Energy Efficiency:
The first and most profitable way to delay Climate Change

UCLA Institute of the Environment
Environmental Science Colloquium
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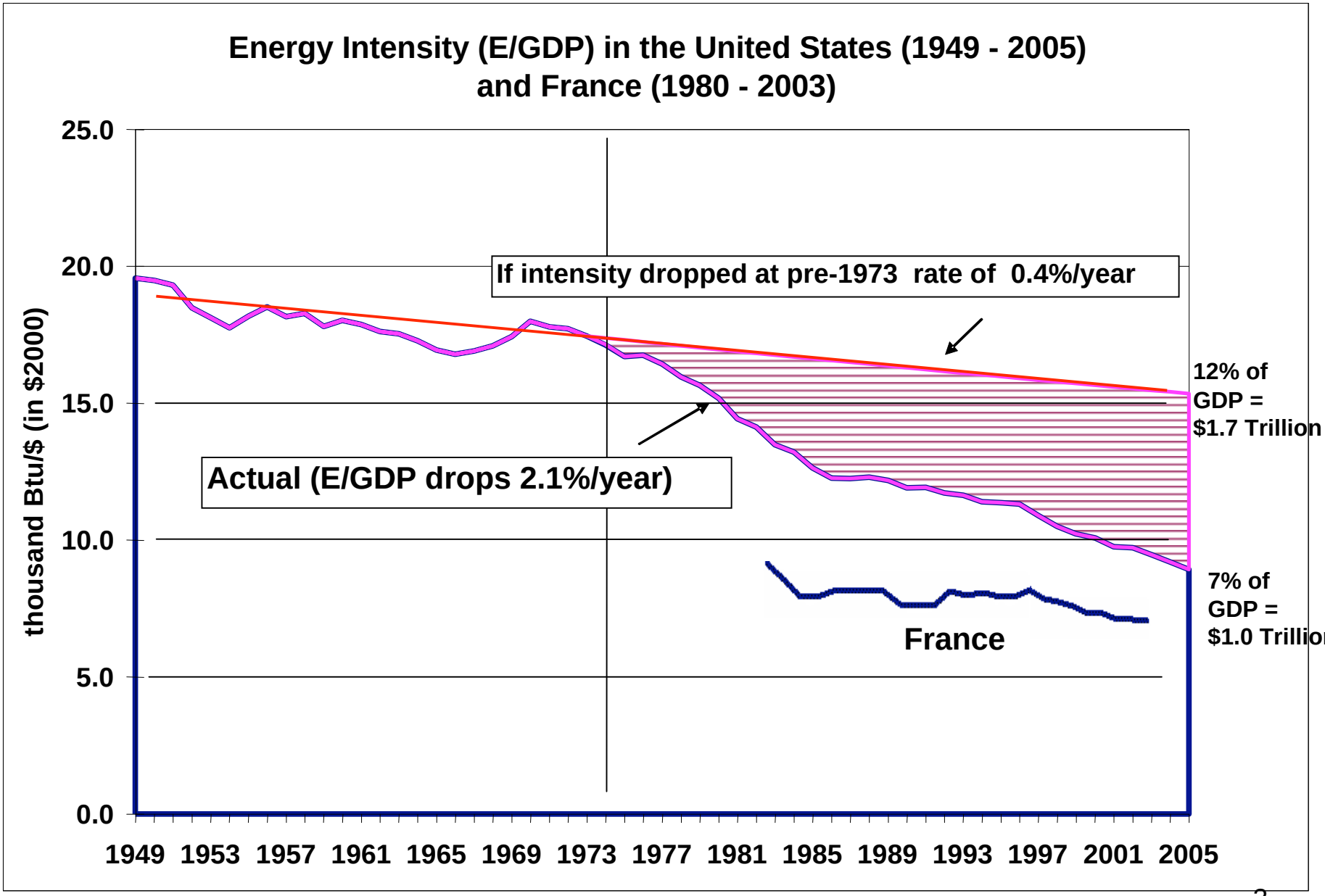
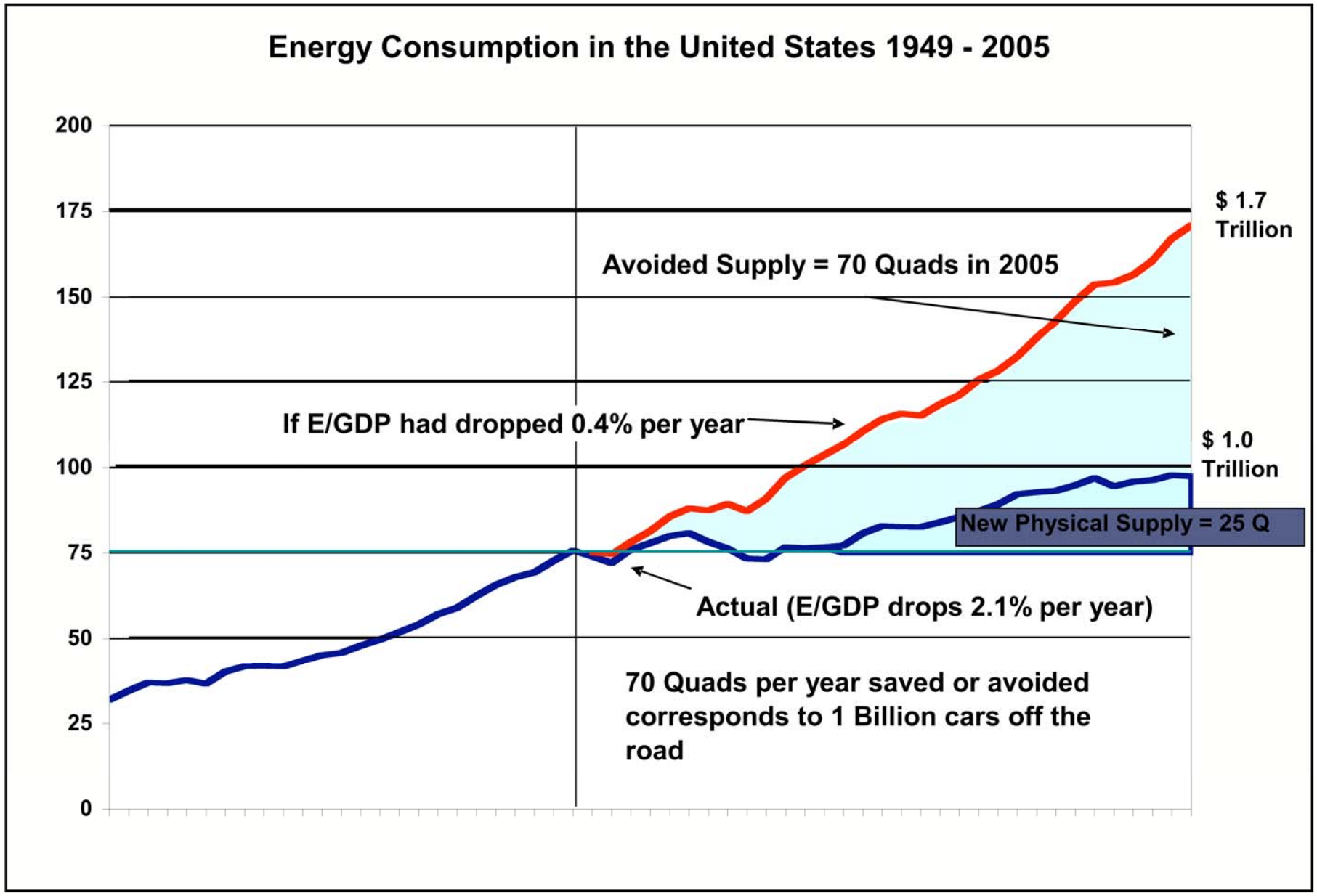
http://www.energy.ca.gov/commission/commissioners/rosenfeld.html
or just Google "Art Rosenfeld"

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
- California is introducing 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
7% of
GDP =
$1.0 Trillion


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

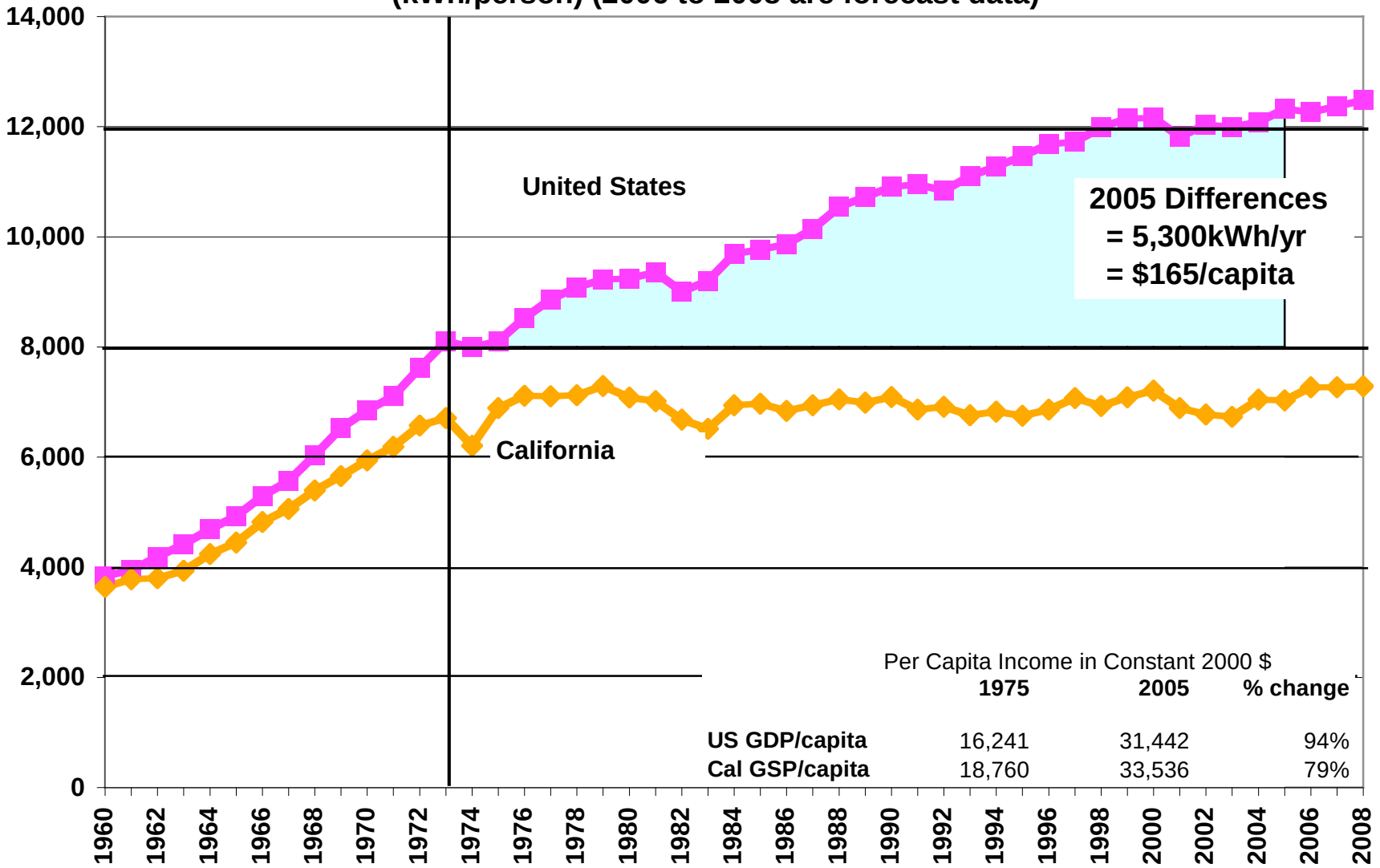
California's Energy Action Plan

- 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.

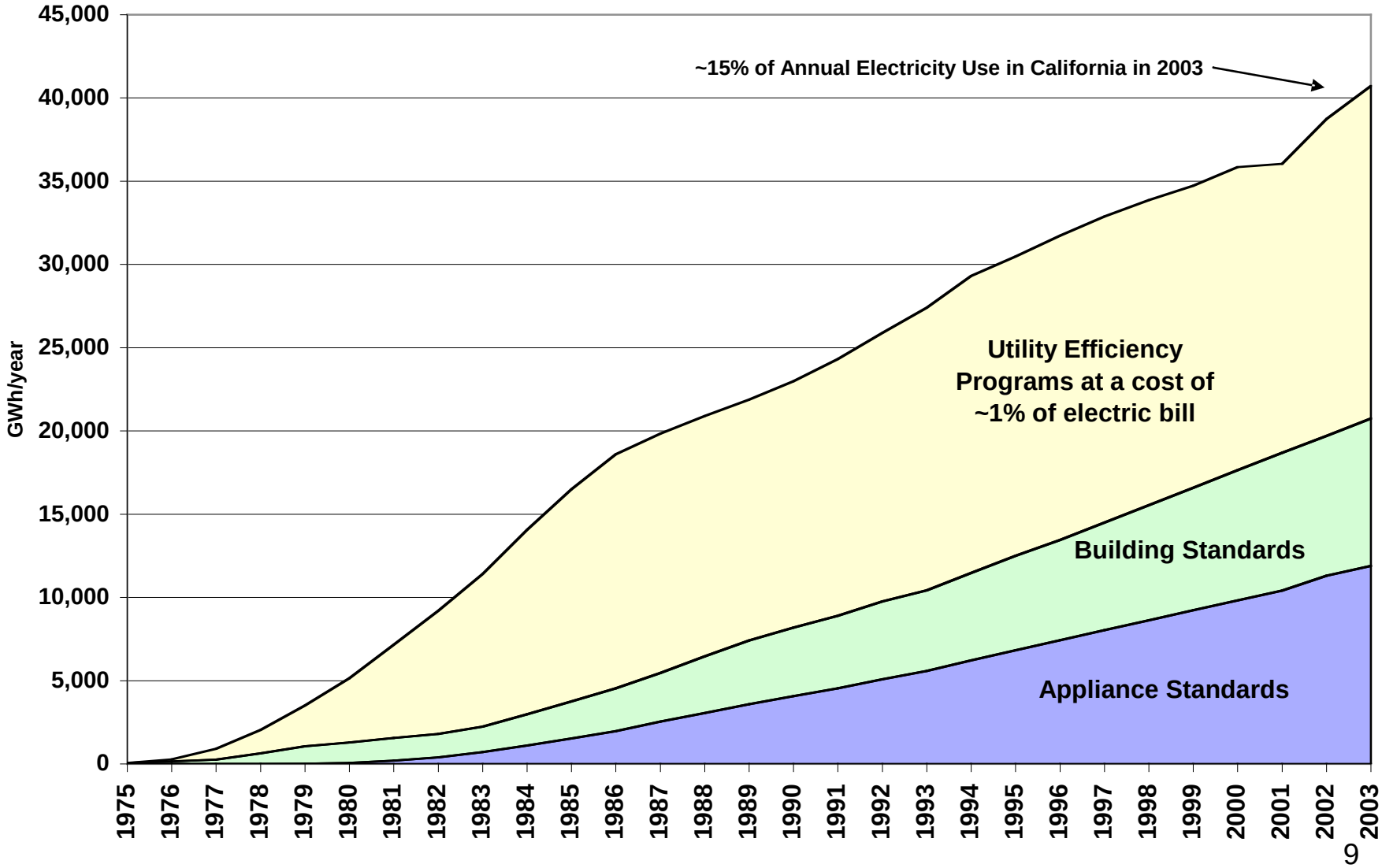
- 1. Energy efficiency and Demand Response
- 2. Renewable Generation,
- 3. Increased development of affordable & reliable conventional generation
- 4. Transmission expansion to support all of California's energy goals.

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

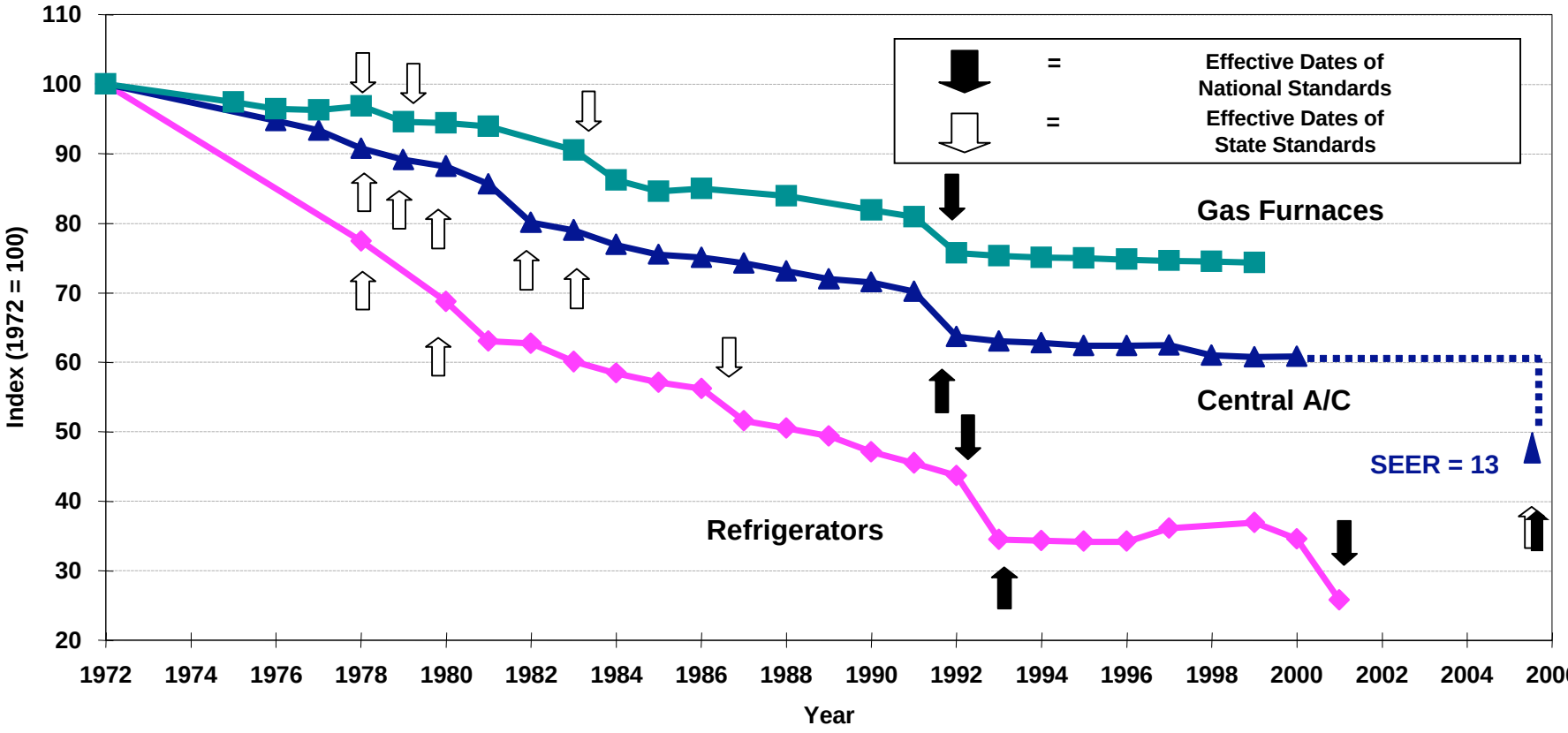
Per Capita Electricity Sales (not including self-generation) (kWh/person) (2006 to 2008 are forecast data)



Annual Energy Savings from Efficiency Programs and Standards



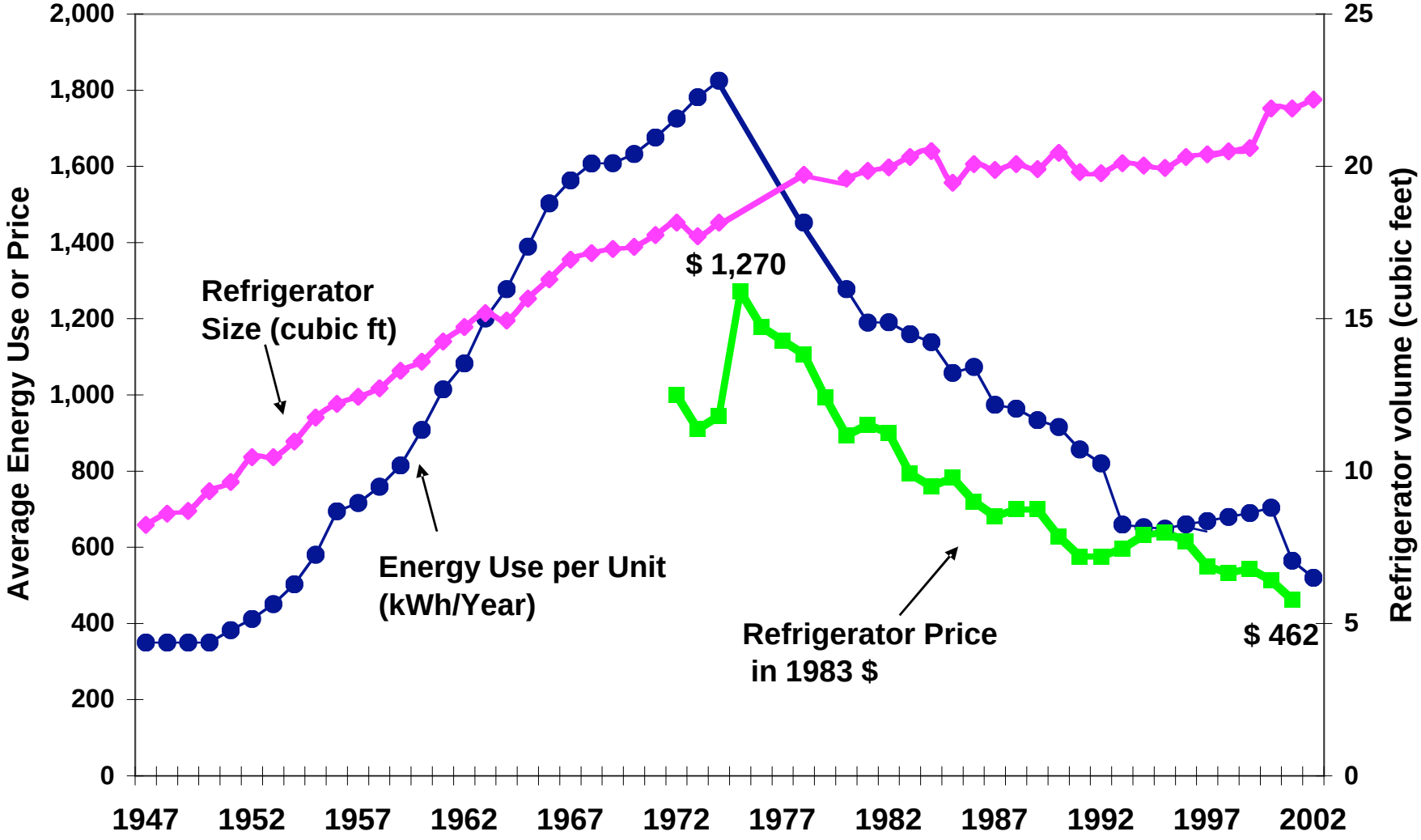
Impact of Standards on Efficiency of 3 Appliances



Source: S. Nadel, ACEEE,

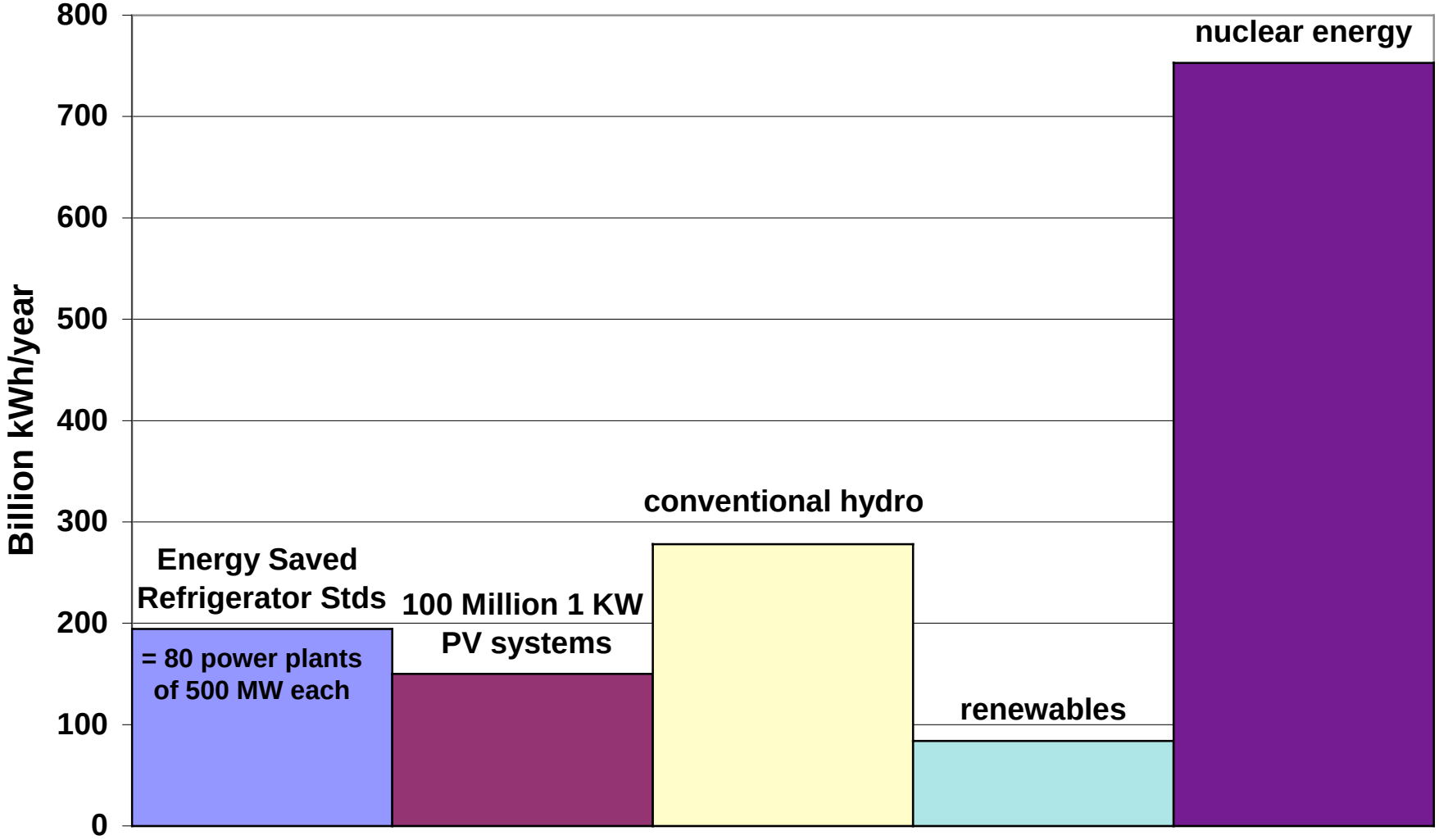
in ECEEE 2003 Summer Study, www.eceee.org

New United States Refrigerator Use v. Time and Retail Prices



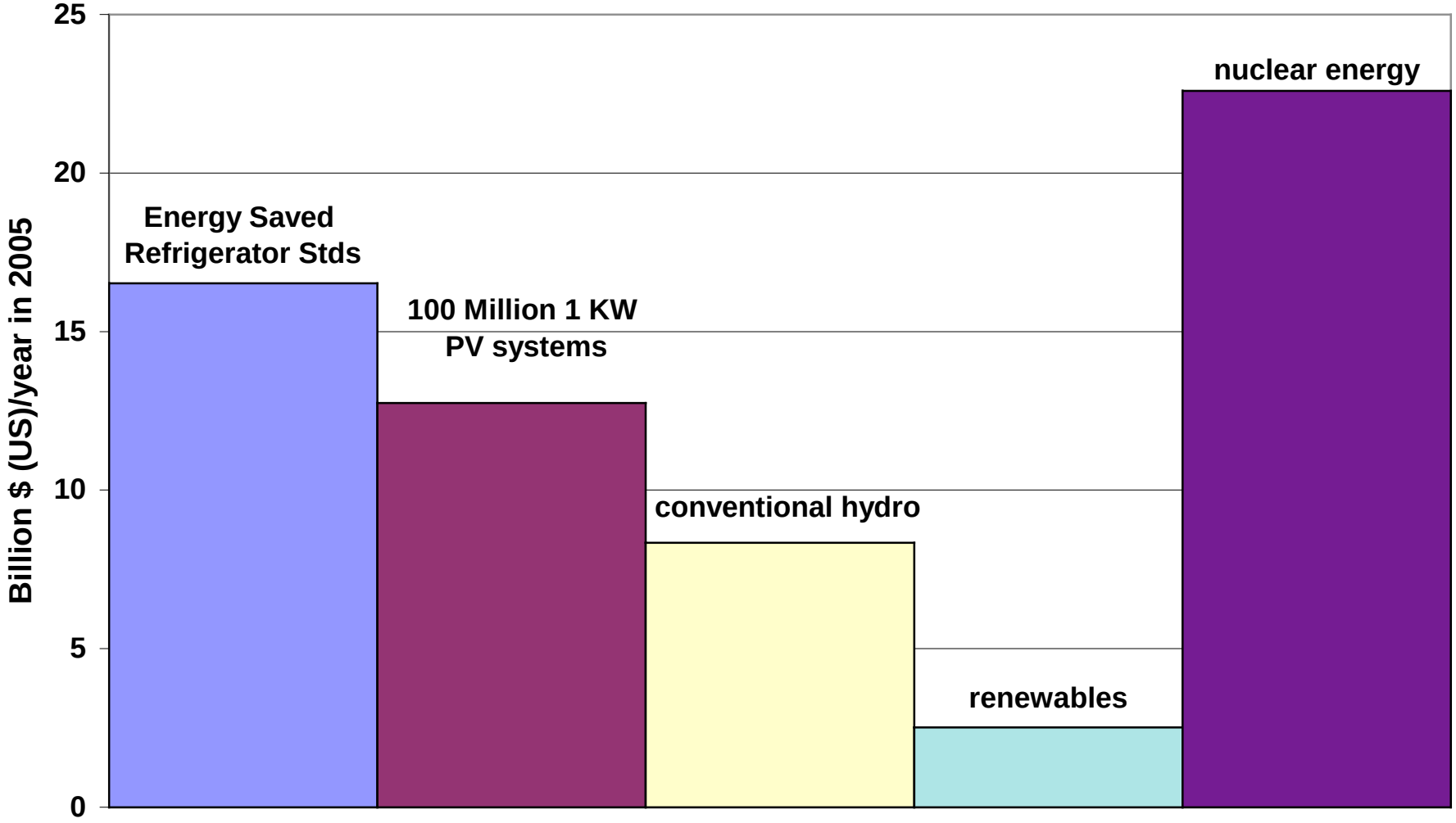
Source: David Goldstein

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

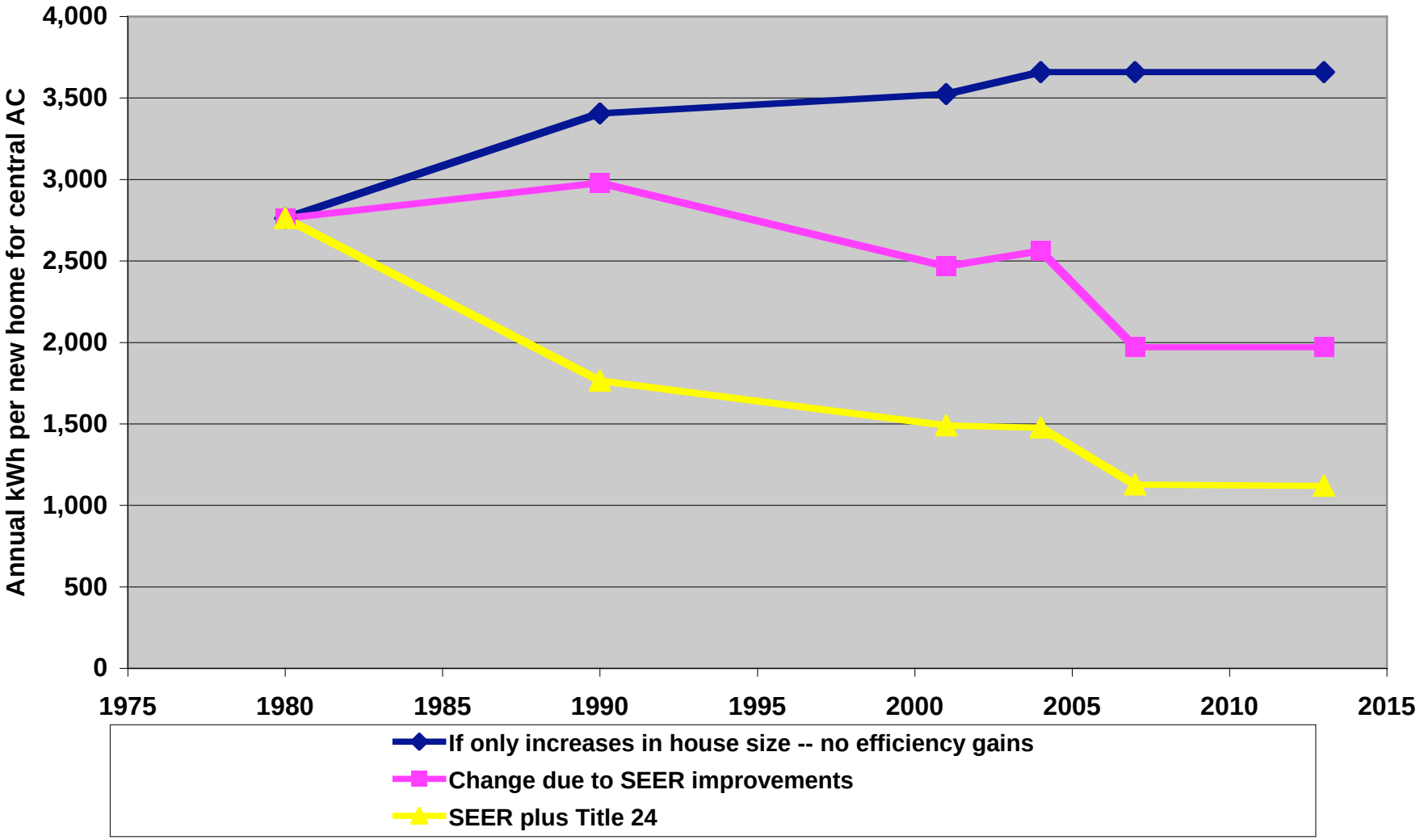


In the United States

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)

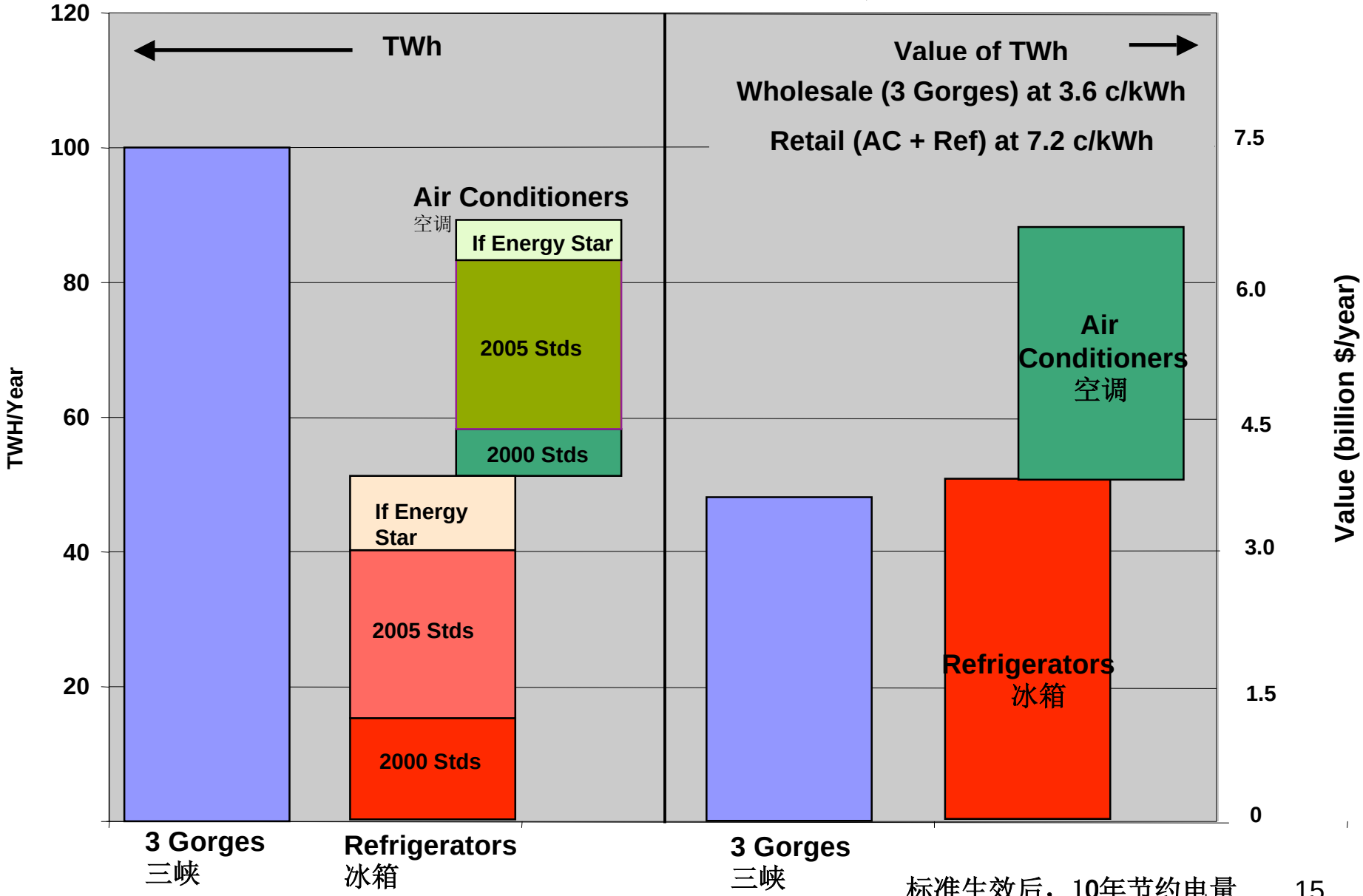


Air Conditioning Energy Use in Single Family Homes in PG&E
The effect of AC Standards (SEER) and Title 24 standards



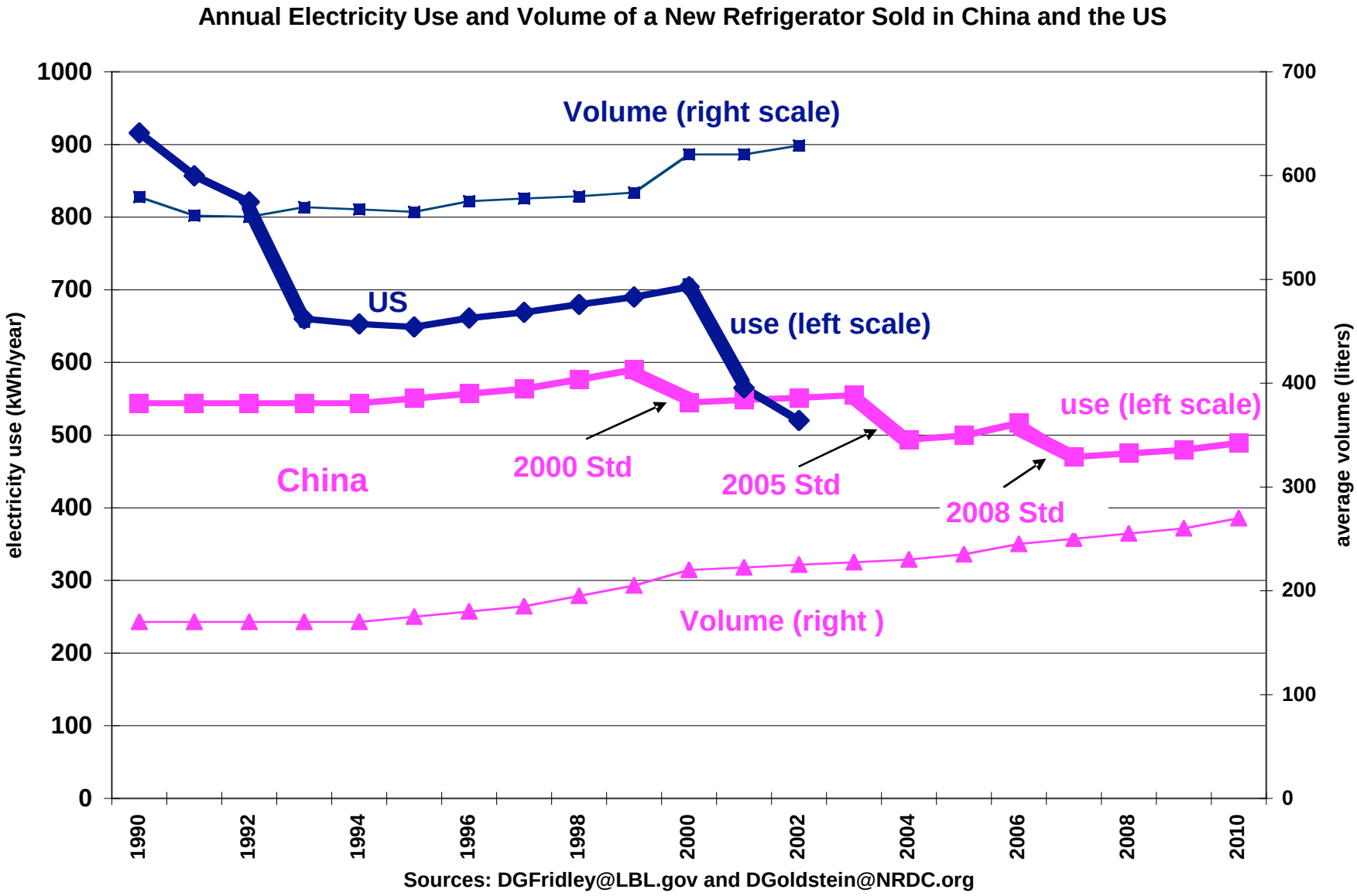
Comparison of 3 Gorges to Refrigerator and AC Efficiency Improvements

三峡电量与电冰箱、空调能效对比

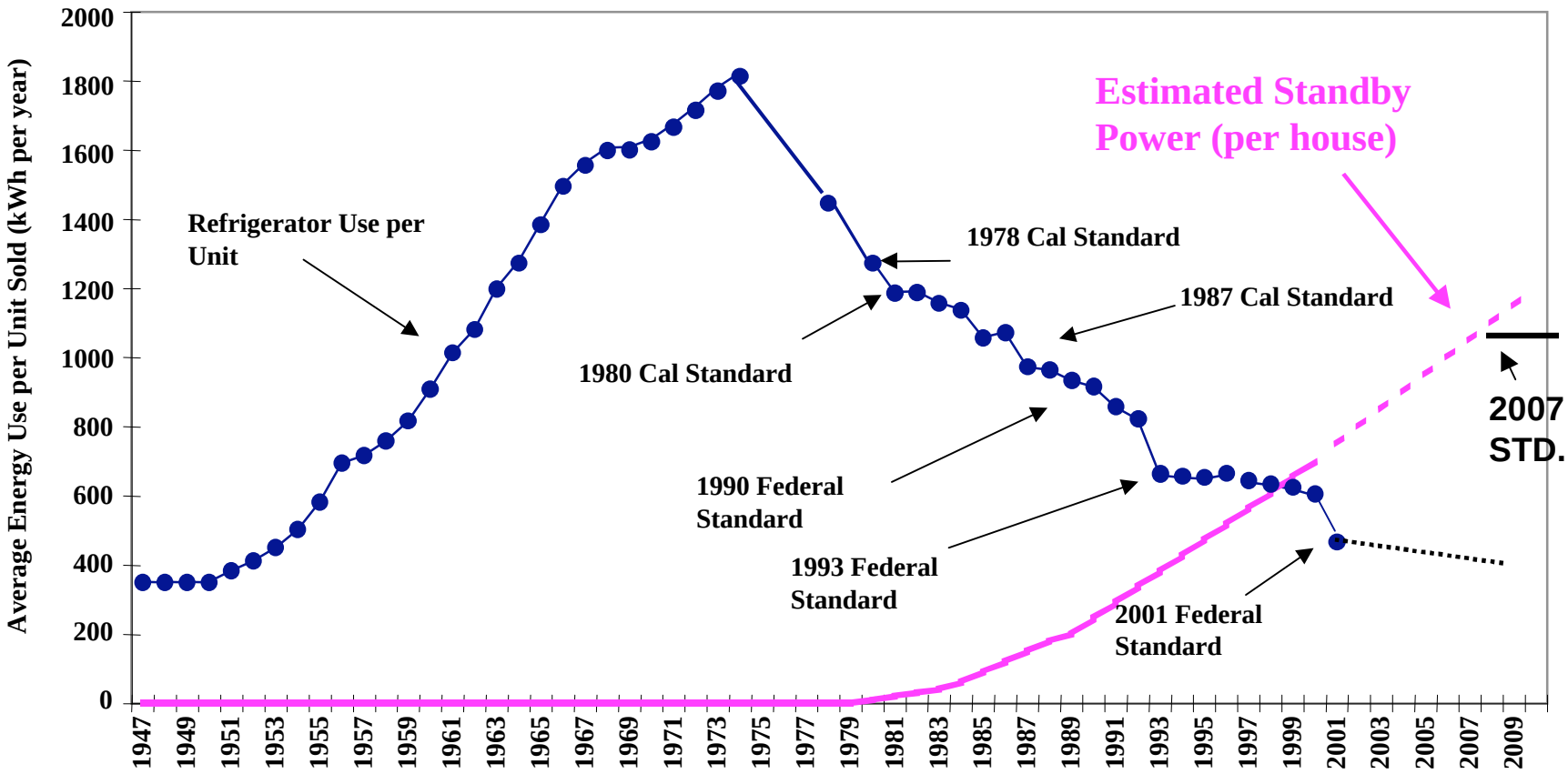


Savings calculated 10 years after standard takes effect. Calculations provided by David Fridley, LBNL

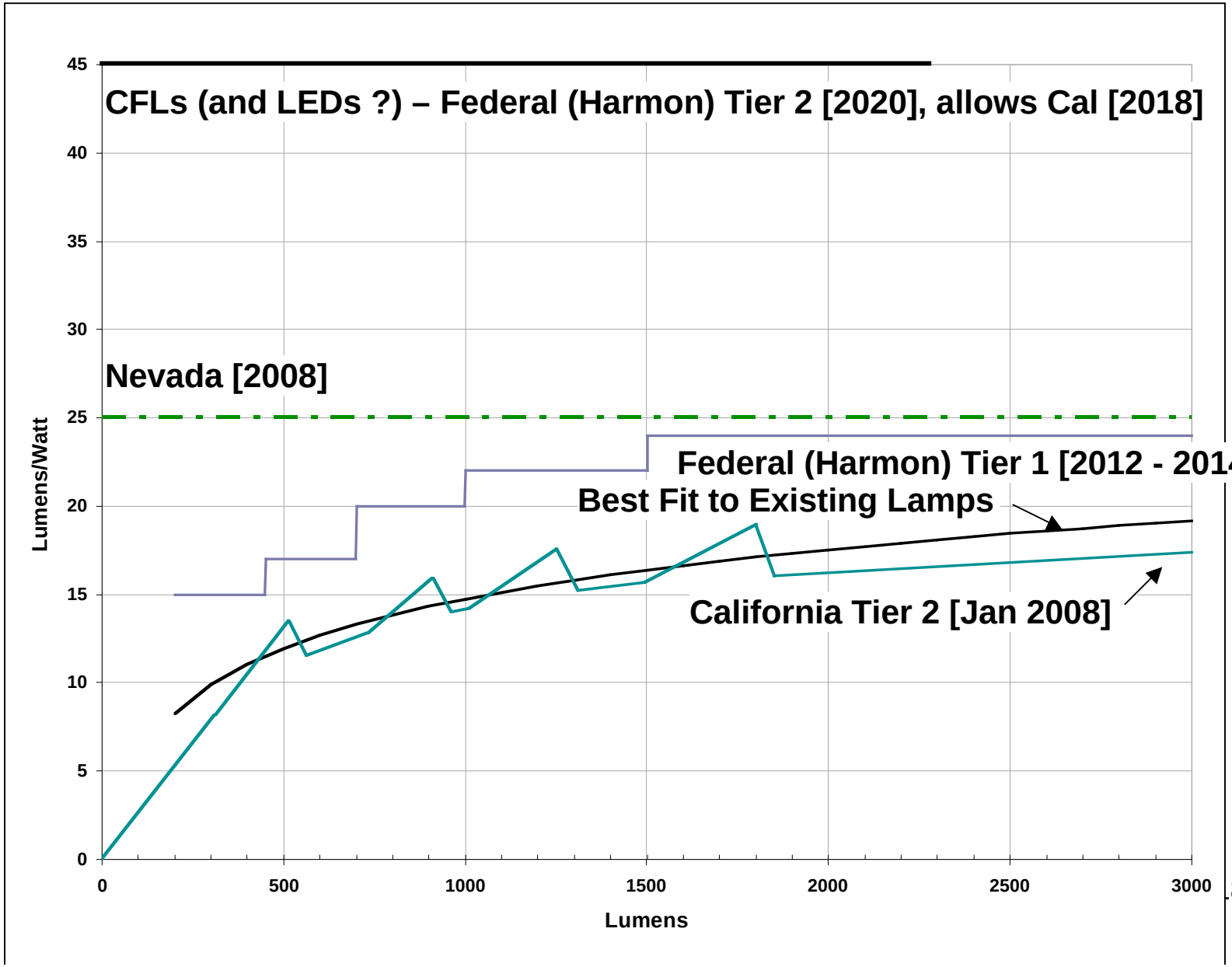
标准生效后，10年节约电量


Annual Electricity Use and Volume of a New Refrigerator Sold in China and the US
electricity use (kWh/year)
average volume (liters)
1000
900
800
700
600
500
400
300
200
100
0
700
600
500
400
300
200
100
0
Volume (right scale)
US
use (left scale)
China
2000 Std
2005 Std
2008 Std
use (left scale)
Volume (right)
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
Sources: DGFridley@LBL.gov and DGoldstein@NRDC.org

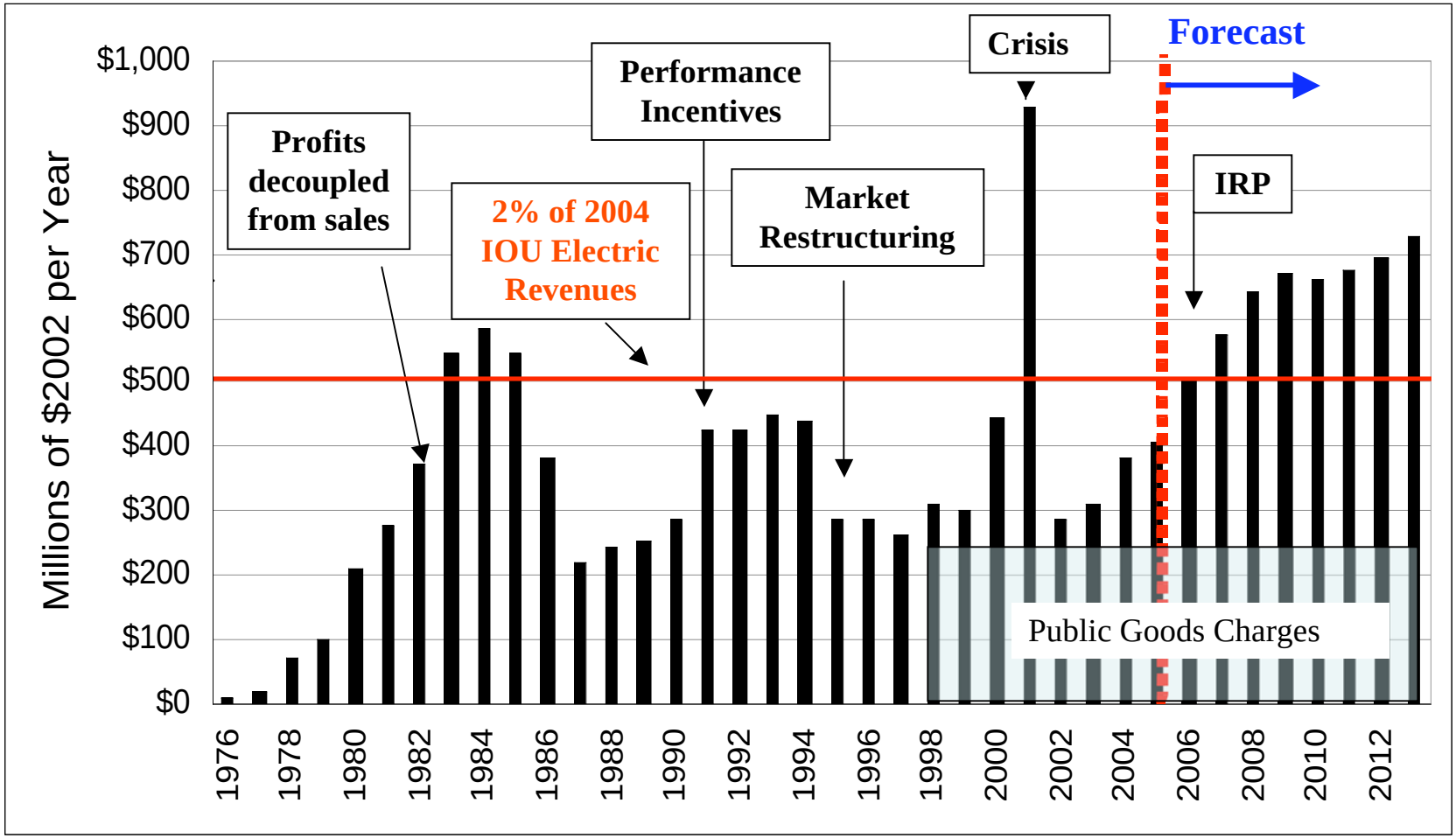
United States Refrigerator Use, repeated, to compare with Estimated Household Standby Use v. Time



Improving and Phasing-Out Incandescent Lamps



California IOU's Investment in Energy Efficiency



Cool Urban Surfaces and Global Warming

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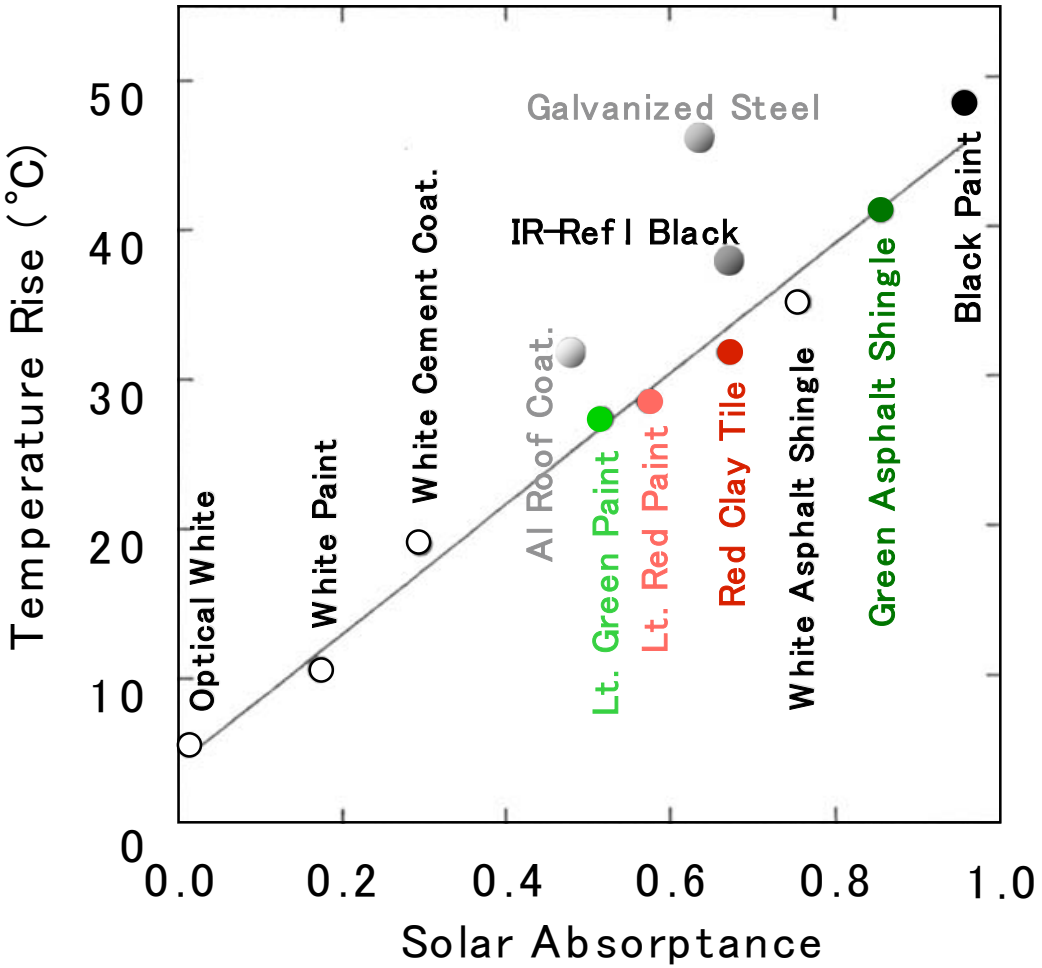
http:HeatIsland.LBL.gov

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

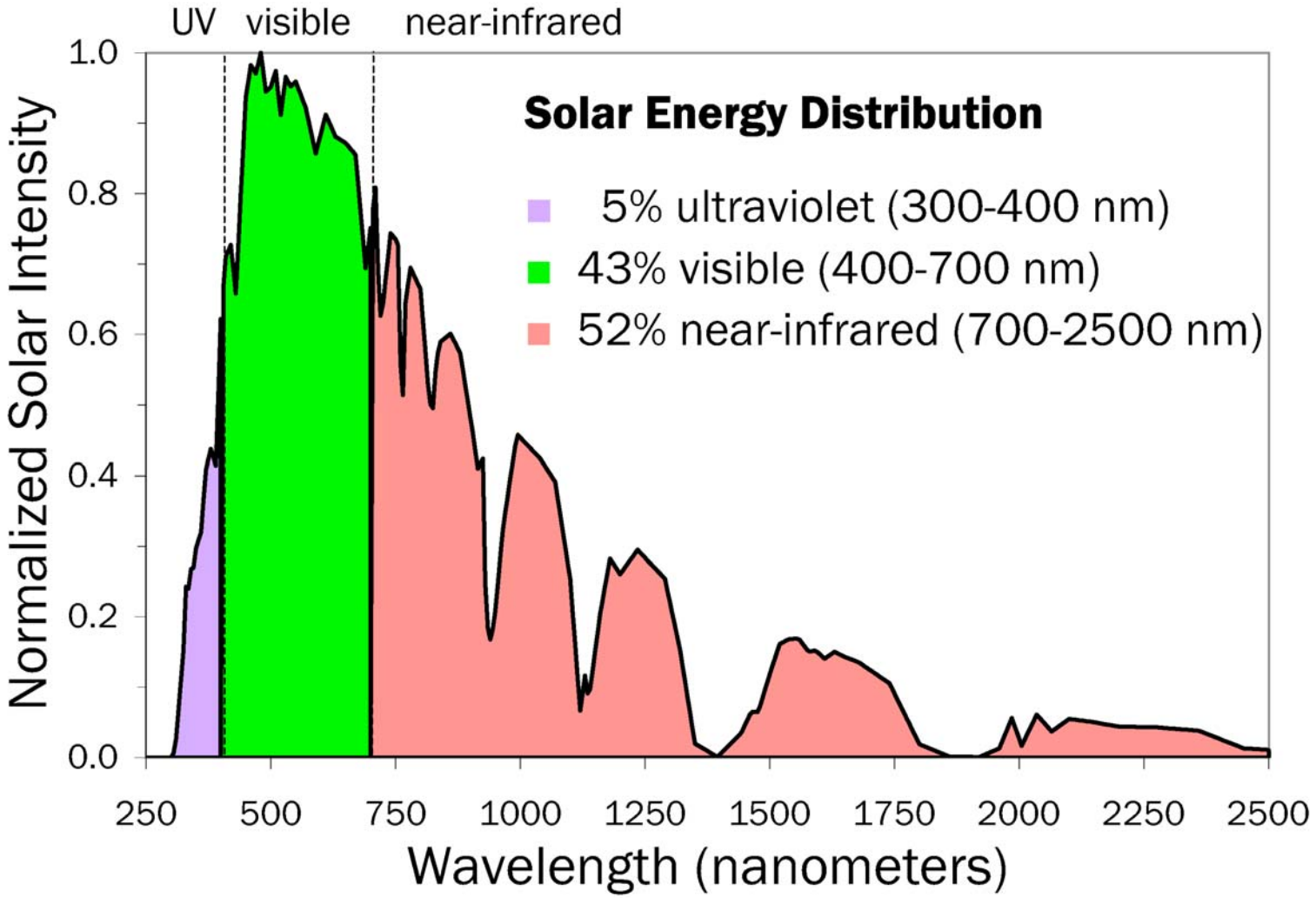
flat, white

pitched, white

New

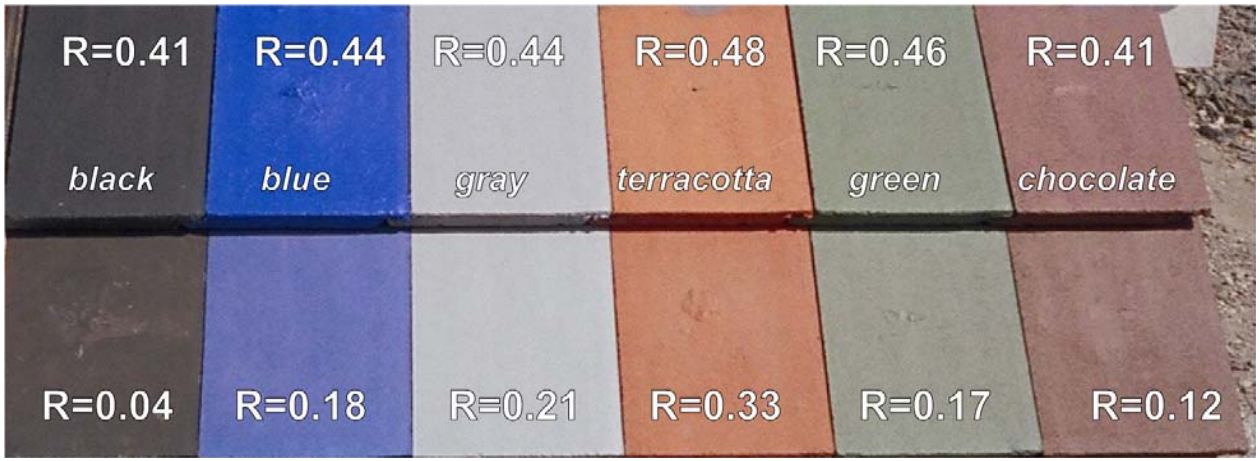
pitched, cool & colored

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)

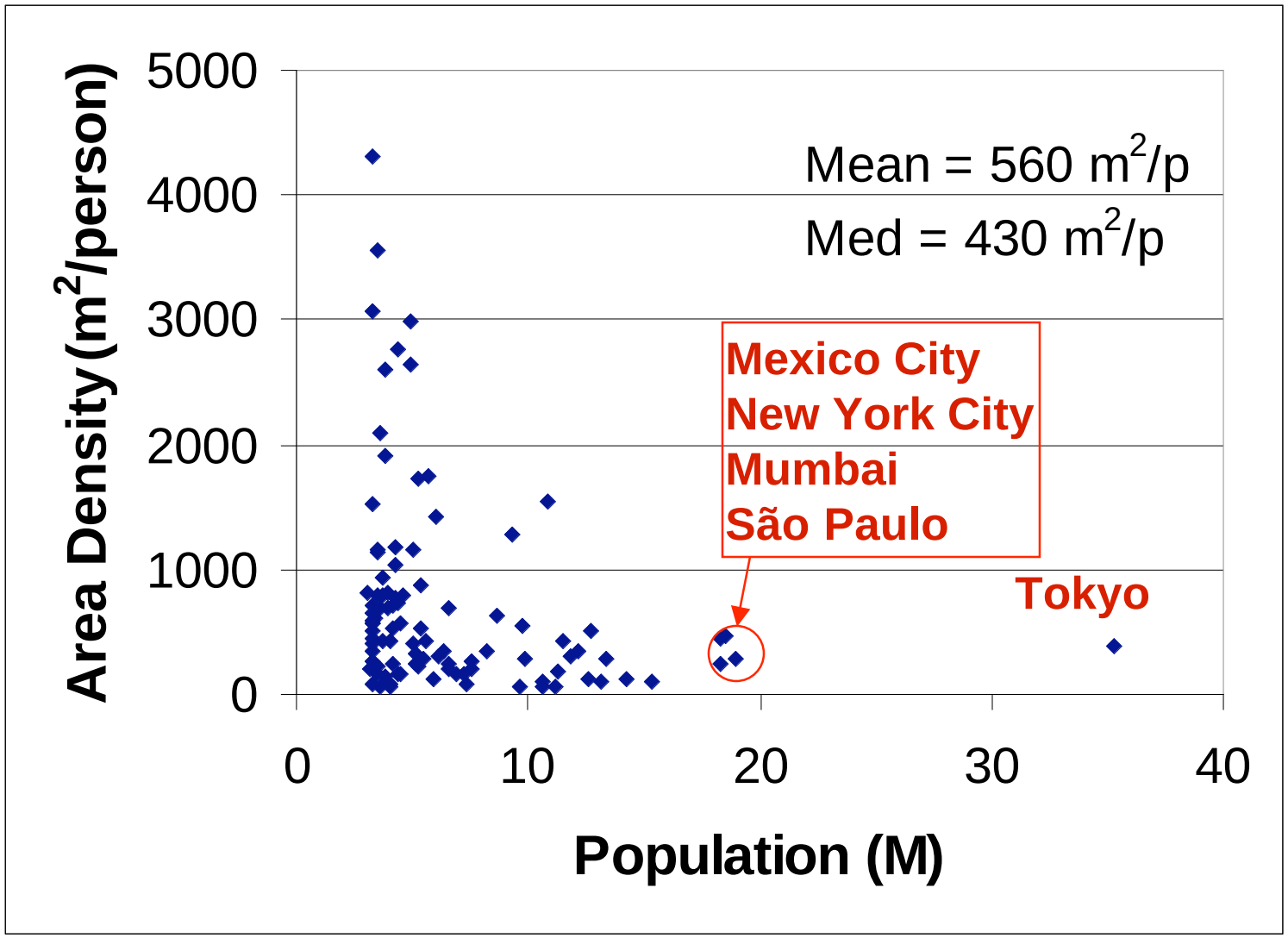
From Cool Color Roofs to Cool Color Cars

- **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.

100 Largest Cities have 670 M People

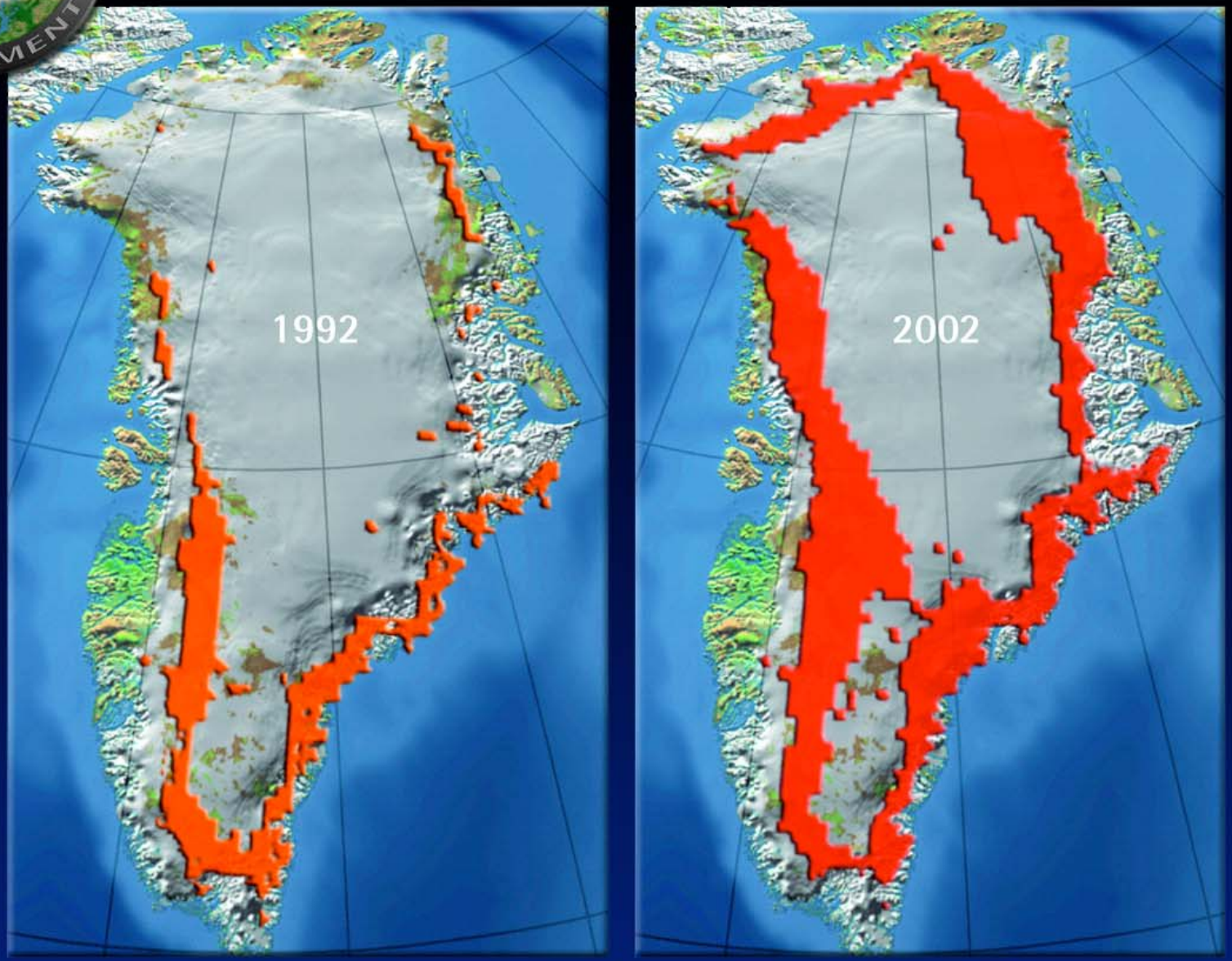


Dense Urban Areas are 1% of Land

- 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



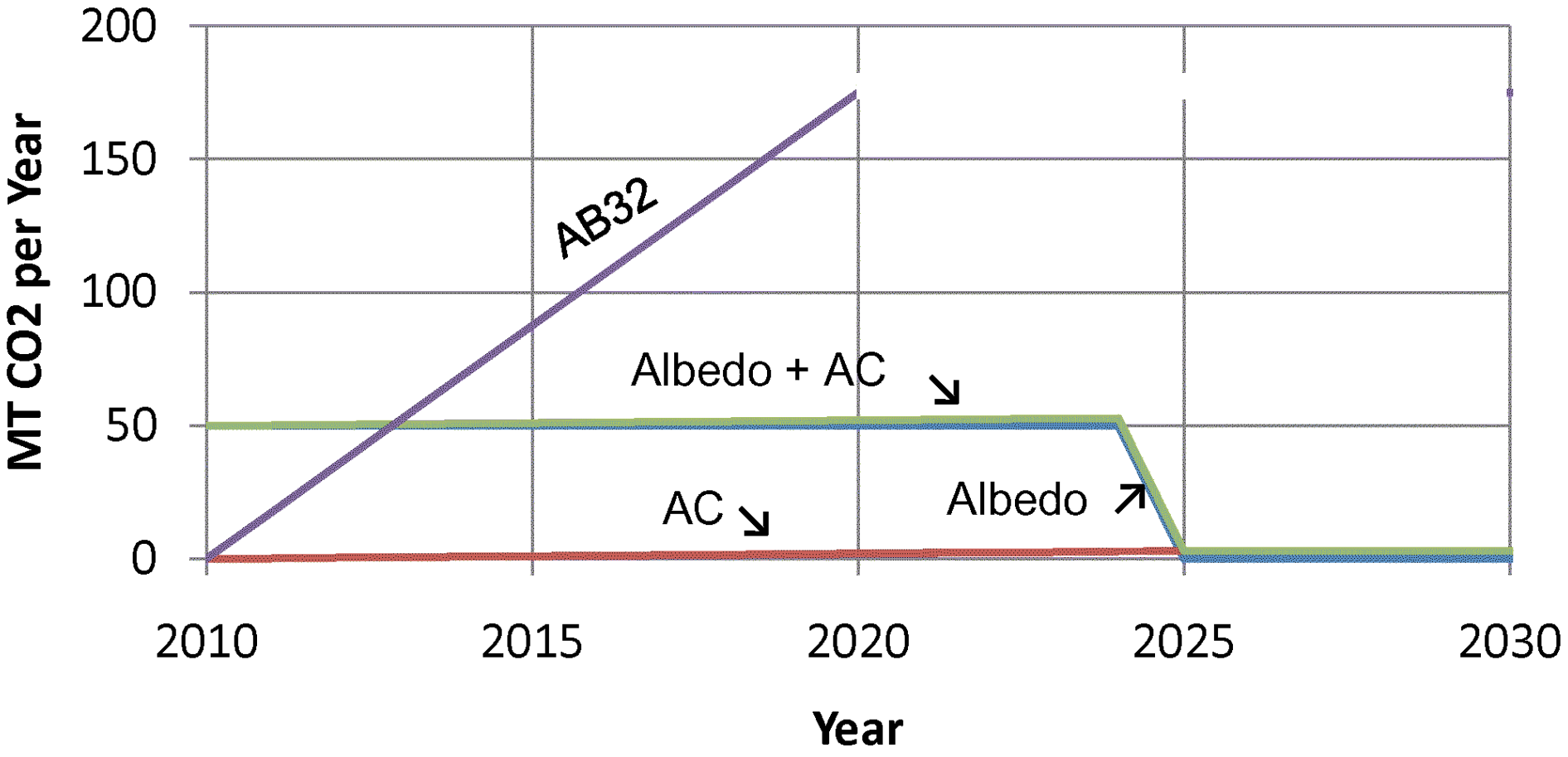
Cooler cities as a mirror

- 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?*

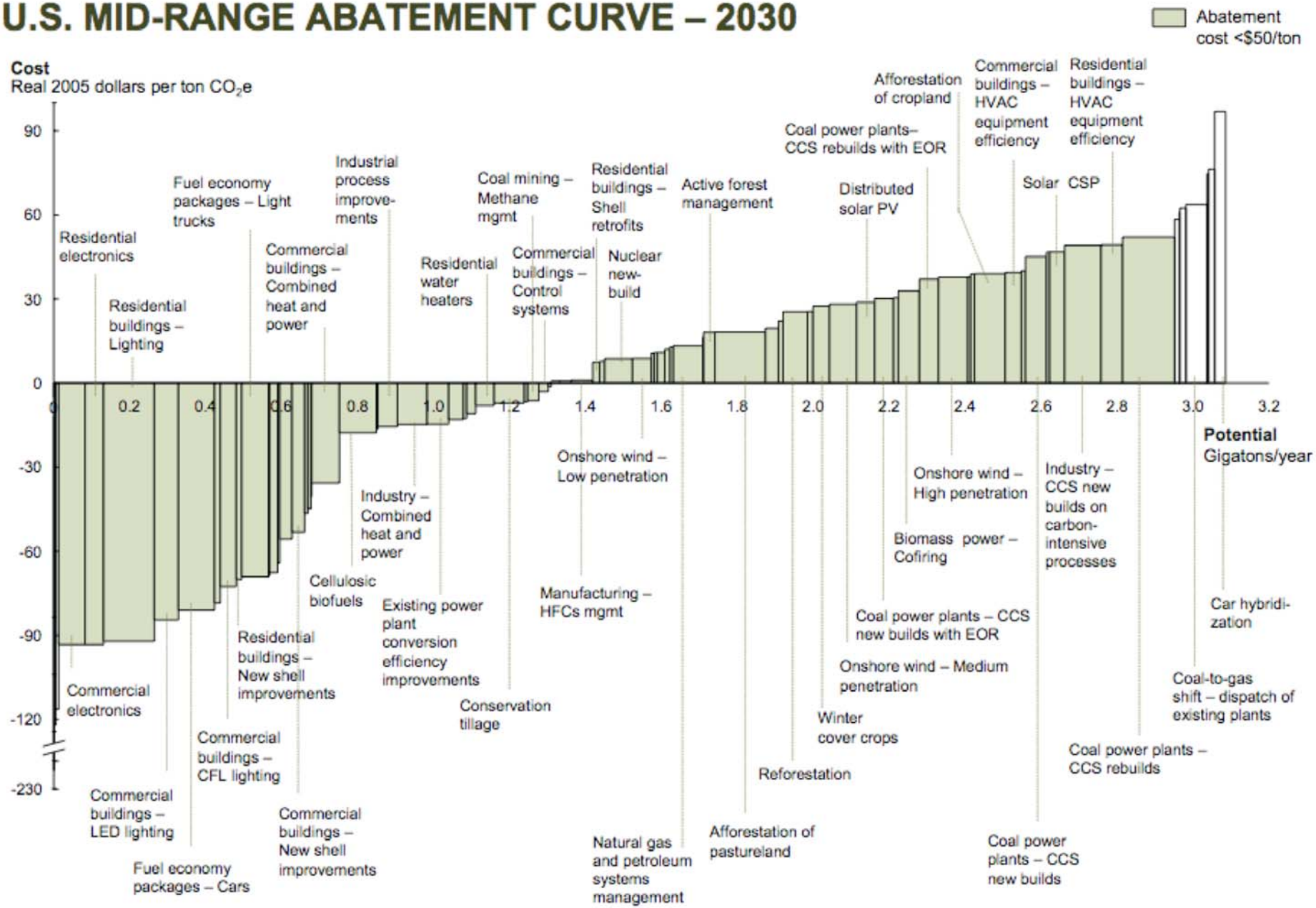
US Greenhouse Gas Abatement Mapping Initiative

December 12, 2007

McKinsey&Company

Exhibit B

U.S. MID-RANGE ABATEMENT CURVE – 2030

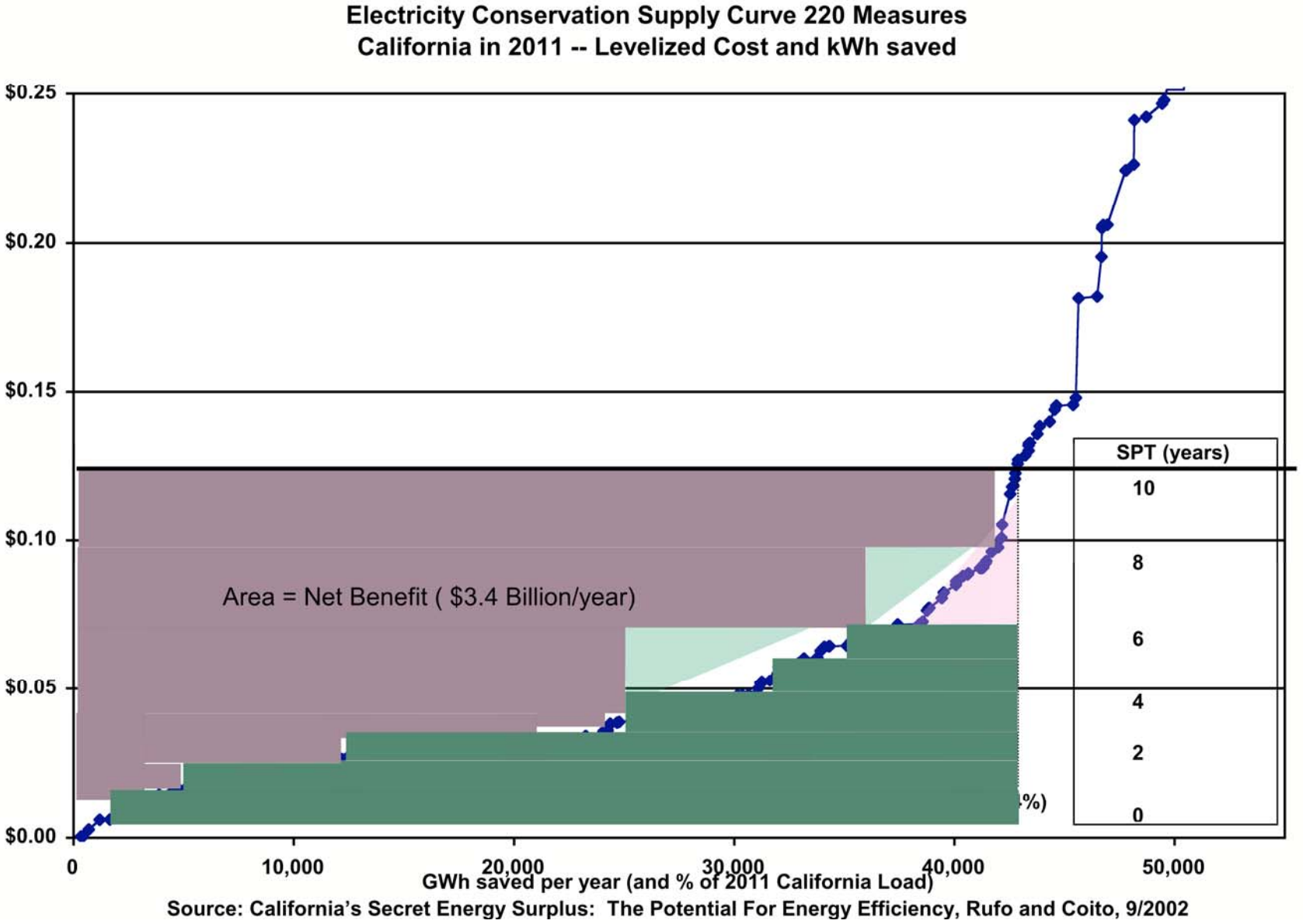


Source: McKinsey analysis

McKinsey CO2 Abatement Curves

- McKinsey provides the first graph we've seen that offers a balanced graphical comparison of
  - Efficiency as a negative cost or profitable investment
  - Renewables as costing > 0
- Two properties of these Supply Curves
  1. The shaded areas are proportional to annualized savings or costs -- the graph shows that efficiency (area below x-axis) saves about $50 Billion per year and nearly pays for the renewables (area above x-axis)

     The ratio is about 40:60
  2. The Simple Payback Time (SPT) can be estimated directly from the graph, if we know the service life of the investment


Electricity Conservation Supply Curve 220 Measures
California in 2011 -- Levelized Cost and kWh saved
$0.25
$0.20
$0.15
$0.10
$0.05
$0.00
Area = Net Benefit ($3.4 Billion/year)
SPT (years)
10
8
6
4
2
0
%)
0
10,000
20,000
30,000
40,000
50,000
GWh saved per year (and % of 2011 California Load)
Source: California's Secret Energy Surplus: The Potential For Energy Efficiency, Rufo and Coito, 9/2002

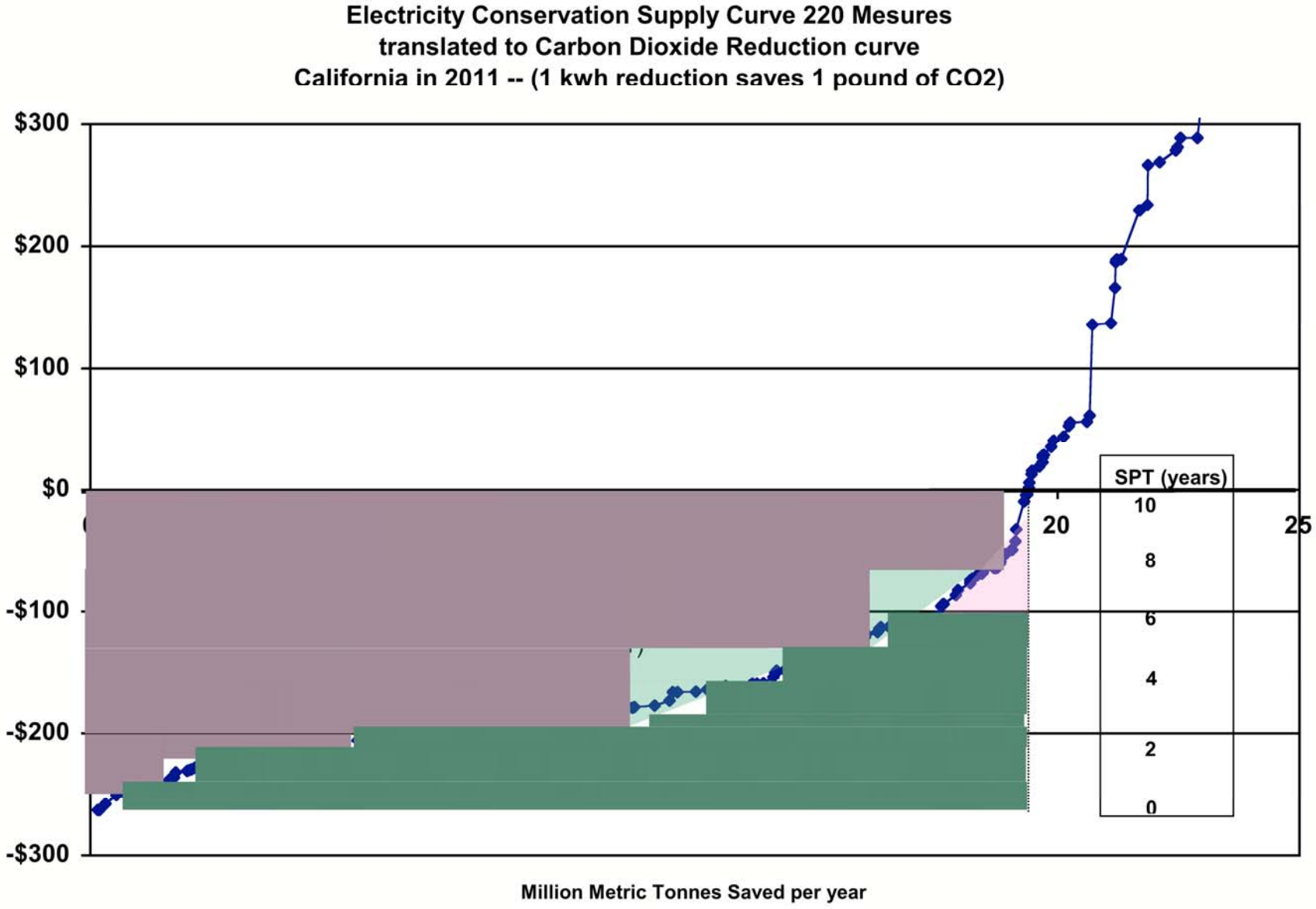
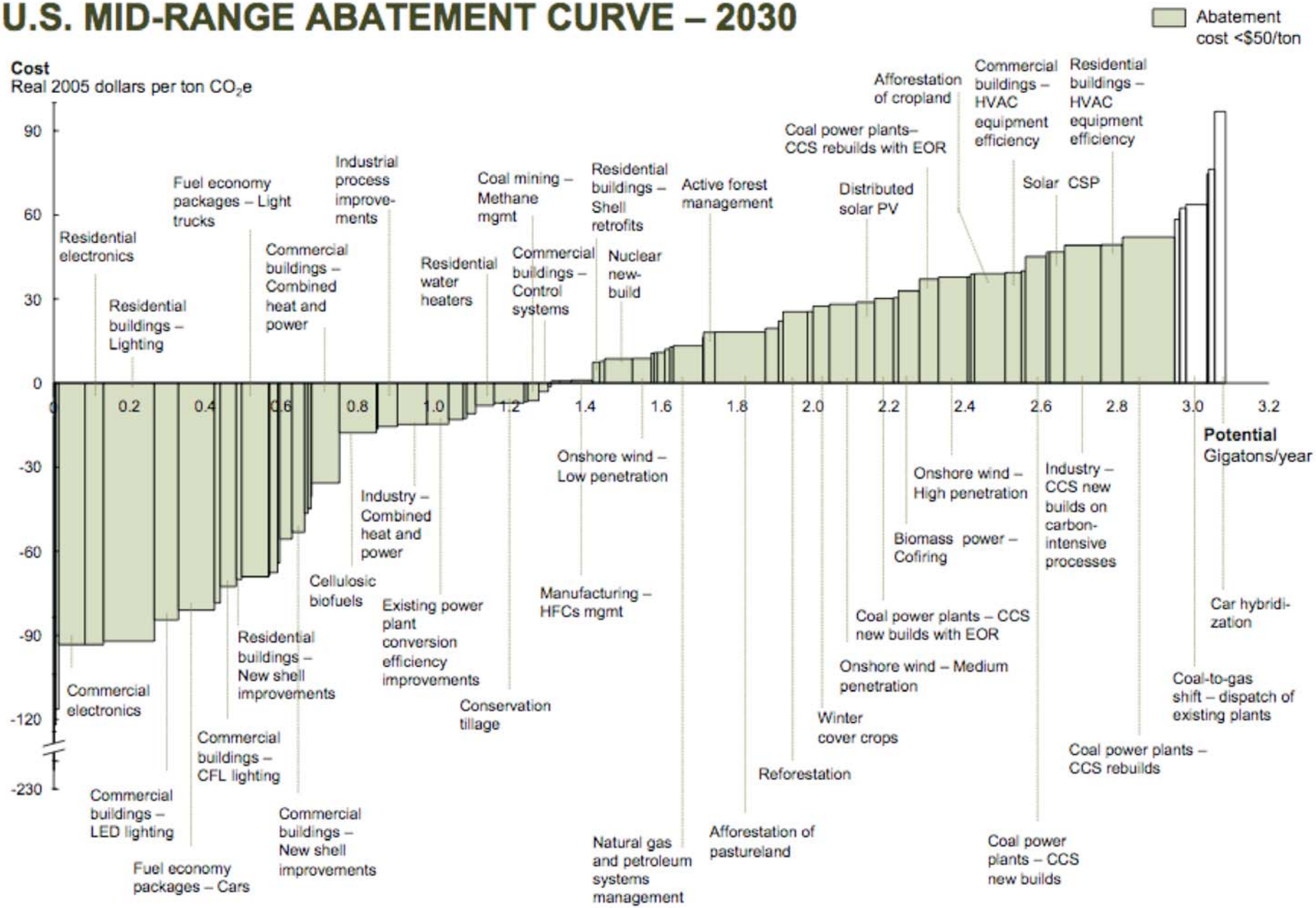

Electricity Conservation Supply Curve 220 Mesures
translated to Carbon Dioxide Reduction curve
California in 2011 -- (1 kwh reduction saves 1 pound of CO2)
$300
$200
$100
$0
-$100
-$200
-$300
20
25
SPT (years)
10
8
6
4
2
0
Million Metric Tonnes Saved per year

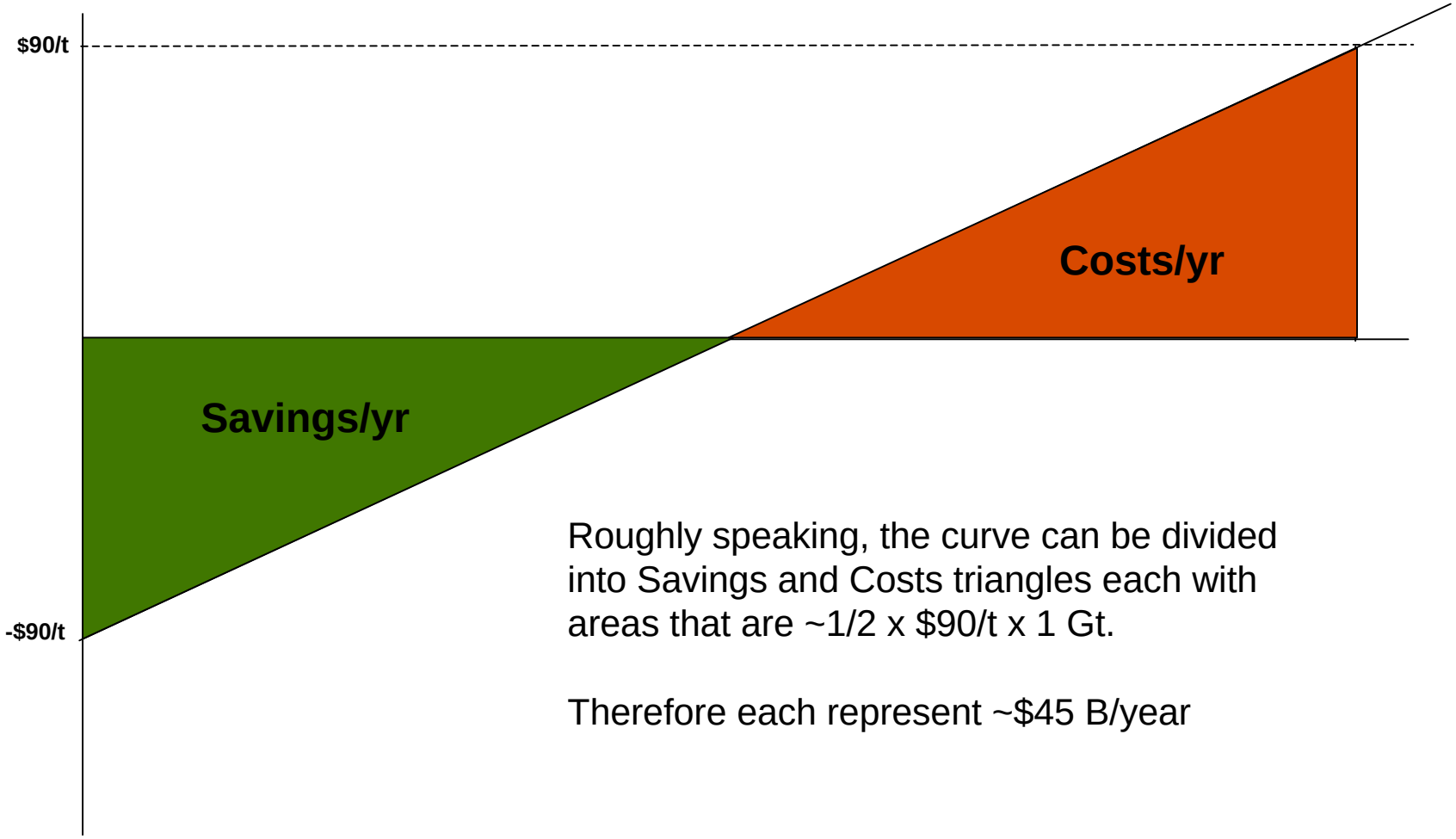
Exhibit B

U.S. MID-RANGE ABATEMENT CURVE – 2030



Source: McKinsey analysis

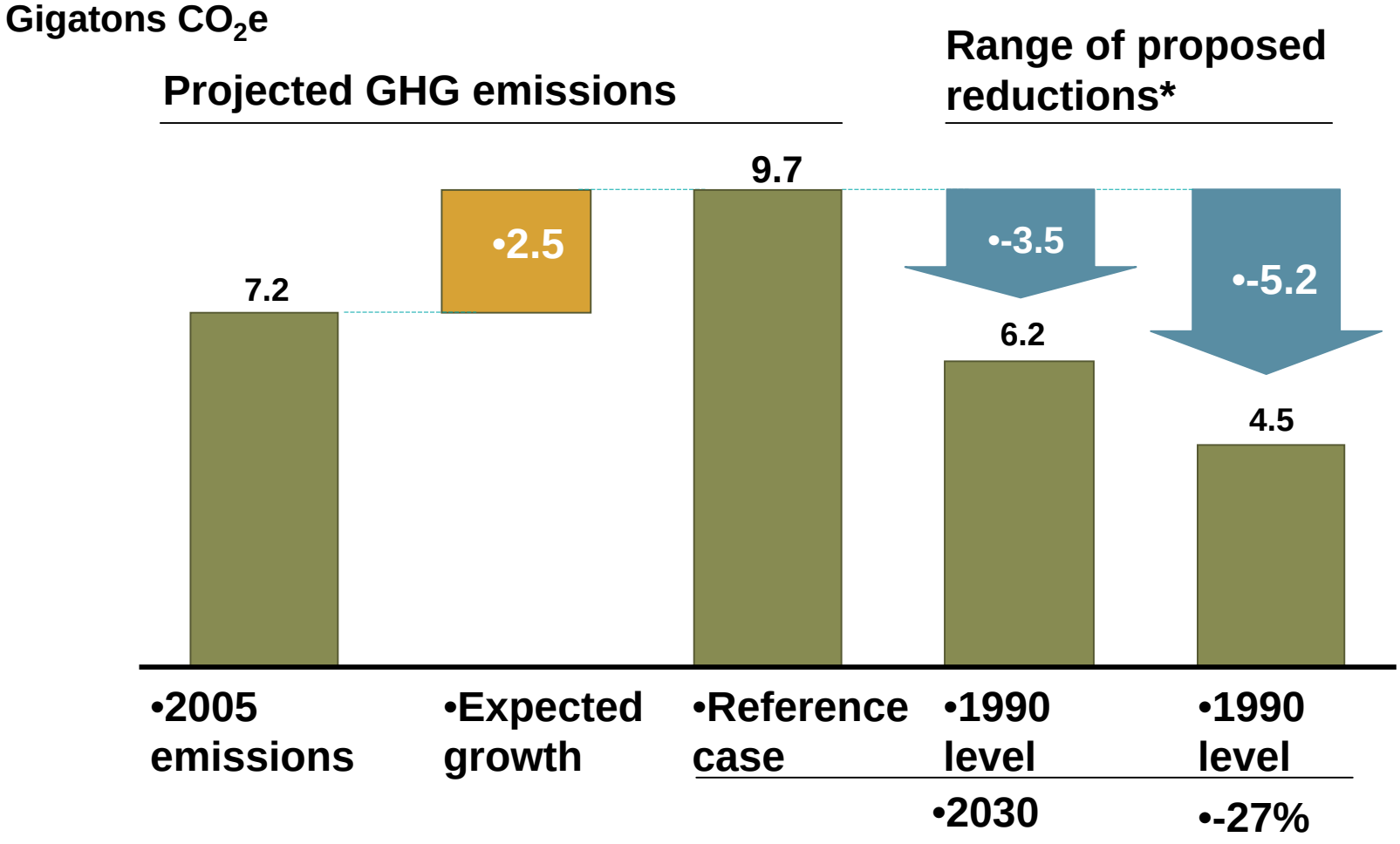
"Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?" McKinsey&Company, 2007



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.

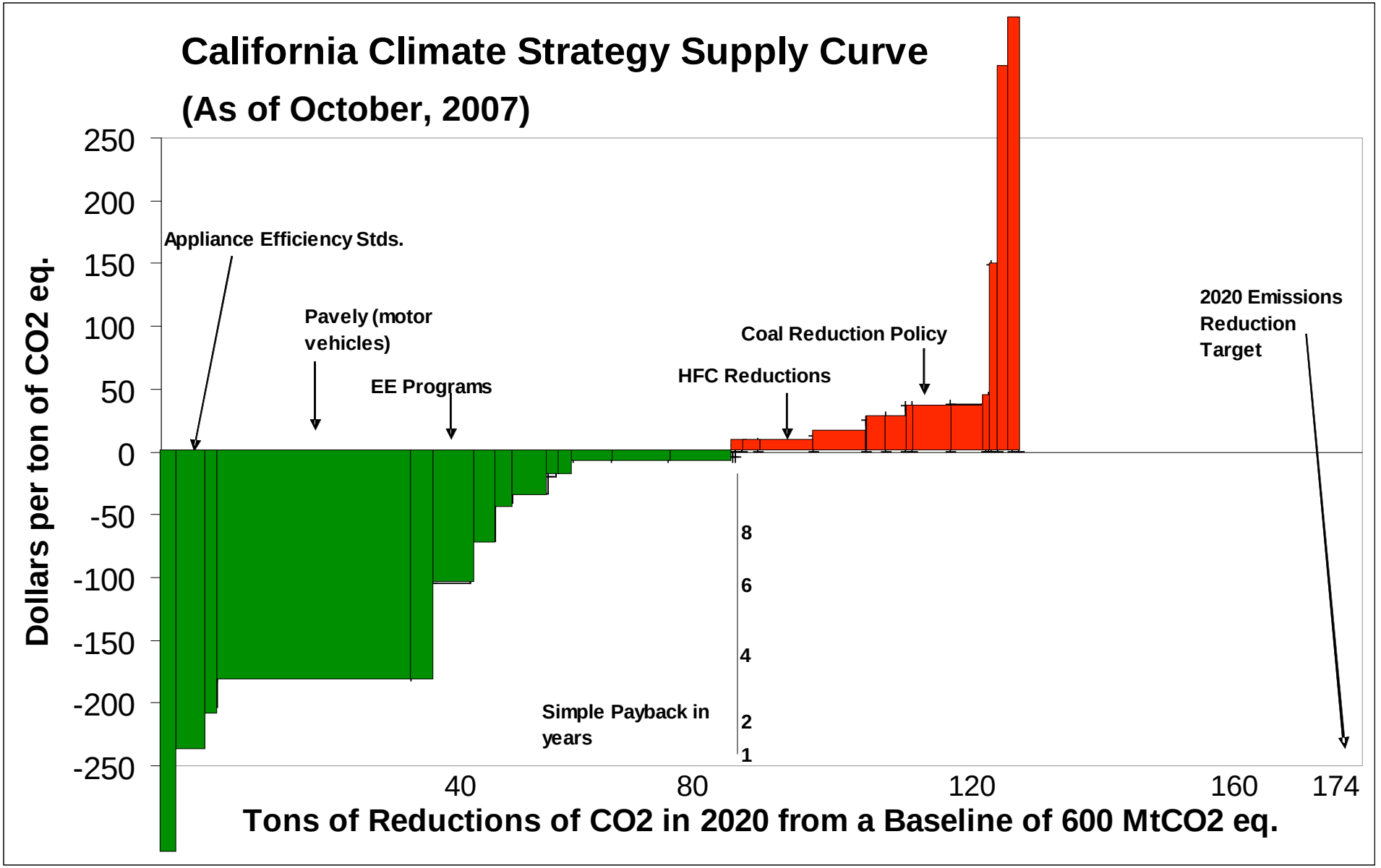
Therefore each represent ~$45 B/year

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]