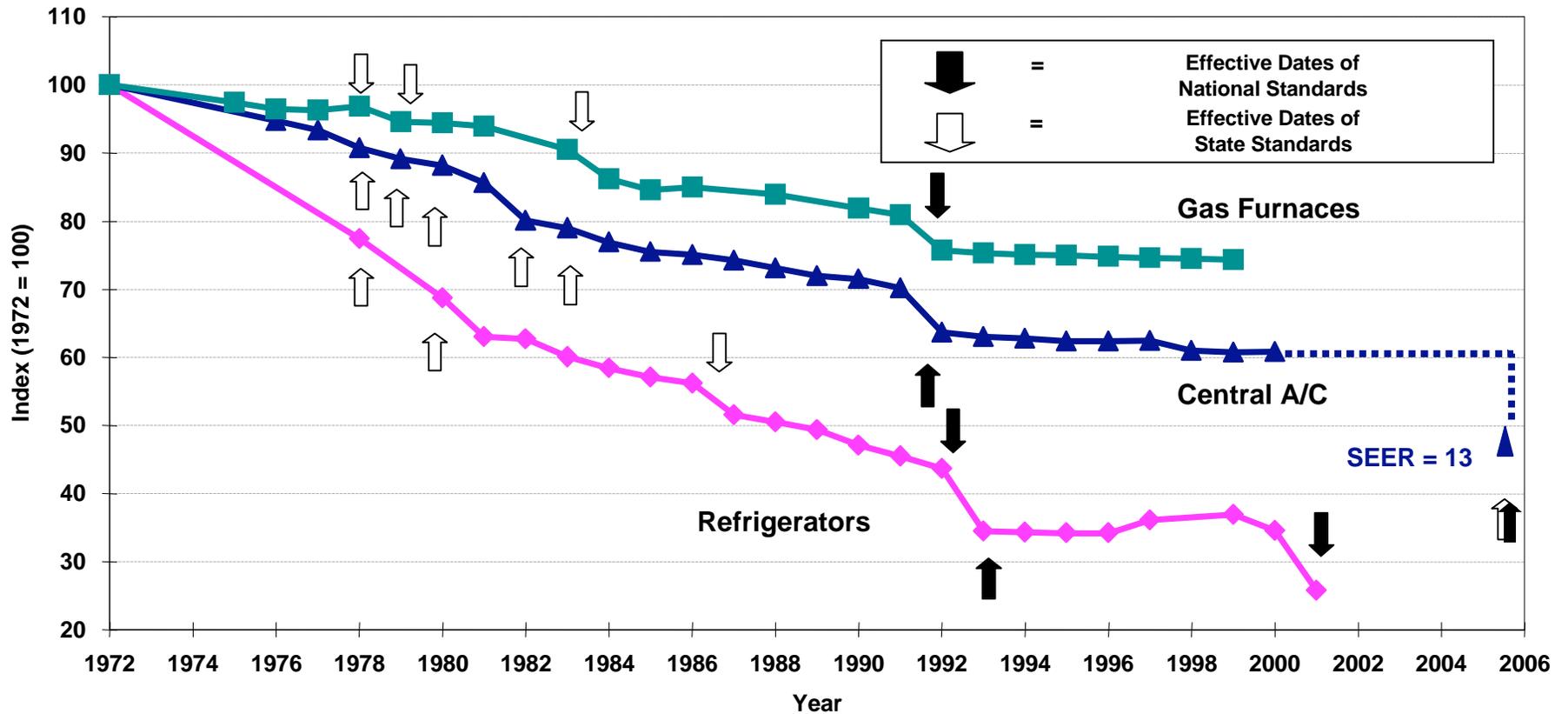
	<b>United States</b> (kWh/person)	<b>California</b> (kWh/person)	<b>Difference</b> (kWh/person)	<b>% of Difference</b>
<b>Residential</b>	4,586	2,369	2,216	42%
<b>Commercial</b>	4,302	3,253	1,048	20%
<b>Industrial</b>	3,438	1,391	2,048	39%
<b>Total</b>	<b>12,326</b>	<b>7,013</b>	<b>5,312</b>	<b>100%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

**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

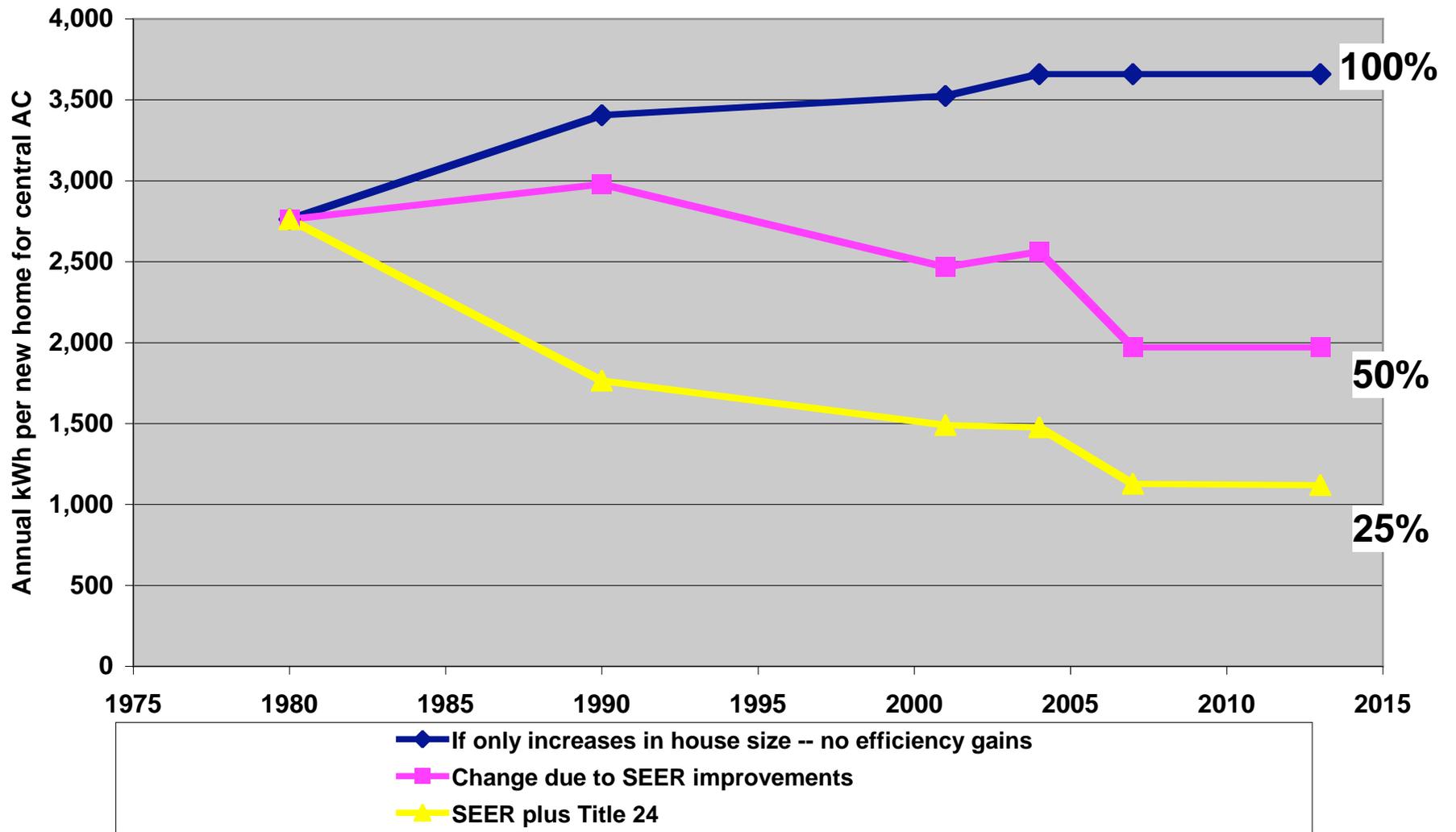


# Impact of Standards on Efficiency of 3 Appliances

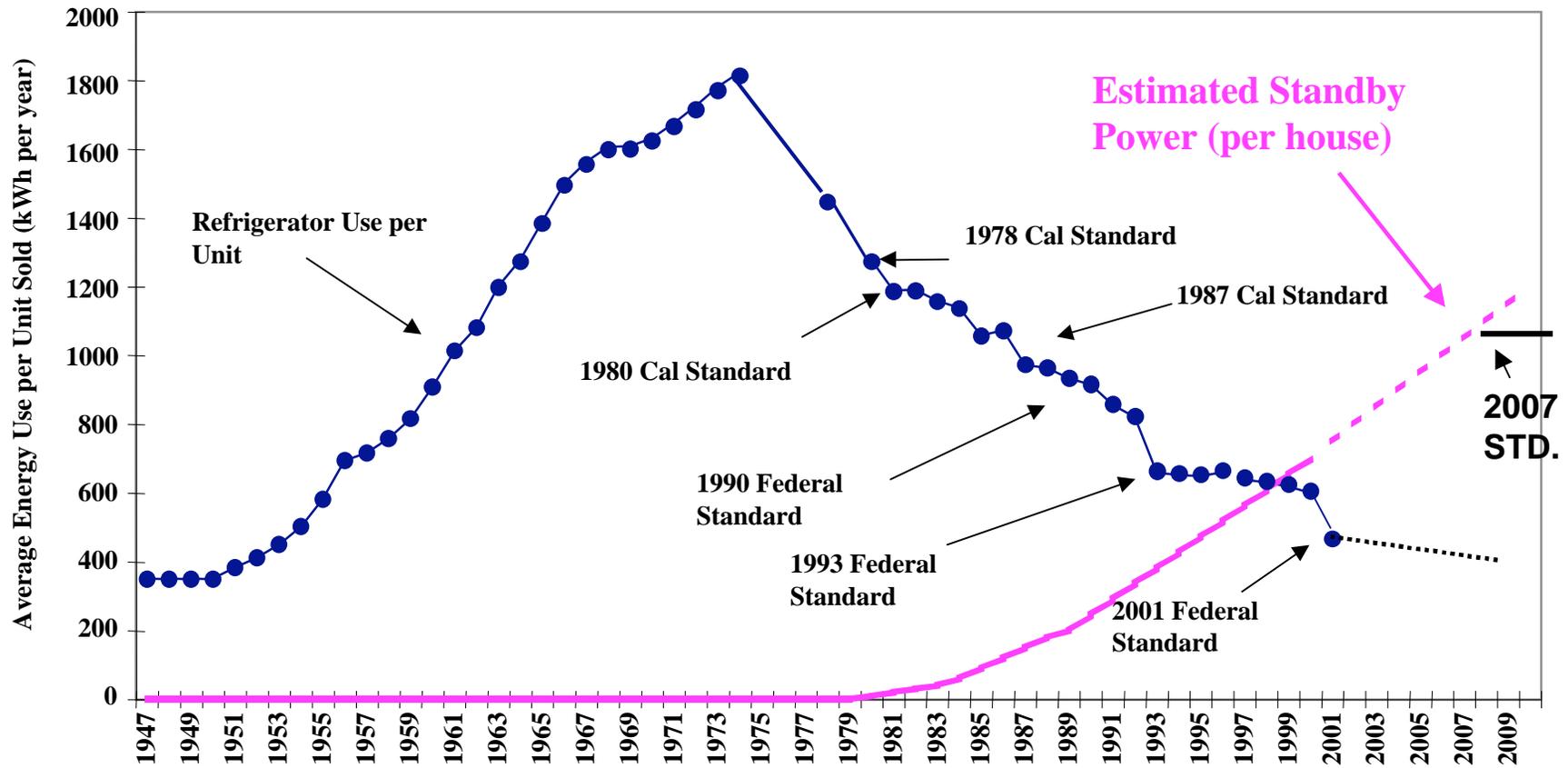


Source: S. Nadel, ACEEE,  
in ECEEE 2003 Summer Study, [www.eceee.org](http://www.eceee.org)

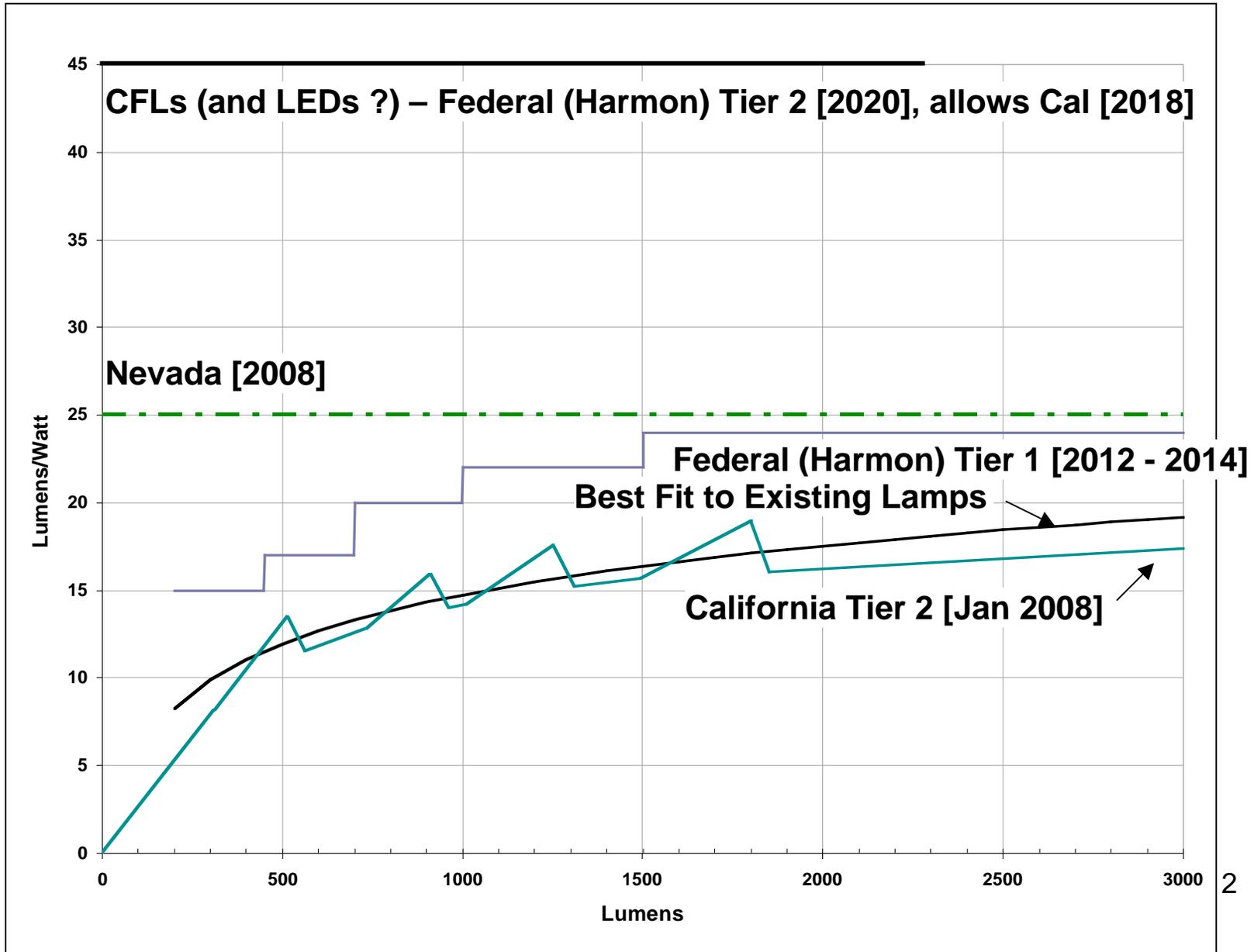
## Air Conditioning Energy Use in Single Family Homes in PG&E The effect of AC Standards (SEER) and Title 24 standards



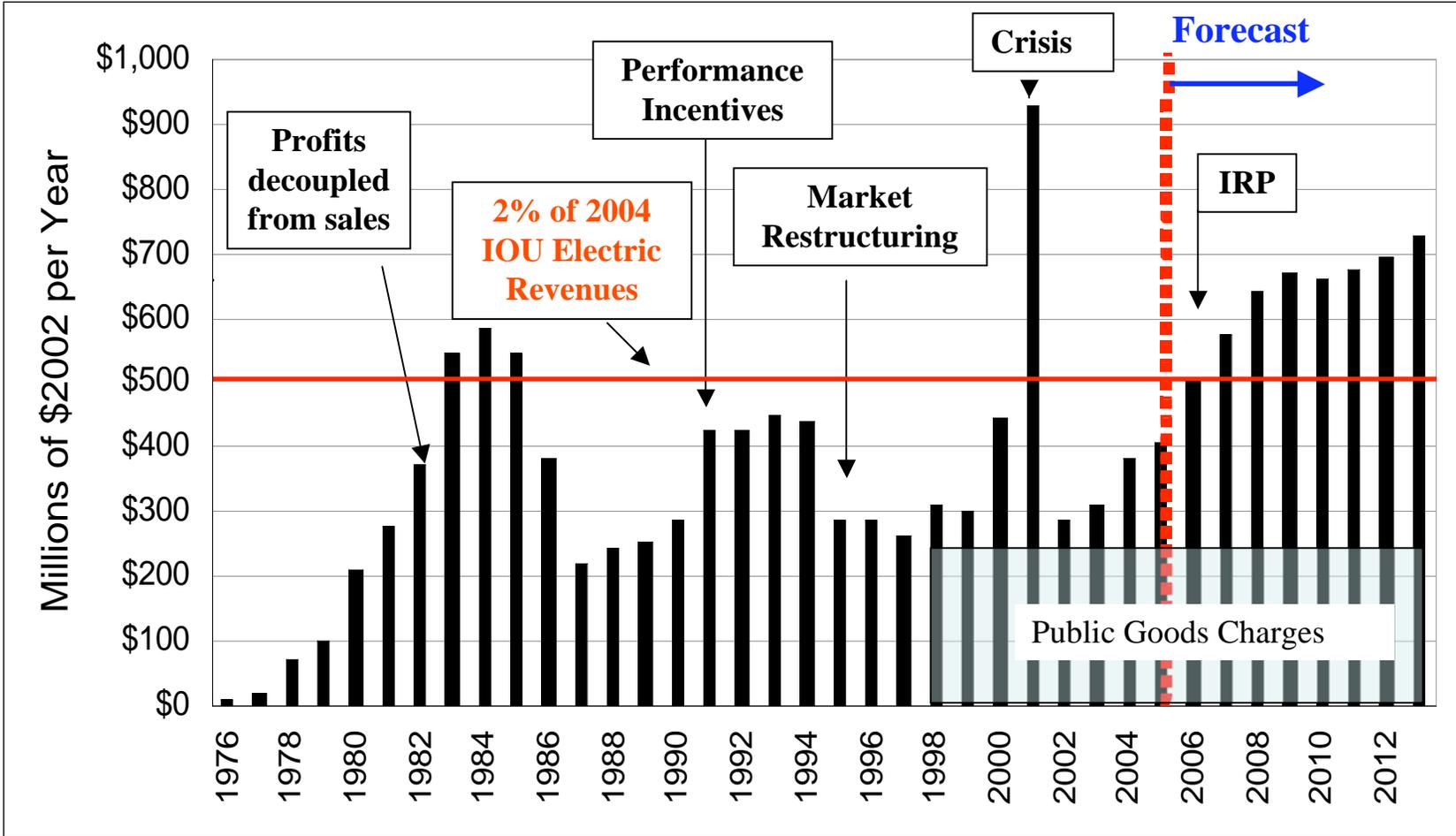
## United States Refrigerator Use, repeated, to compare with Estimated Household Standby Use v. Time



# 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

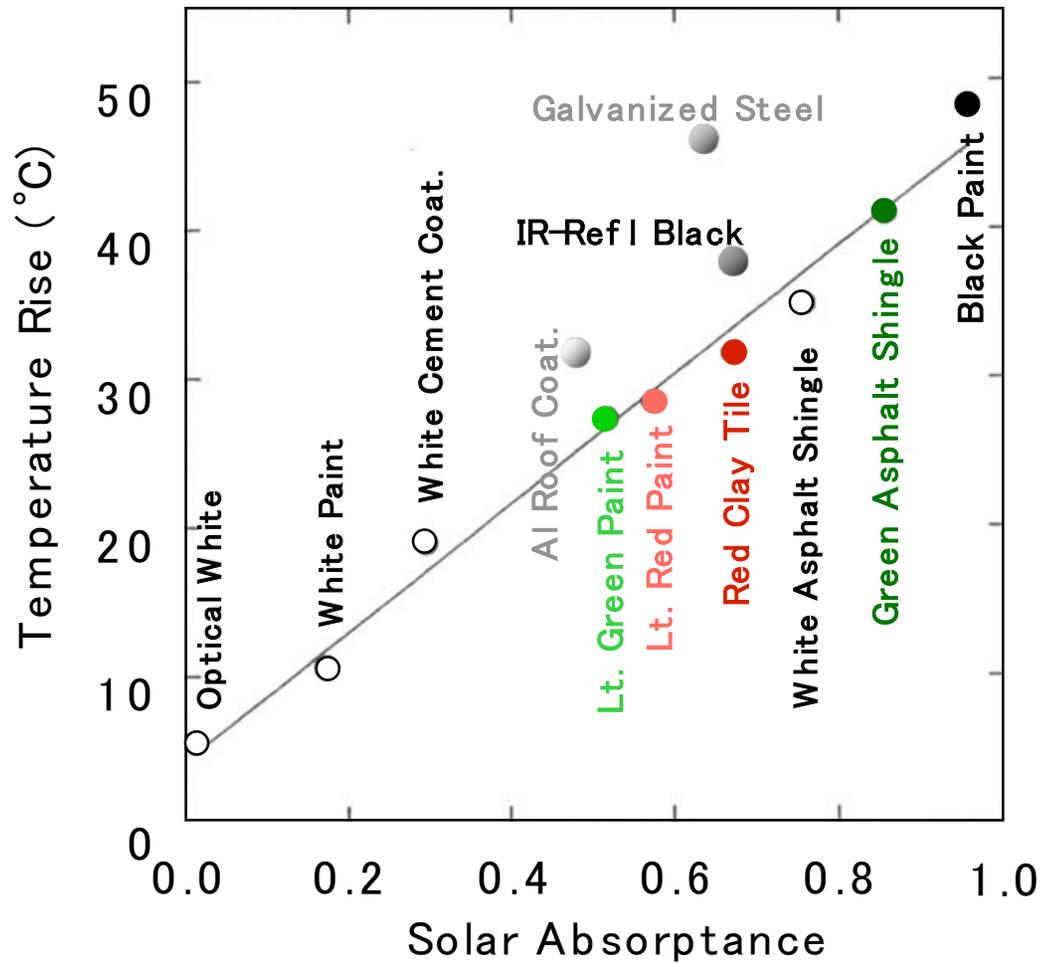
Tel: 510-486-4287

Email: [H\\_Akbari@LBL.gov](mailto: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



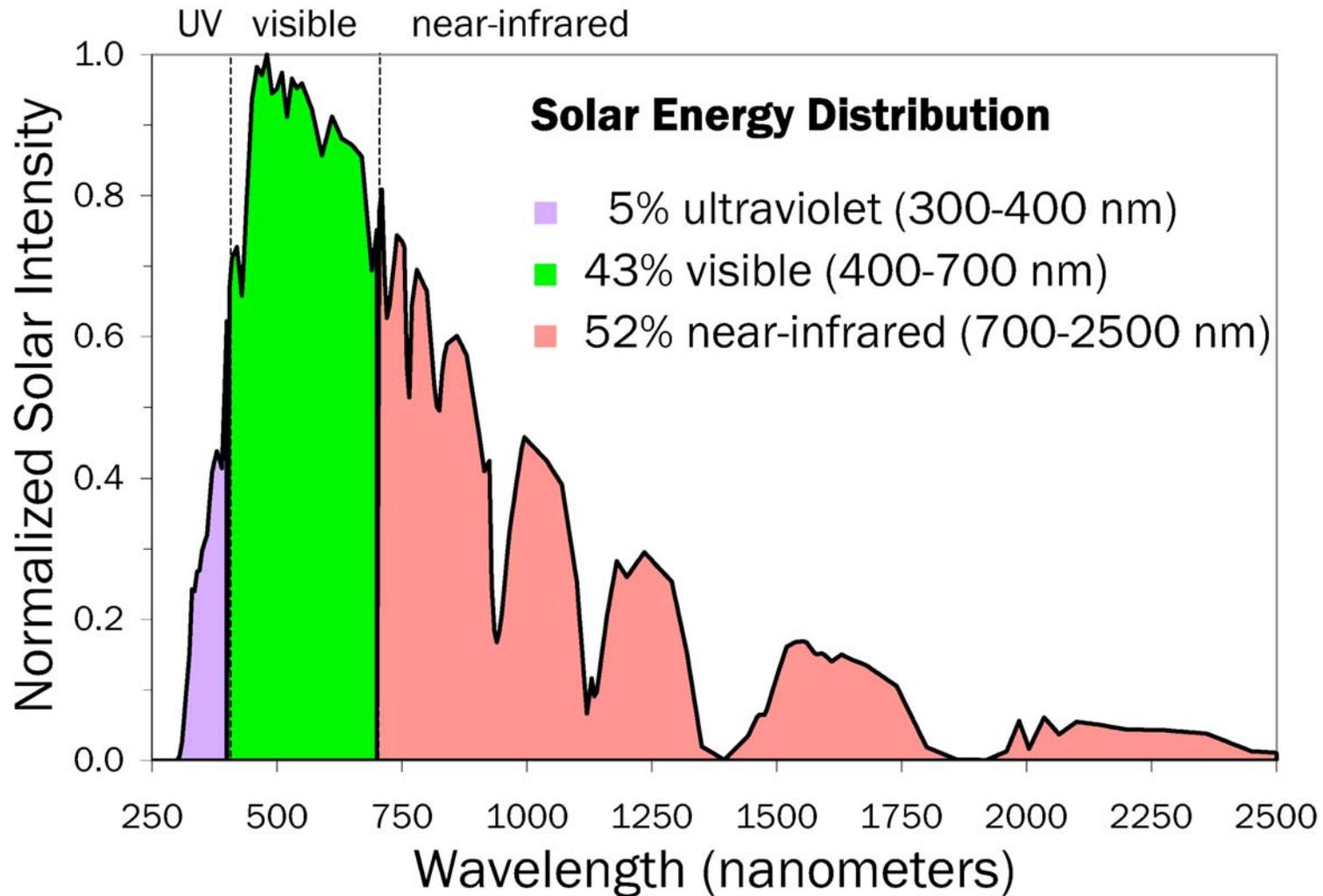
pitched, white

New

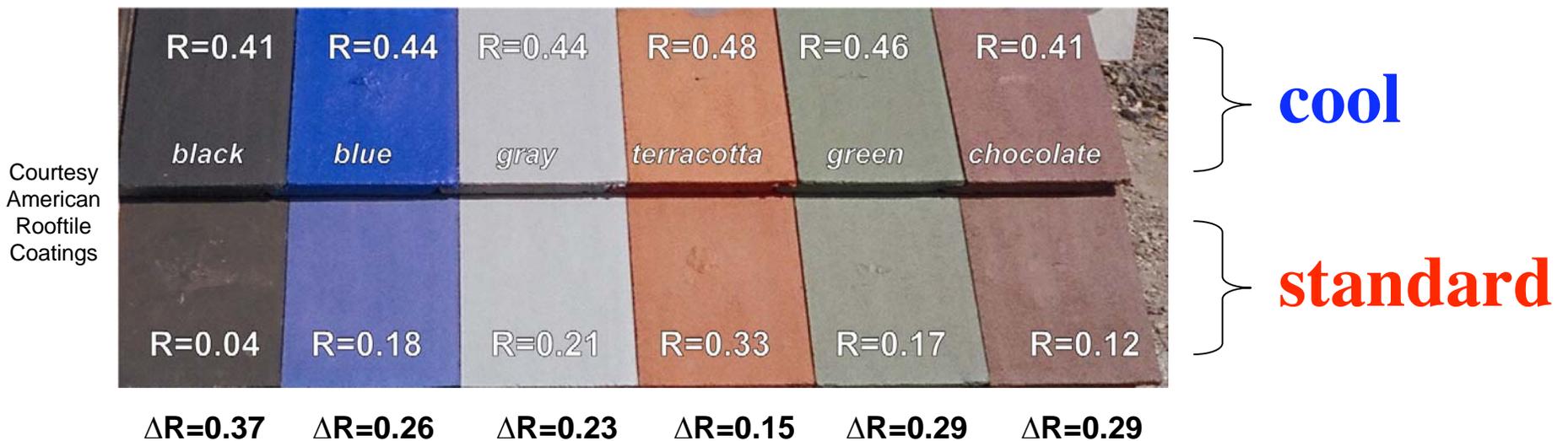


pitched, cool & colored

# Cool Colors Reflect Invisible Near-Infrared Sunlight



# Cool and Standard Color-Matched Concrete Tiles



- 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<sub>2</sub>. So we discuss the effect of cool surfaces for tropical, and temperate cities, and show that
- Each 25m<sup>2</sup> (250 square feet) of cooler roof offsets 1 ton of CO<sub>2</sub> each 35 m<sup>2</sup> (350 square feet) of cooler pavement offsets another ton.

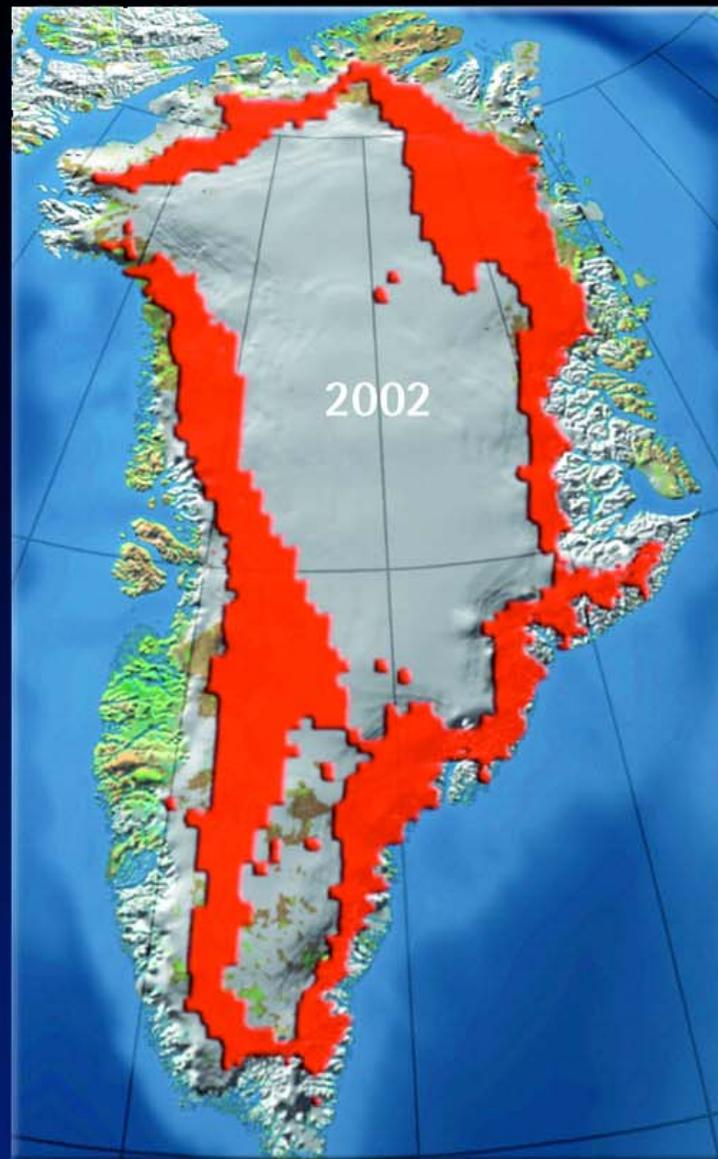
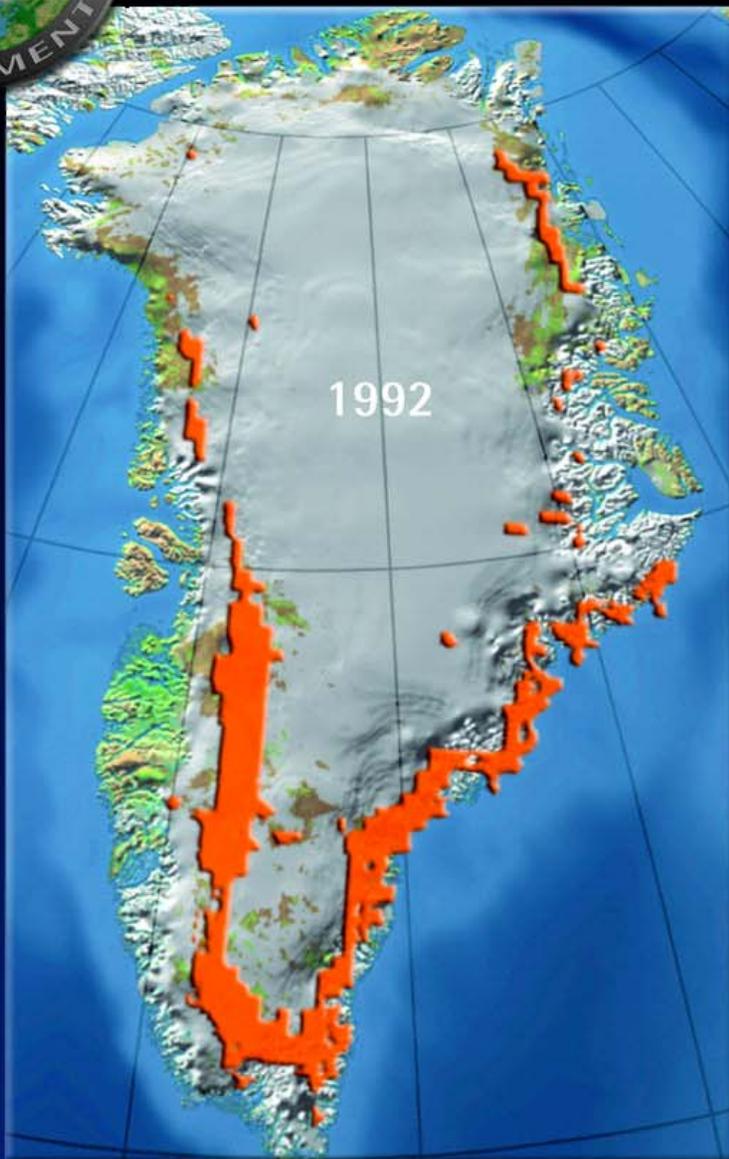
## Dense Urban Areas are 1% of Land

- Area of the Earth =  $511 \times 10^{12} \text{ m}^2$
- 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]
- **1% of land is  $1.5 \times 10^{12} \text{ m}^2 =$  area of a square of side  $s = 1200 \text{ km}$  or  $750 \text{ miles}$  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

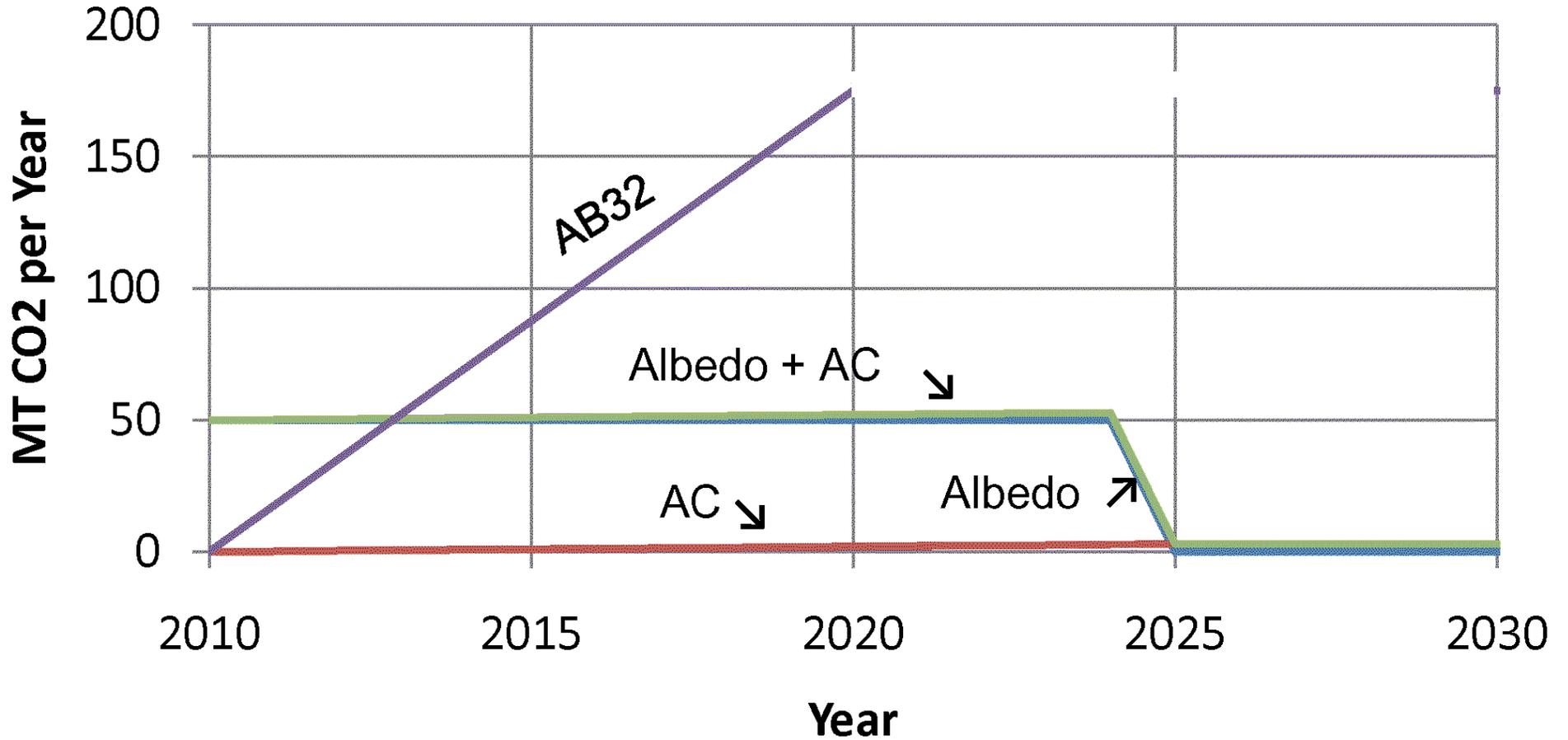
- Mirror Area =  $1.5 \times 10^{12} \text{ m}^2$  [5]  $\times (0.1/0.7)$  [ $\delta$  albedo of cities/  $\delta$  albedo of mirror]  
=  $0.2 \times 10^{12} \text{ m}^2 = 200,000 \text{ km}^2$  {This is equivalent to an square of 460 km on the side}  
= 10% of Greenland = 50% of California



## Equivalent Value of Avoided CO<sub>2</sub>

- CO<sub>2</sub> 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?*



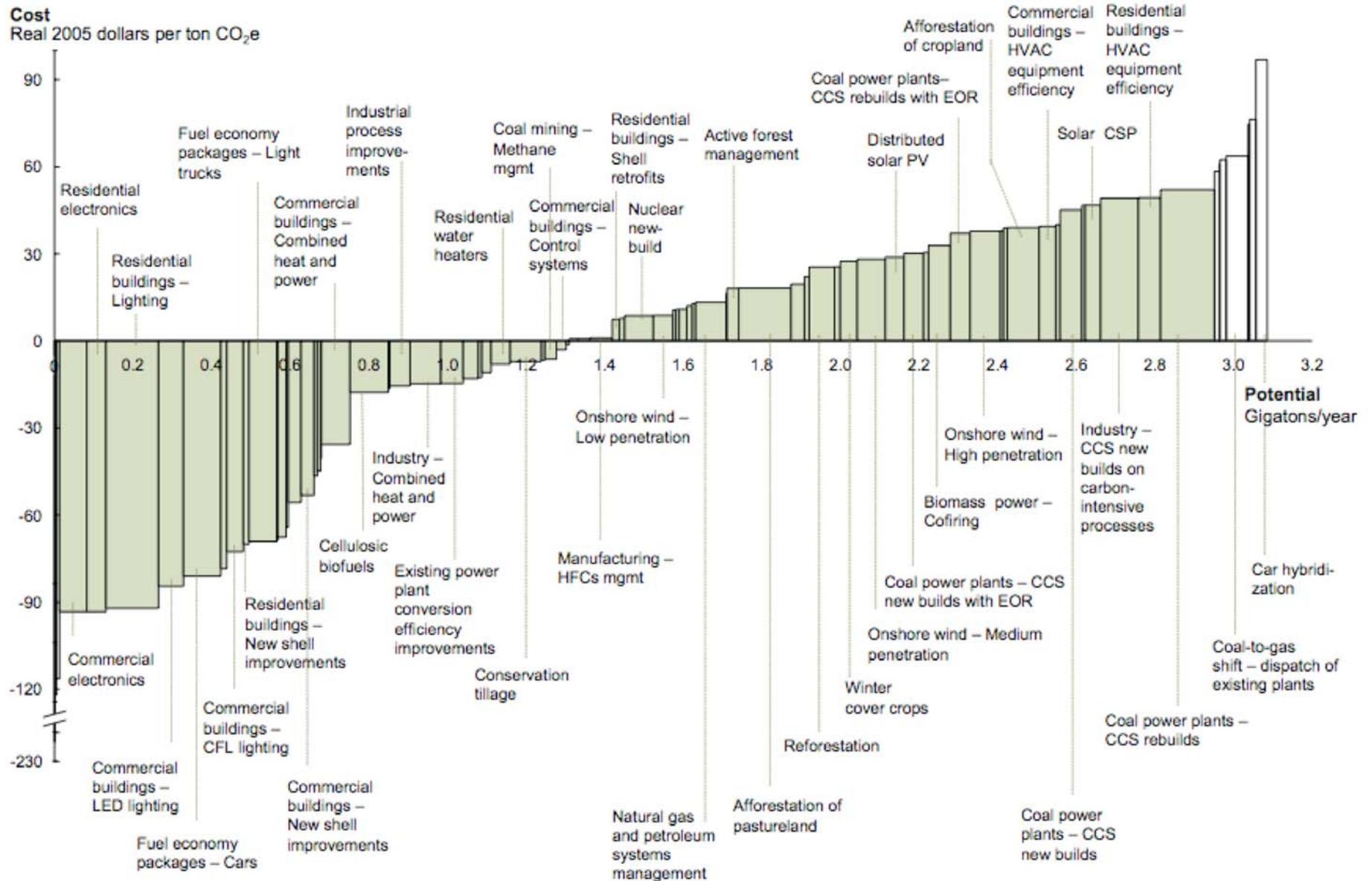
**US Greenhouse Gas Abatement Mapping Initiative**

December 12, 2007

**McKinsey & Company**

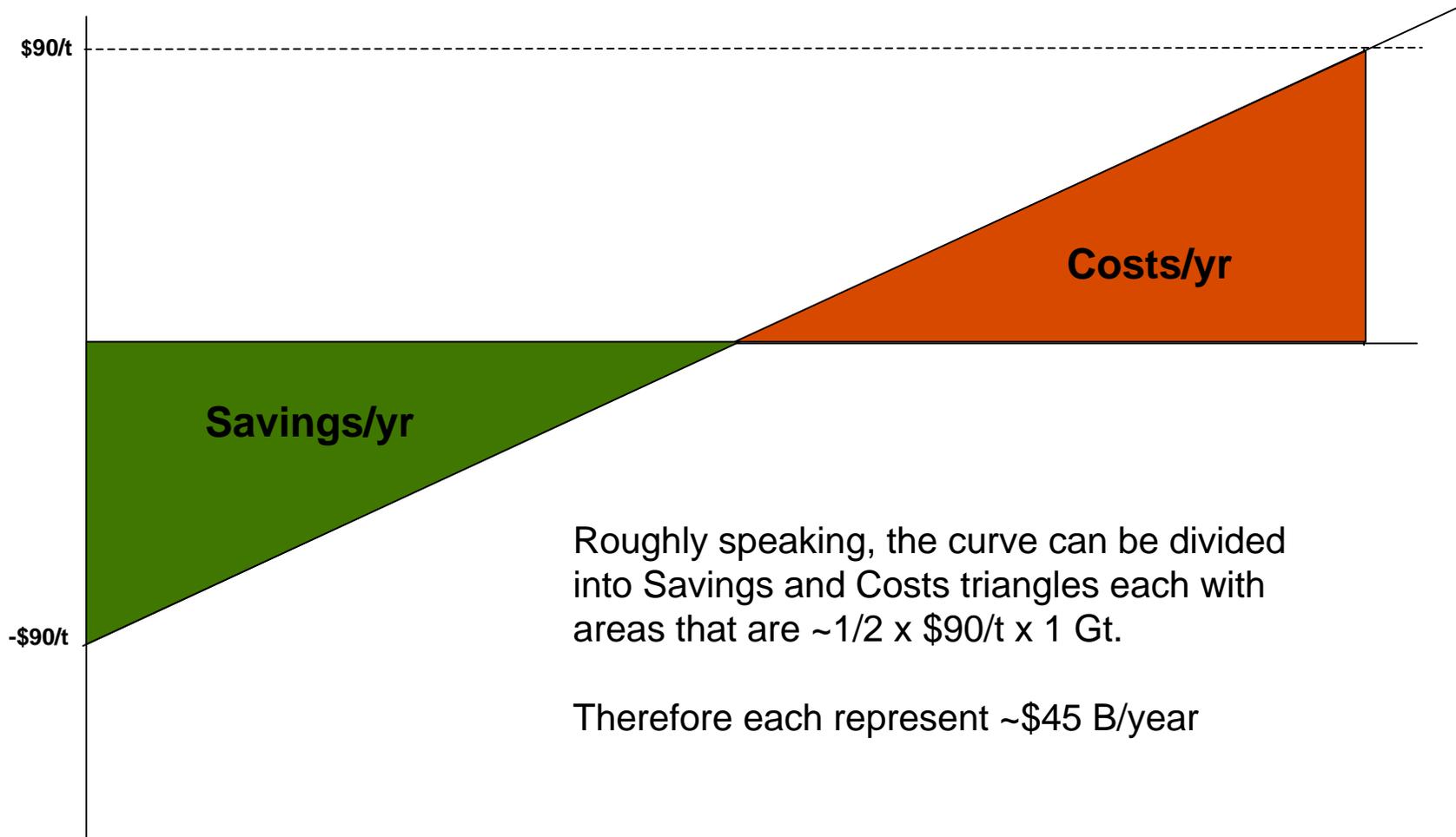
Exhibit B

# U.S. MID-RANGE ABATEMENT CURVE – 2030



Source: McKinsey analysis

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

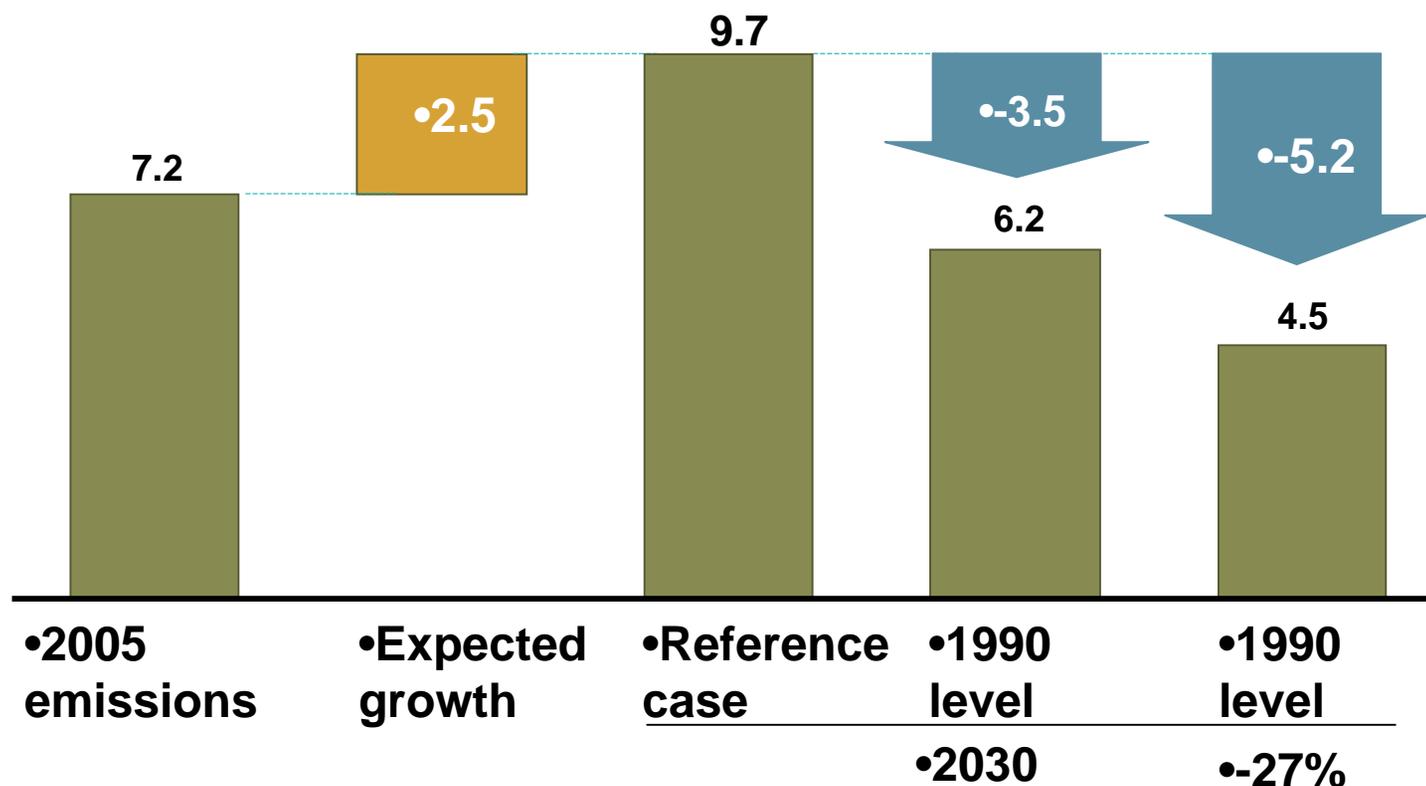


U.S. GHG emissions in 2030 are projected to exceed proposed targets being considered in Congress by a wide margin

Gigatons CO<sub>2</sub>e

**Projected GHG emissions**

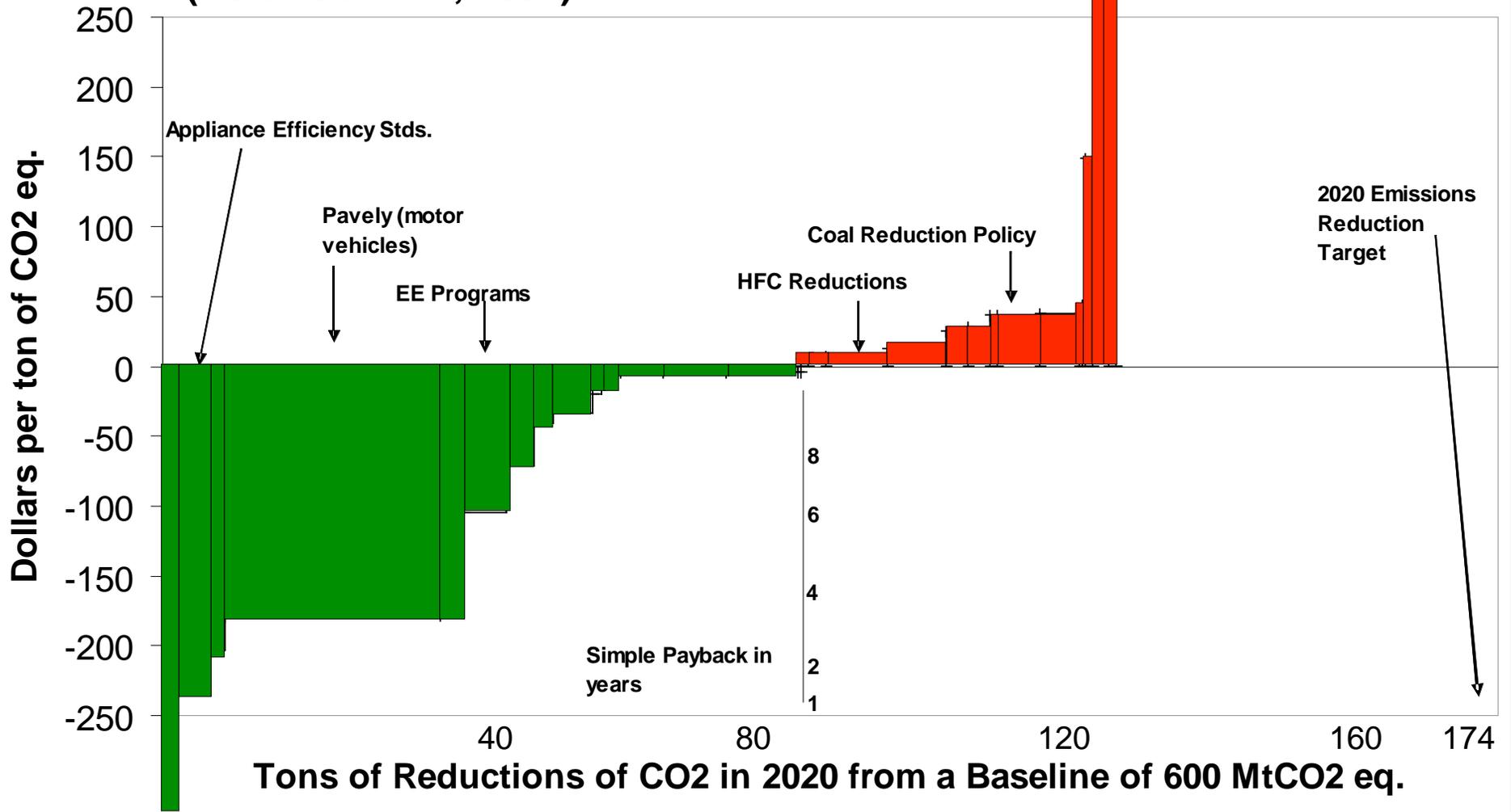
**Range of proposed reductions\***



\* 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

# California Climate Strategy Supply Curve (As of October, 2007)



A **cost curve** for  
greenhouse gas reduction  
With a Worldwide Perspective

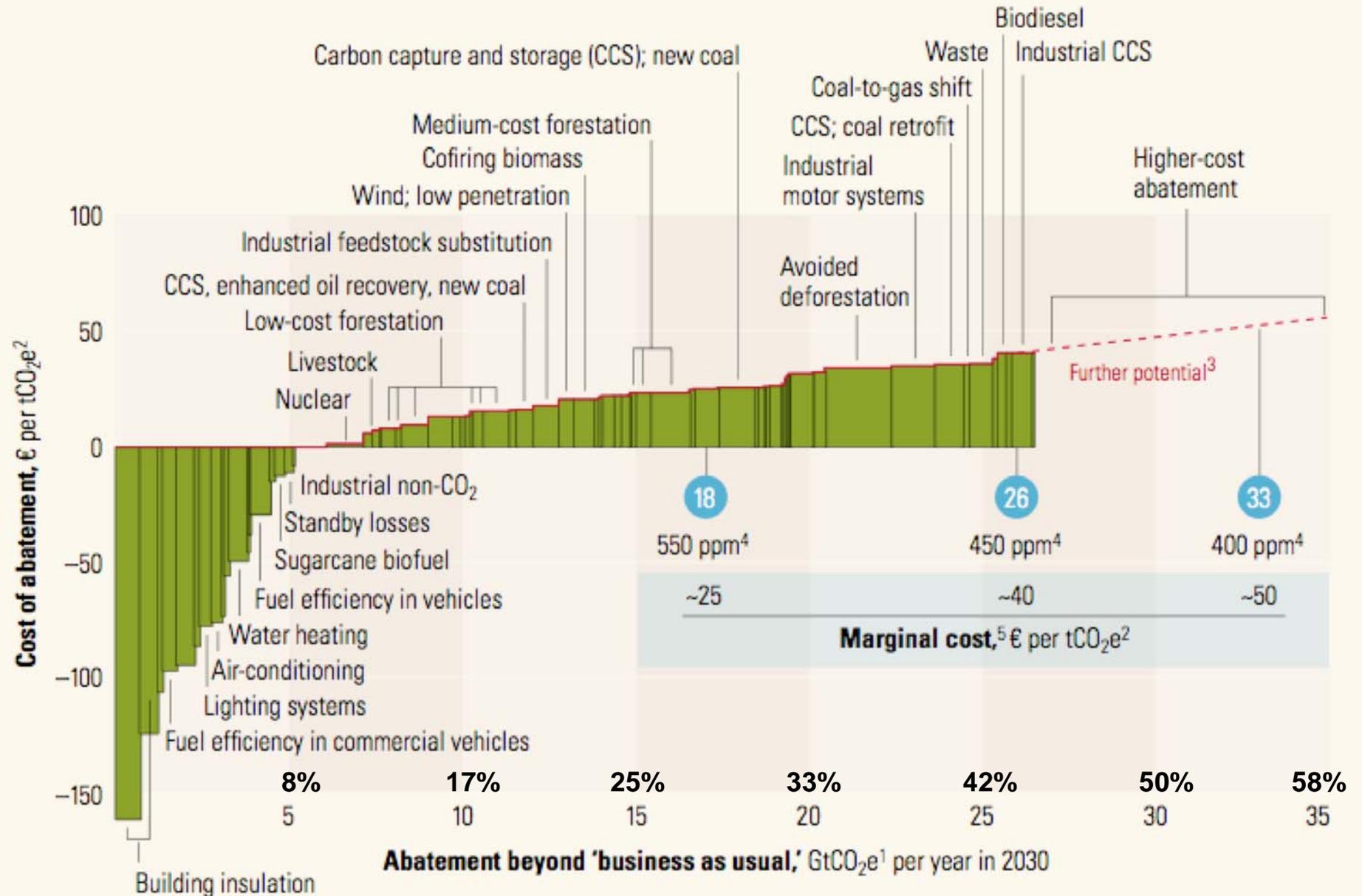
*A global study of the size and cost of measures to reduce greenhouse gas emissions yields important insights for businesses and policy makers.*

**Per-Anders Enkvist, Tomas Nauc ler,  
and Jerker Rosander**

[http://www.mckinseyquarterly.com/Energy\\_Resources\\_Materials/  
A\\_cost\\_curve\\_for\\_greenhouse\\_gas\\_reduction\\_abstract](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<sub>2</sub>e<sup>1</sup>

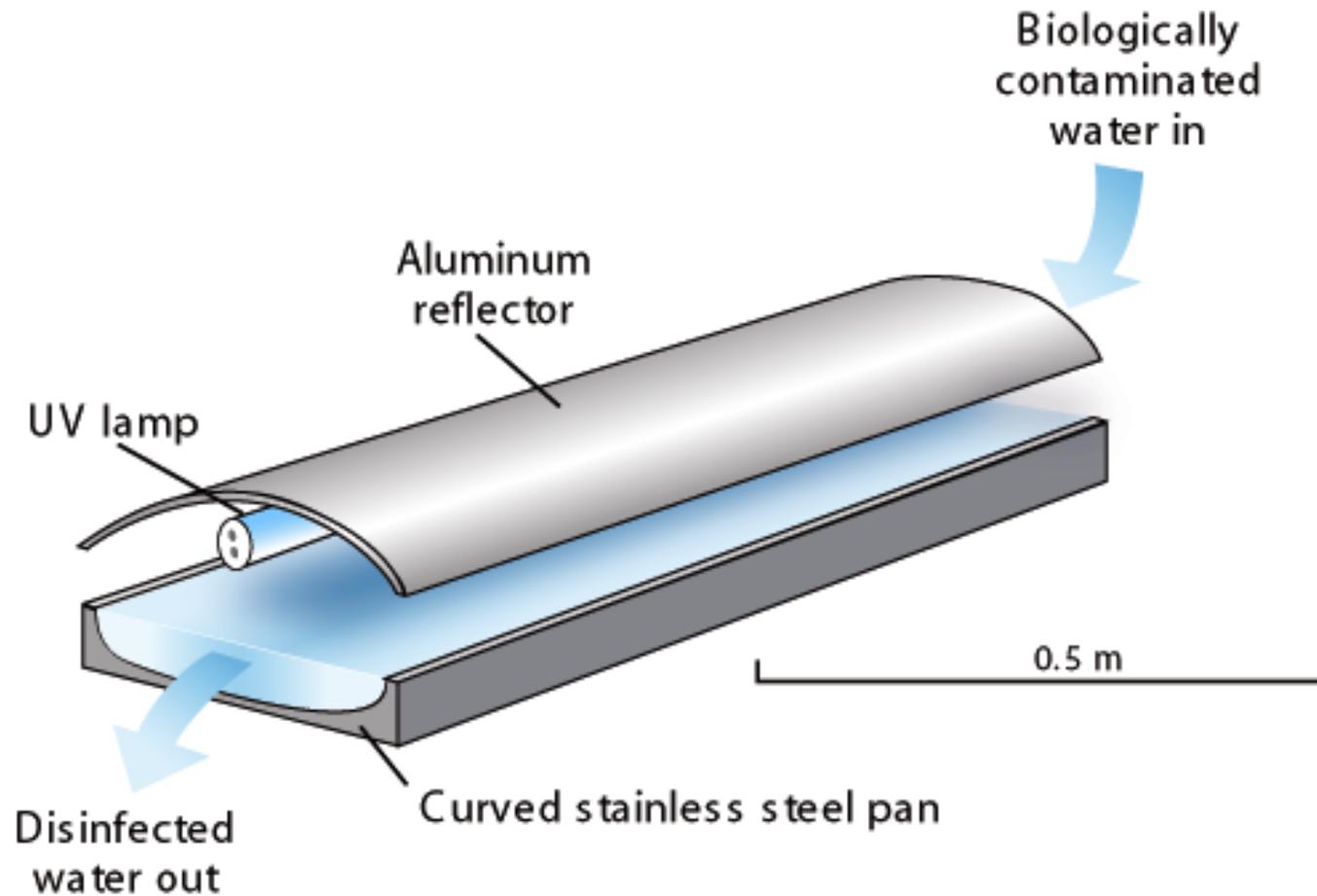
● Approximate abatement required beyond 'business as usual,' 2030



## 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 MtCO<sub>2</sub> 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 MtCO<sub>2</sub> 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 MtCO<sub>2</sub> eq.** per year

The total of **40 MtCO<sub>2</sub> 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

