International Seminars, Erice
Monday August 20, 2007
Energy and Climate
Managing Climate Change

Arthur H. Rosenfeld, Commissioner
California Energy Commission
(916) 654-4930
ARosenfe@Energy.State.CA.US

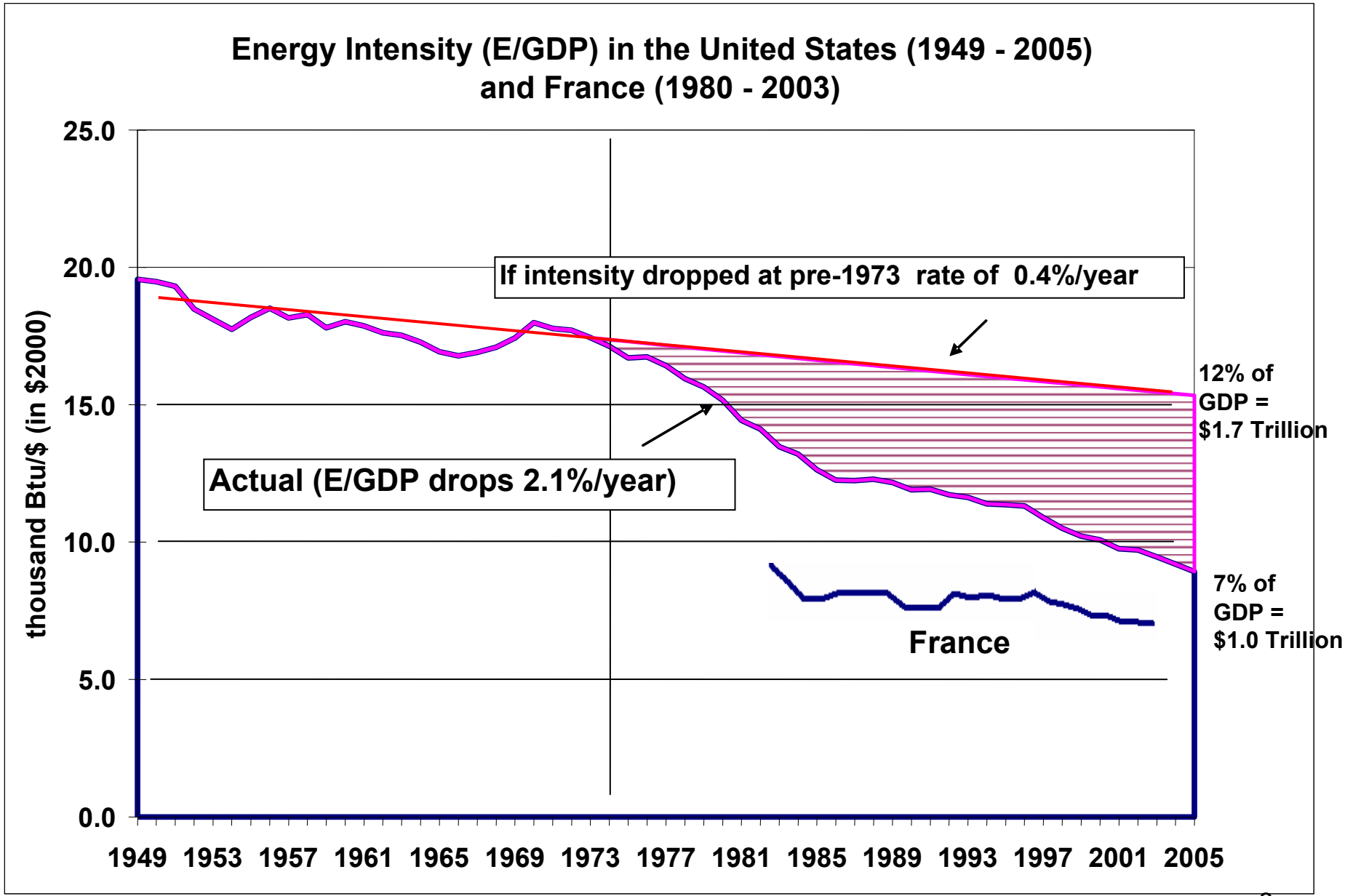
http://www.energy.ca.gov/commission/commissioners/rosenfeld.html

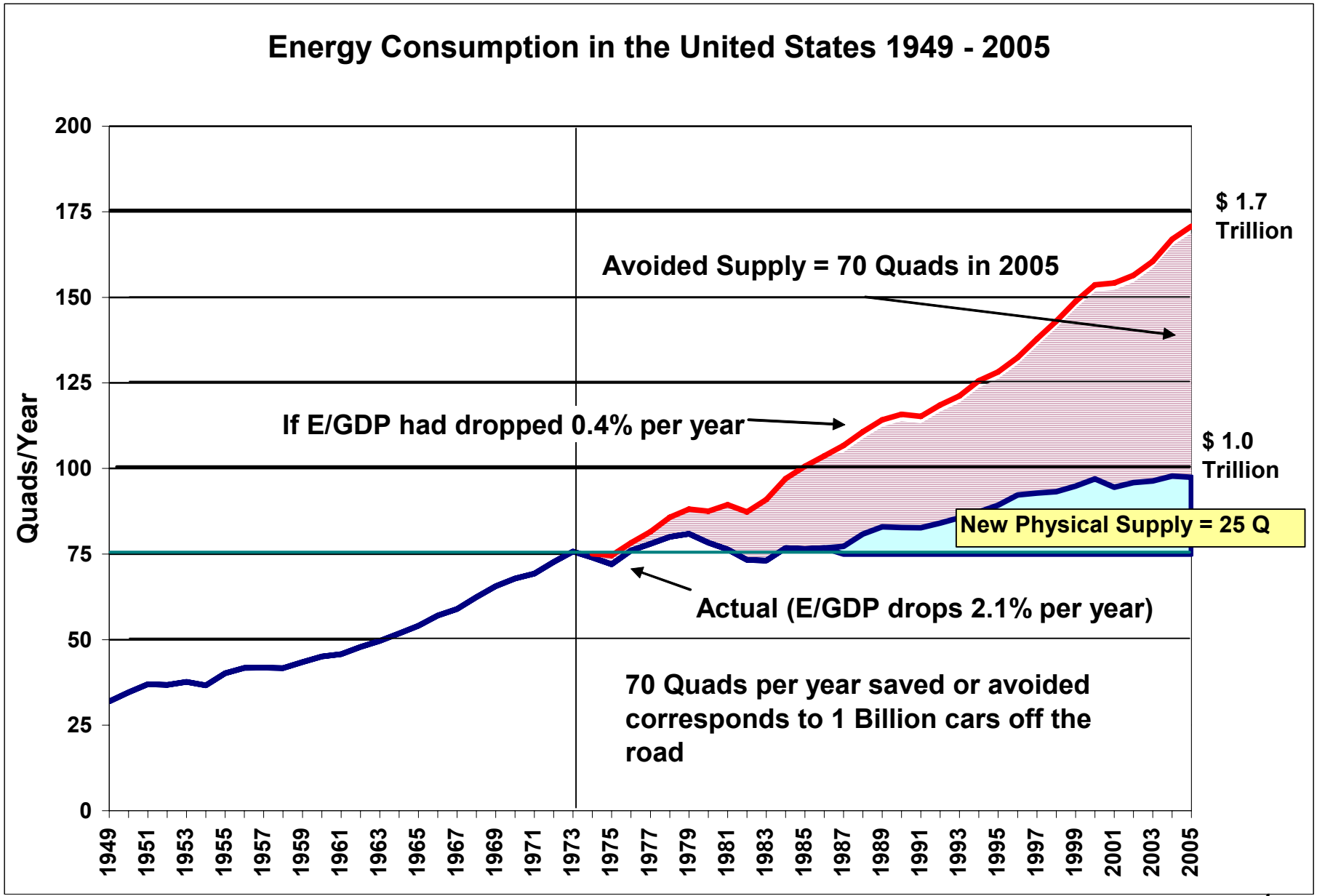
or just Google "Art Rosenfeld"

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

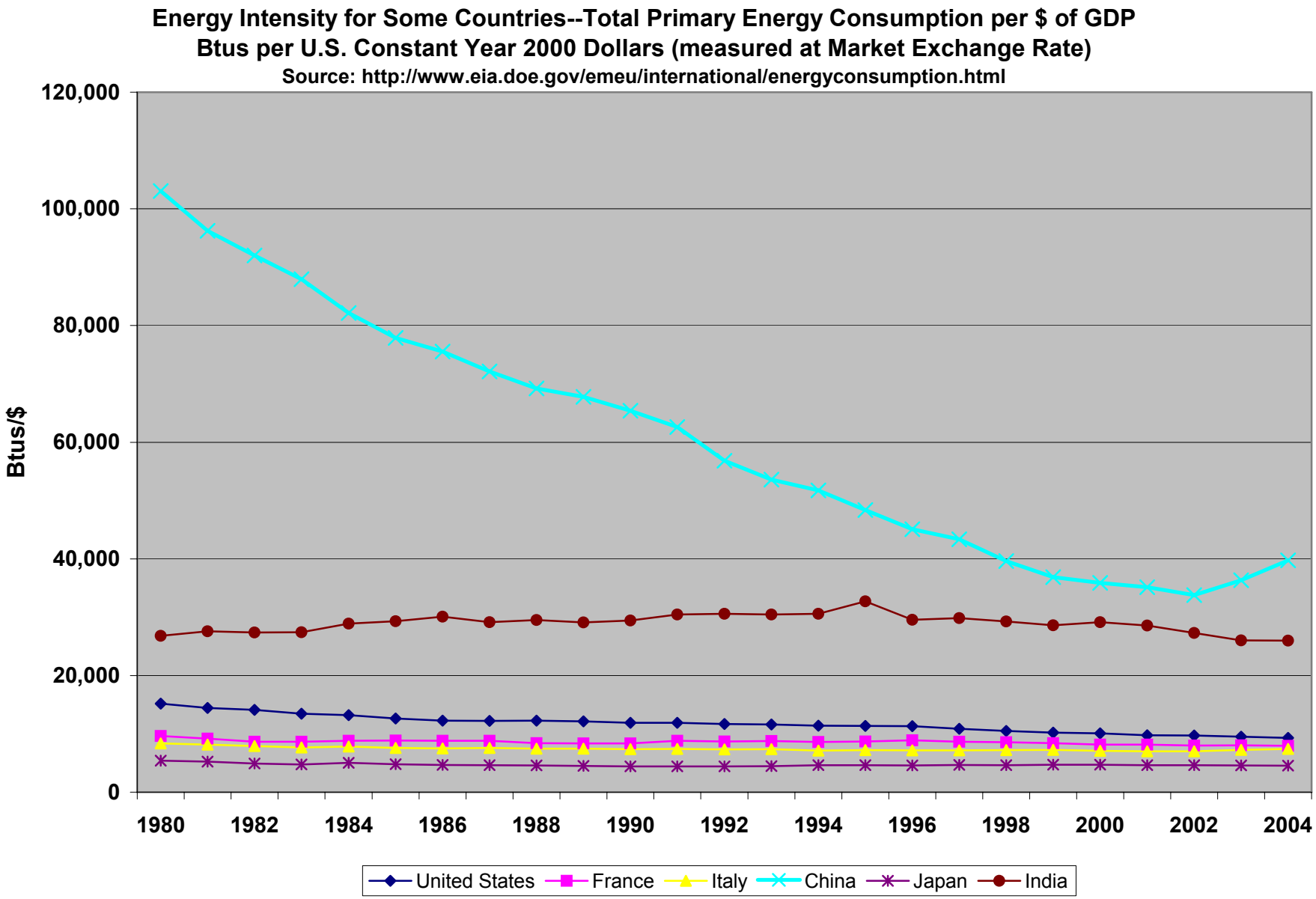

Energy Consumption in the United States 1949 - 2005
Quads/Year
200
175
150
125
100
75
50
25
0
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
$ 1.7 Trillion
Avoided Supply = 70 Quads in 2005
If E/GDP had 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

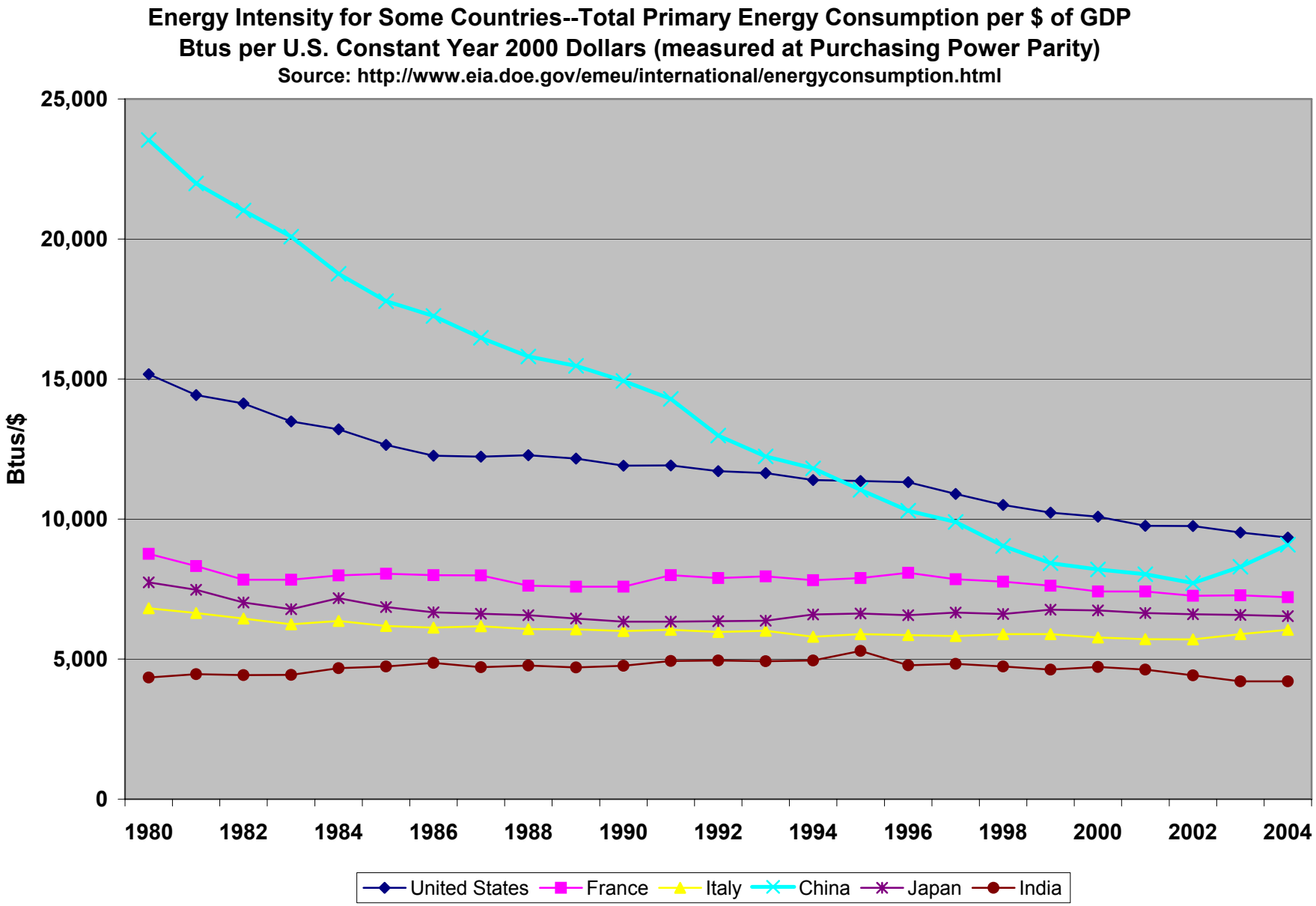
How Much of The Savings Come from Efficiency

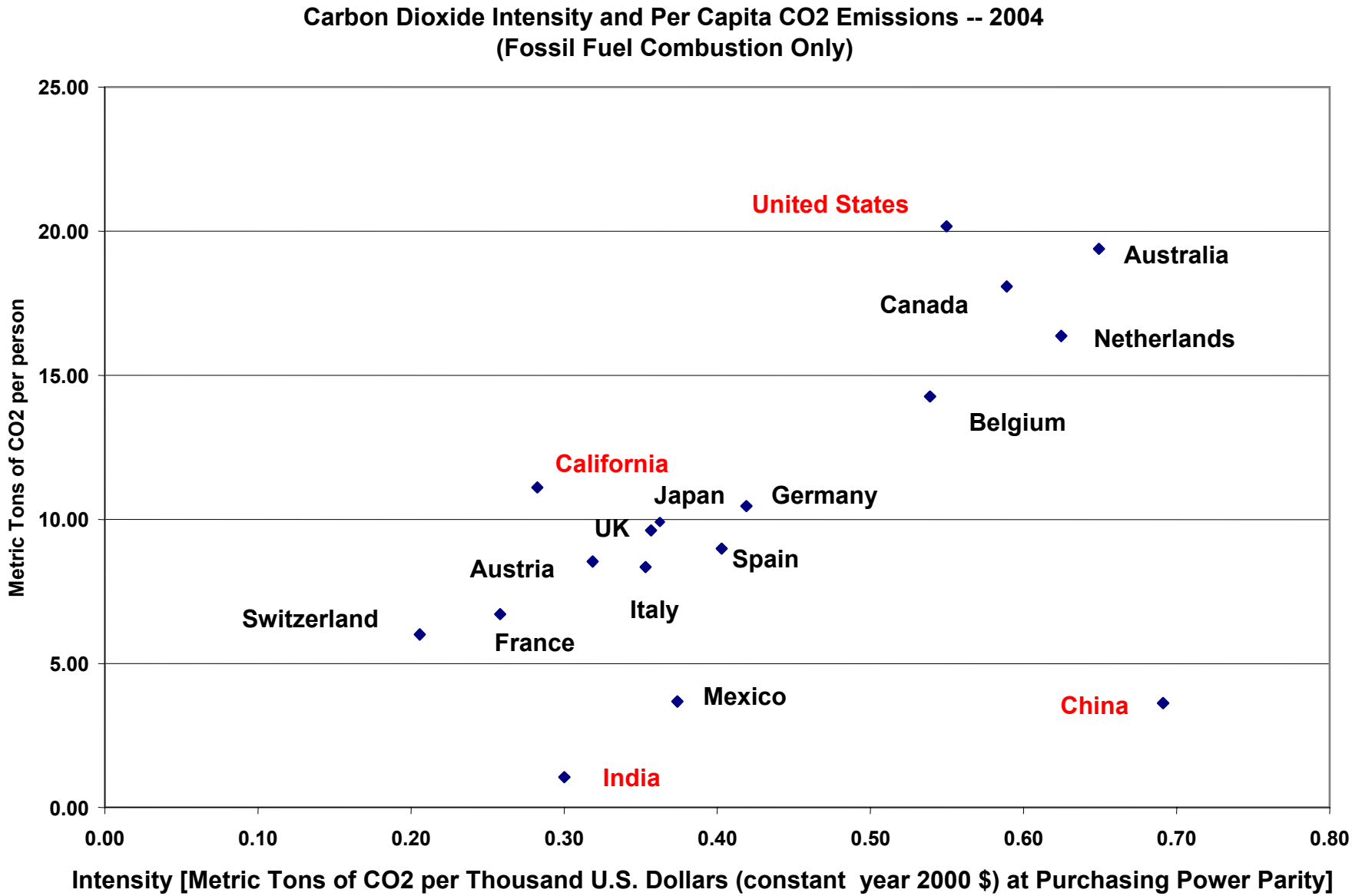
- Some examples of estimated savings in 2006 based on 1974 efficiencies minus 2006 efficiencies

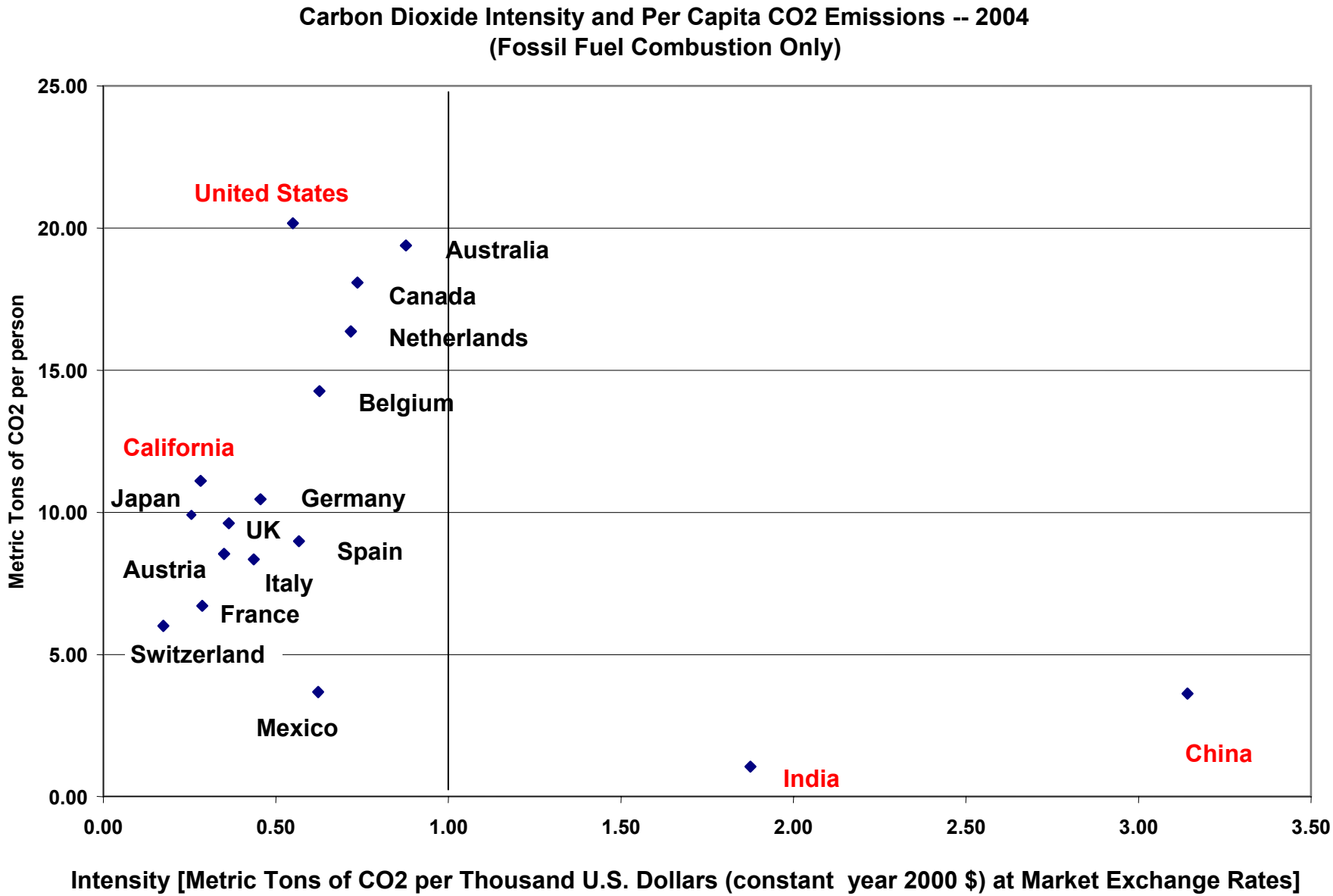
	Billion $
Space Heating	**40**
Air Conditioning	**30**
Refrigerators	**15**
Fluorescent Tube Lamps	**5**
Compact Floursecent Lamps	**5**
Total	**95**

- 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.


Energy Intensity for Some Countries--Total Primary Energy Consumption per $ of GDP
Btus per U.S. Constant Year 2000 Dollars (measured at Market Exchange Rate)
Source: http://www.eia.doe.gov/emeu/international/energyconsumption.html
Btus/$
120,000
100,000
80,000
60,000
40,000
20,000
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
United States
France
Italy
China
Japan
India


Energy Intensity for Some Countries--Total Primary Energy Consumption per $ of GDP
Btus per U.S. Constant Year 2000 Dollars (measured at Purchasing Power Parity)
Source: http://www.eia.doe.gov/emeu/international/energyconsumption.html
Btus/$
25,000
20,000
15,000
10,000
5,000
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
United States
France
Italy
China
Japan
India


Carbon Dioxide Intensity and Per Capita CO2 Emissions -- 2004
(Fossil Fuel Combustion Only)
Metric Tons of CO2 per person
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
Intensity [Metric Tons of CO2 per Thousand U.S. Dollars (constant year 2000 $) at Purchasing Power Parity]
United States
Australia
Canada
Netherlands
Belgium
California
Japan
Germany
UK
Spain
Austria
Italy
Switzerland
France
Mexico
China
India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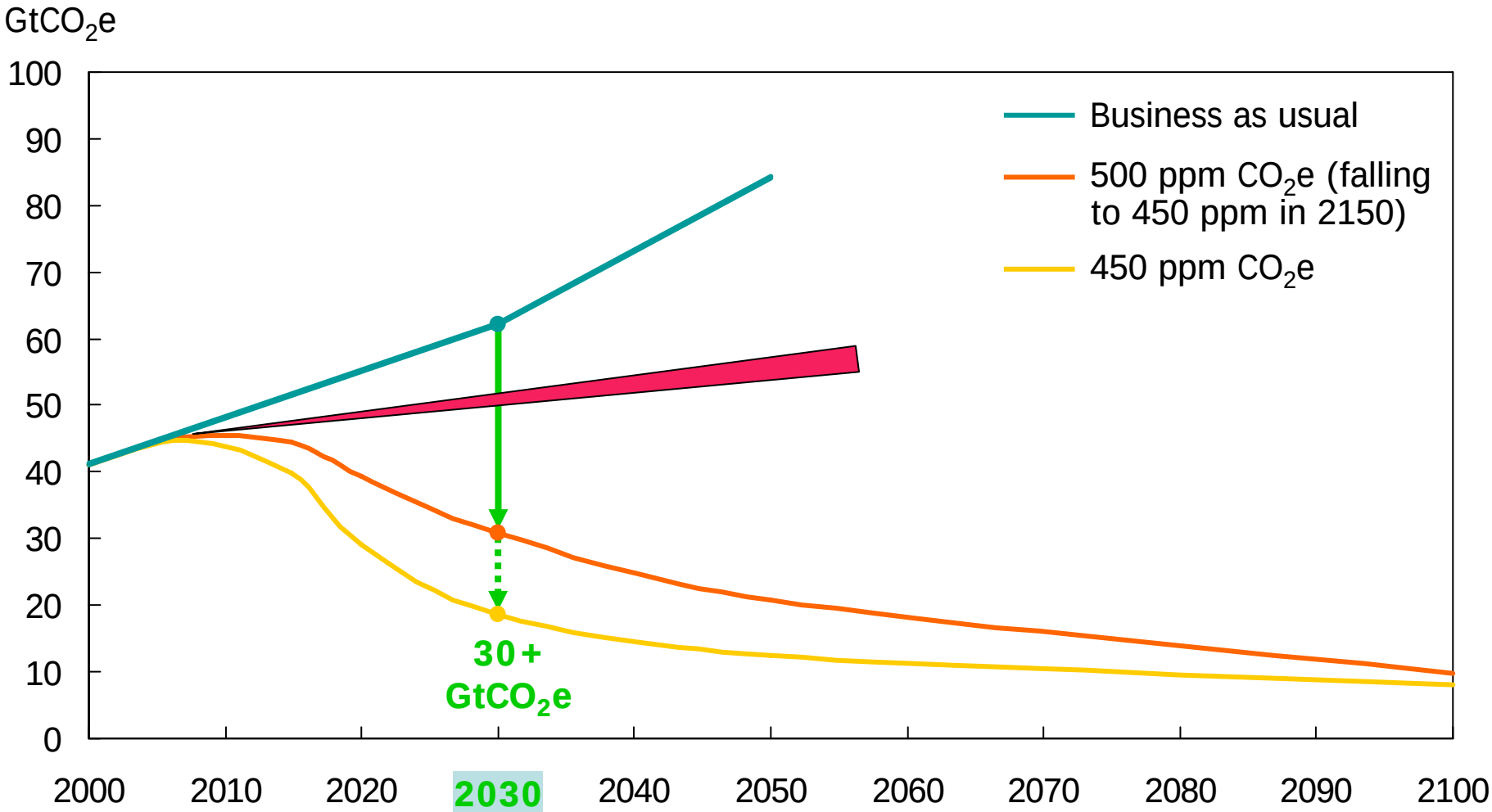
(Fossil Fuel Combustion Only)
Metric Tons of CO2 per person
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
3.50
United States
Australia
Canada
Netherlands
Belgium
California
Japan
Germany
UK
Spain
Austria
Italy
France
Switzerland
Mexico
India
China
Intensity [Metric Tons of CO2 per Thousand U.S. Dollars (constant year 2000 $) at Market Exchange Rates]

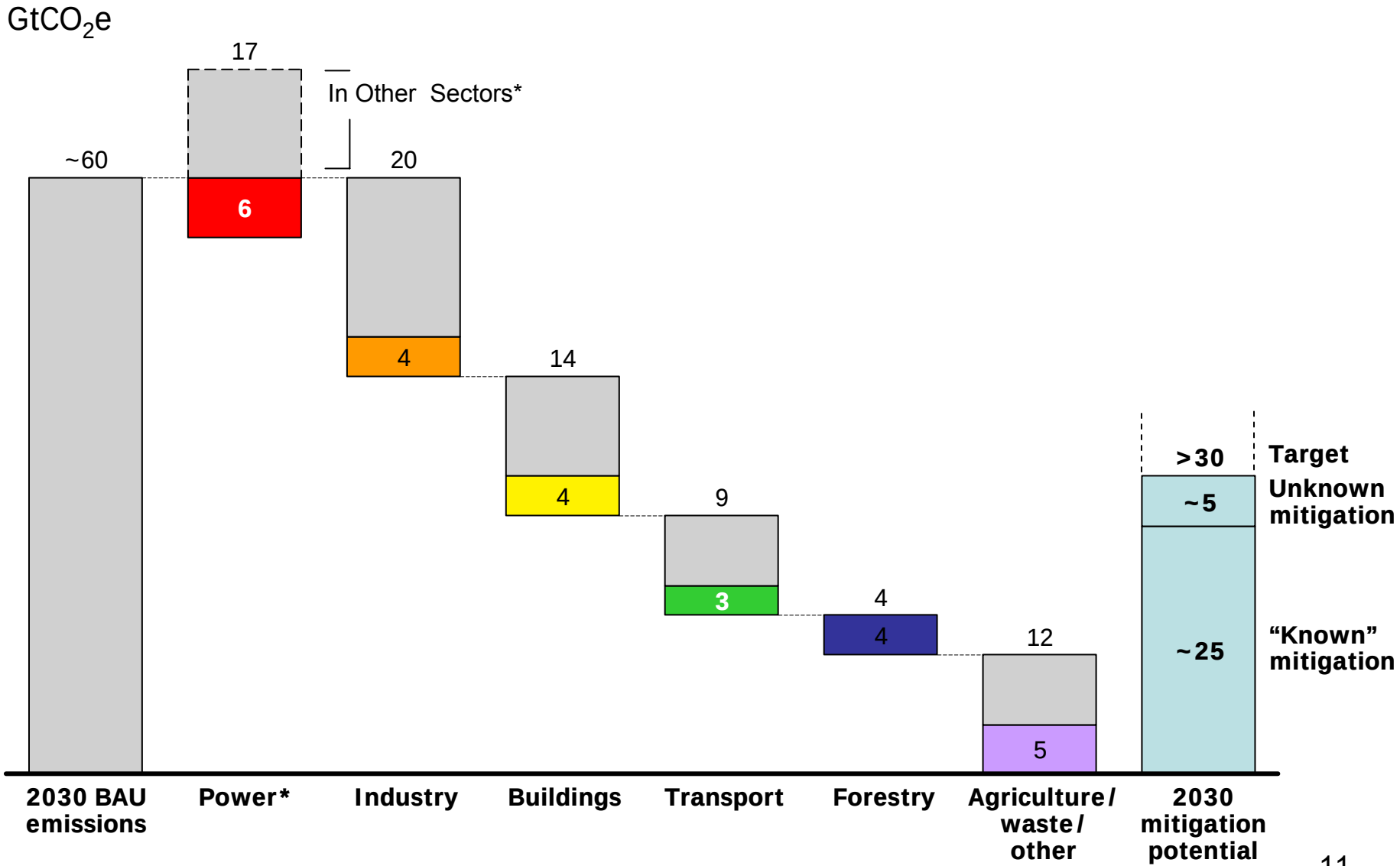
To maintain 50/50 chance of staying below 2°C implies stabilizing <450ppm $GtCO_2e$ (*at least* 30 Gt reduction by 2030)

Possible emission trajectories 2000-2100 of global Emissions: from Hal Harvey, Hewlett Foundation, **adapted from Stern Review (next 8 slides)**



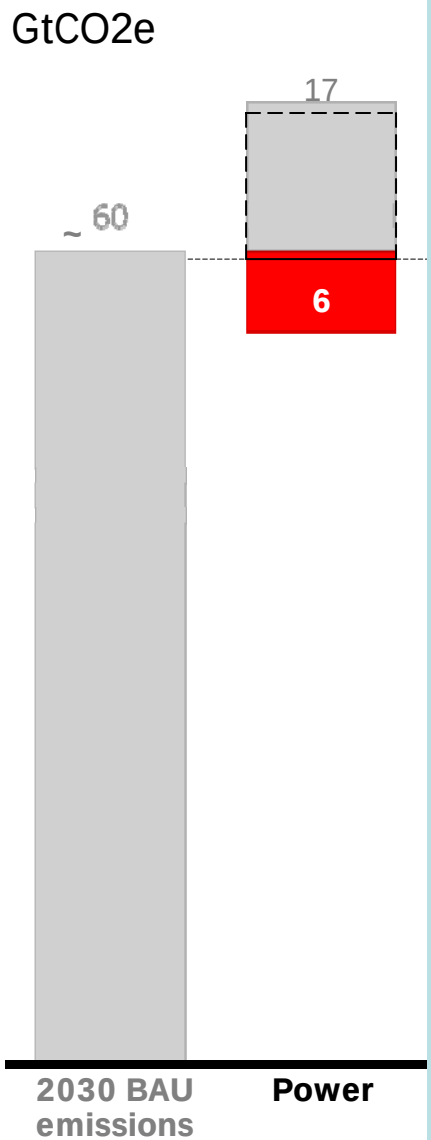
Source: Adapted from Stern Review, 2006; BAU emissions ~WEO A2 scenario; 450 ppm budget range based on Stern and preliminary IPCC analysis by

Available interventions in 6 sectors secure 83% of target



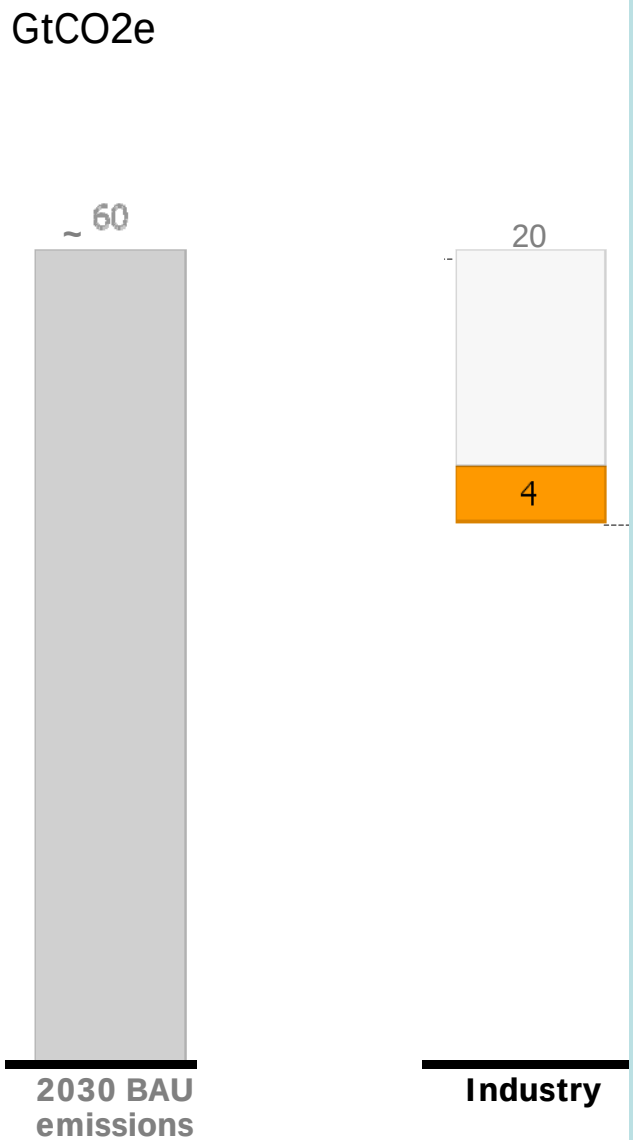
* Power sector emissions (but not mitigation potential) counted in industry and building sectors

Utilities



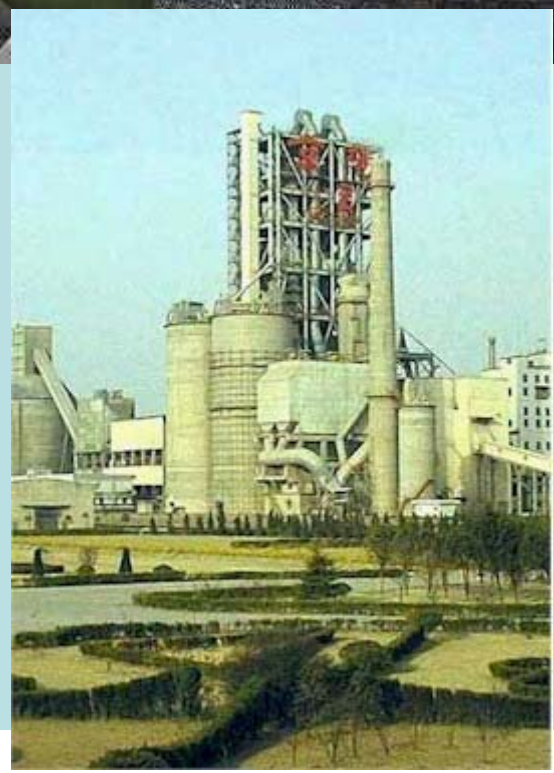
1. No New Conventional Coal
2. Carbon Capture and Sequestration
3. Renewable Portfolio Standard
4. Nuclear Power?

Industry



1. Standards for motors, other key technologies.

2. Sectoral targets.

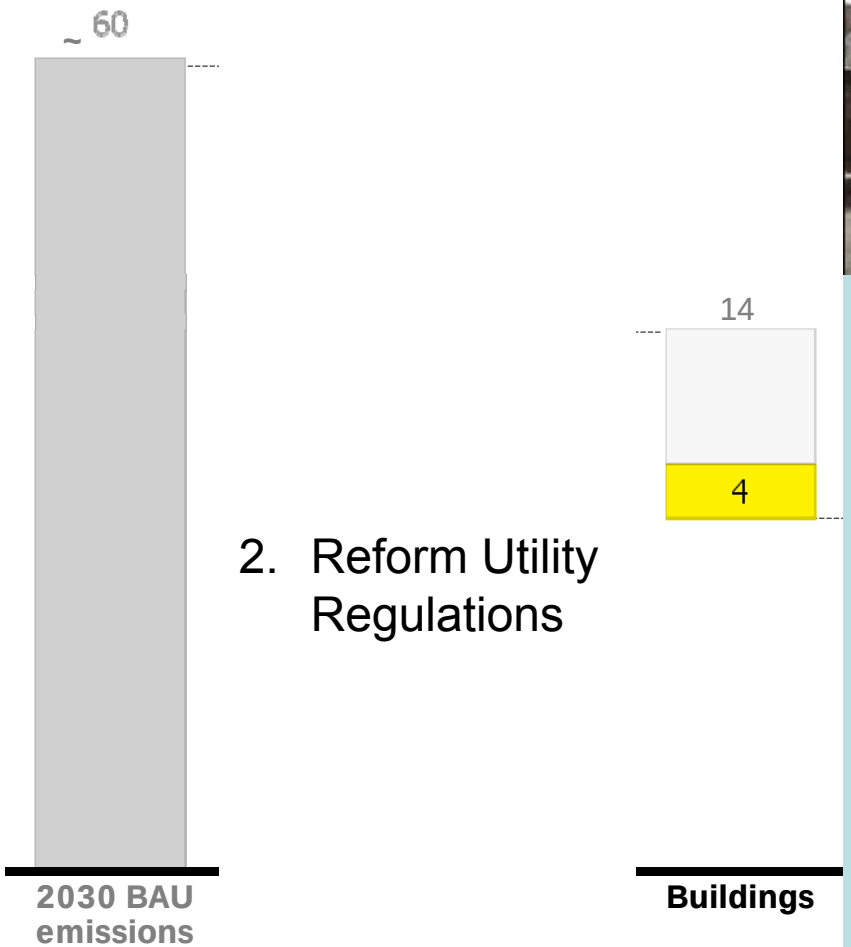


Buildings

GtCO2e

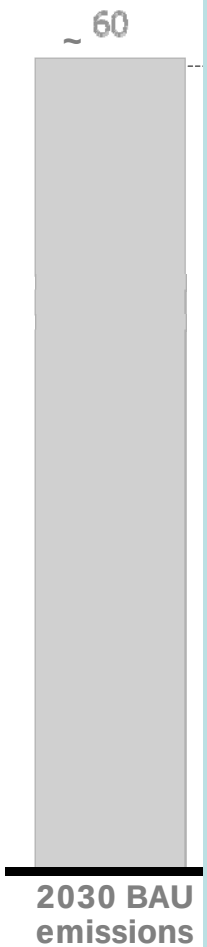
1. Strict Building Codes

2. Reform Utility Regulations

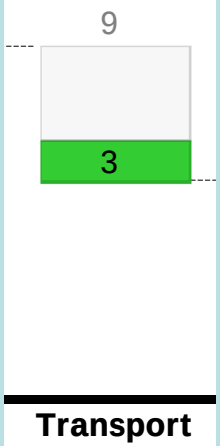


Transportation

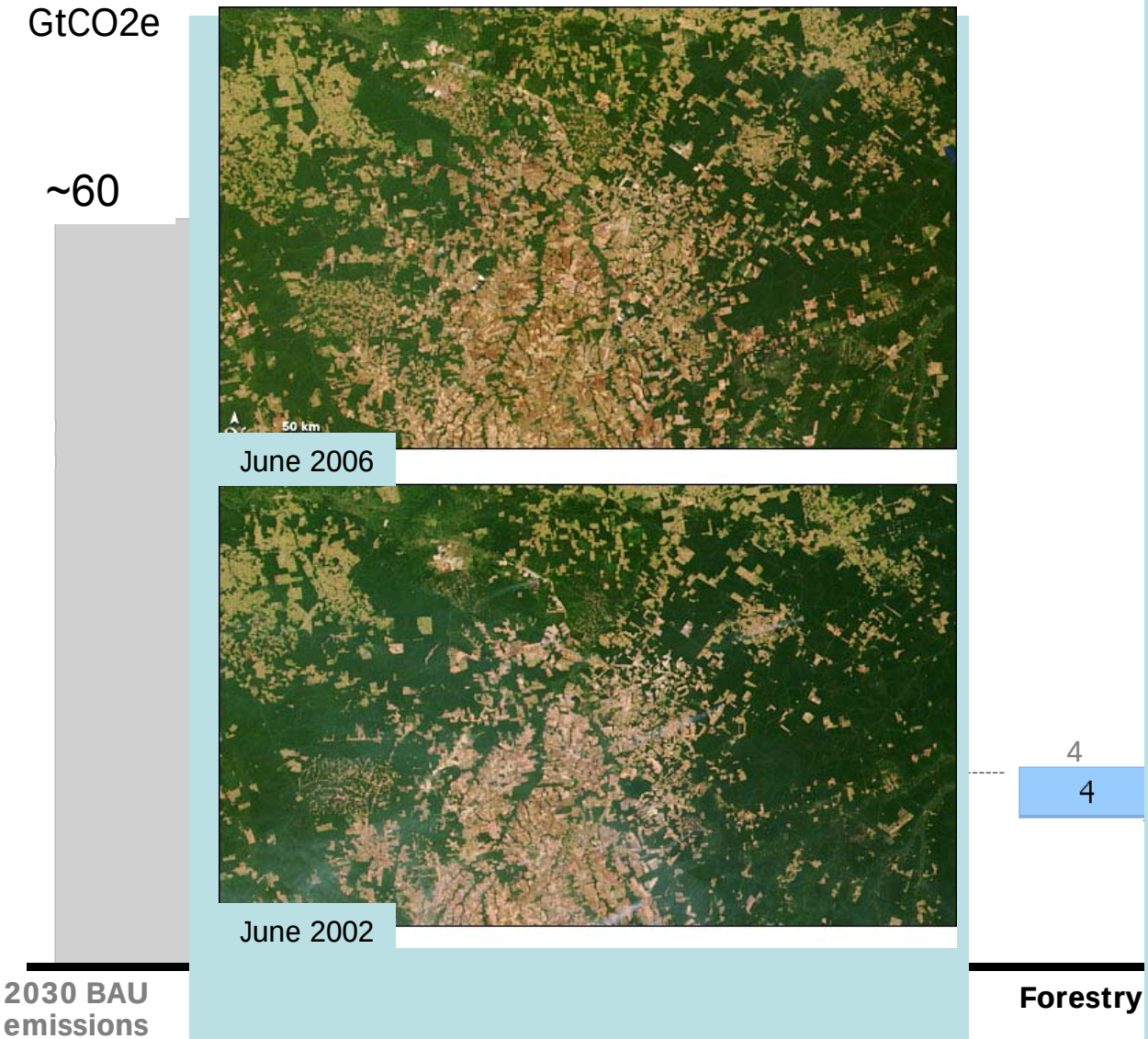
GtCO2e



1. Fuel efficient cars
2. Low carbon fuels
3. Reduced vehicle-miles traveled through e.g. congestion pricing, Bus Rapid Transit



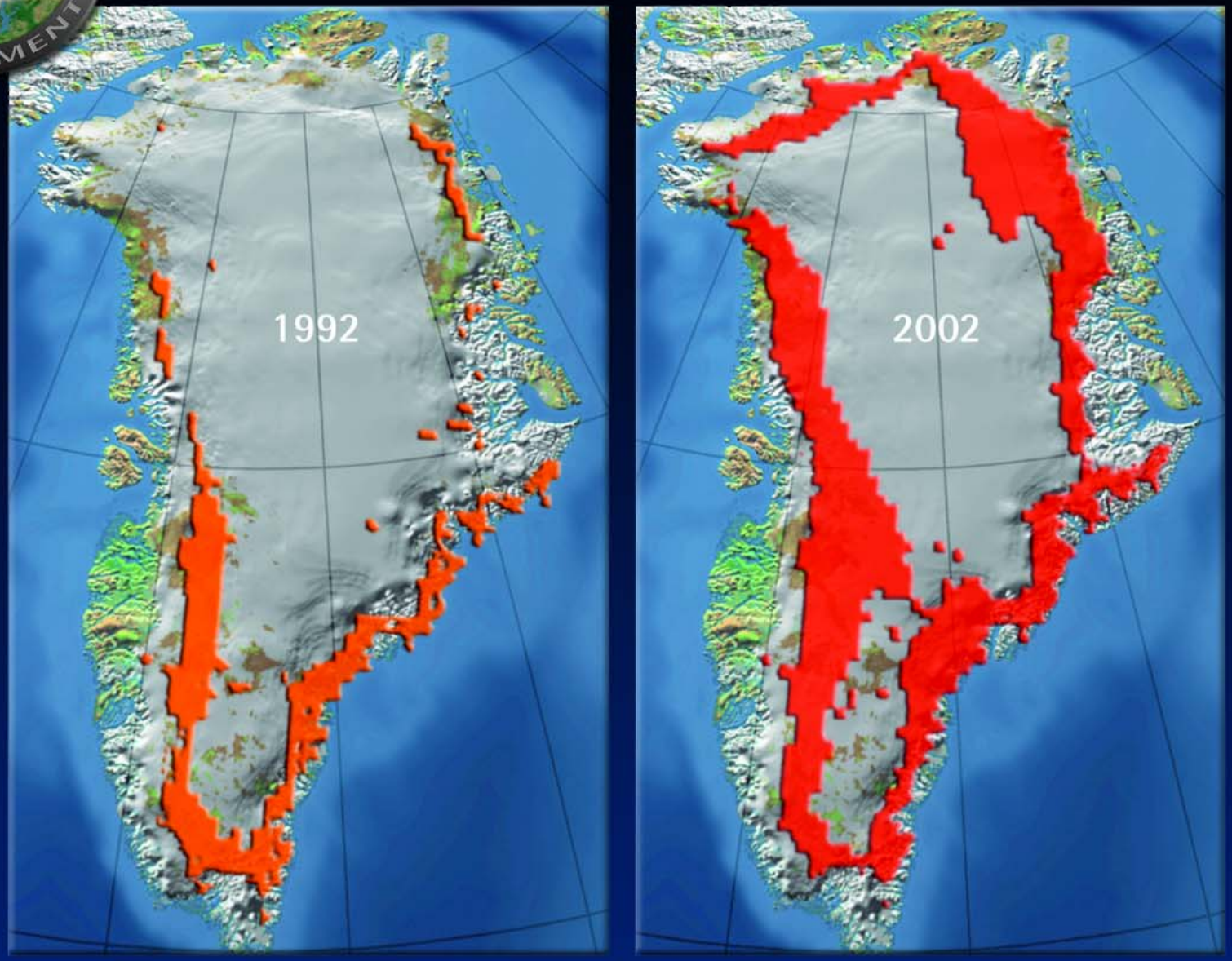
Forestry



1. Stop Deforestation in the Amazon, Congo, Indonesia.

IMPACTS OF A WARMING ARCTIC

Greenland Ice Sheet Melt Extent



McKinsey Quarterly

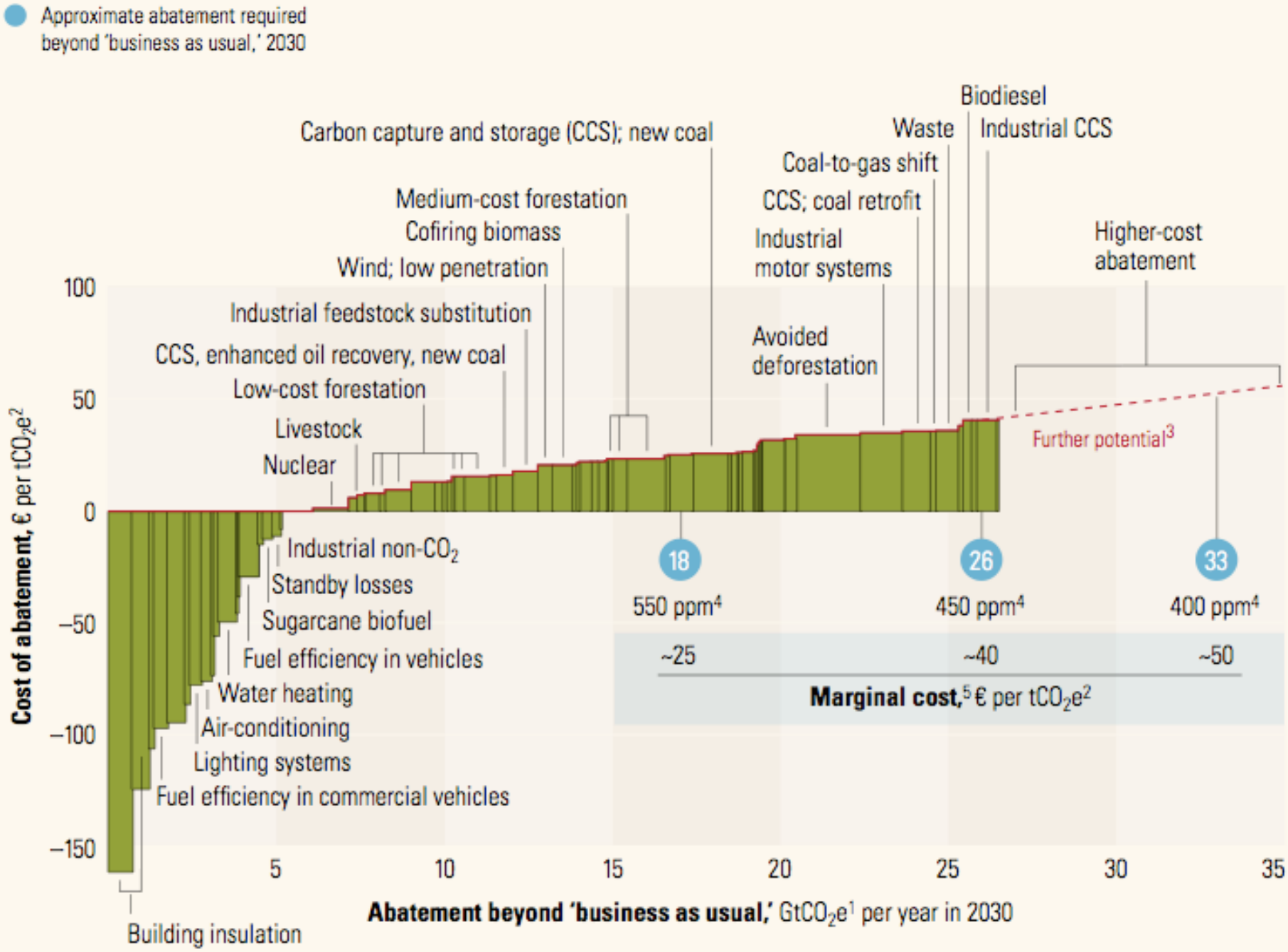
A **cost curve** for greenhouse gas reduction

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]



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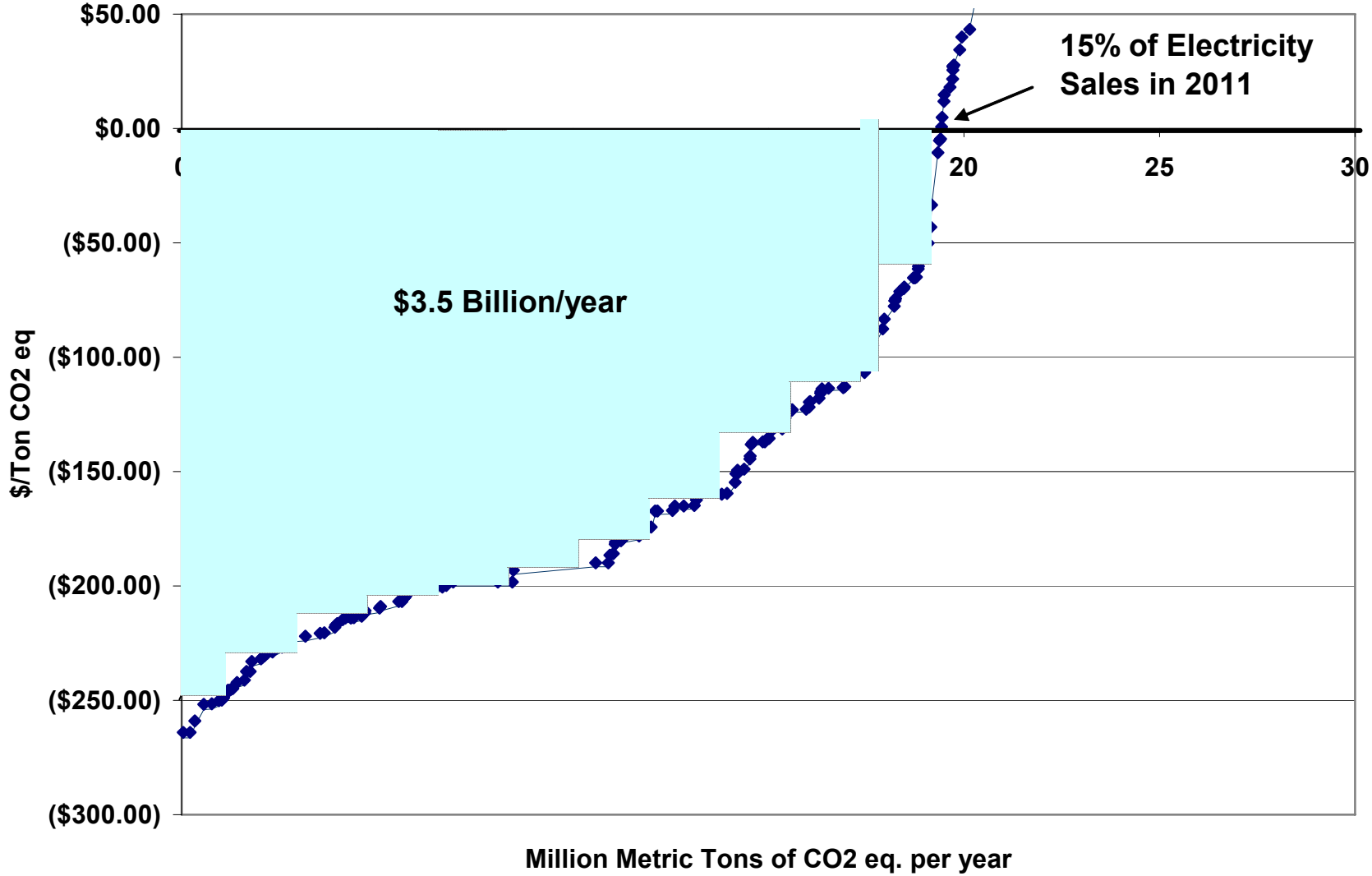
Plenary Session:

Policy and Potential for Energy Efficient Buildings

Supply Curve for CO2, Conserved thru Energy Efficiency in Electricity Sector in California - Potential in 2011 at 1 kwh = 0.454 kg of CO2



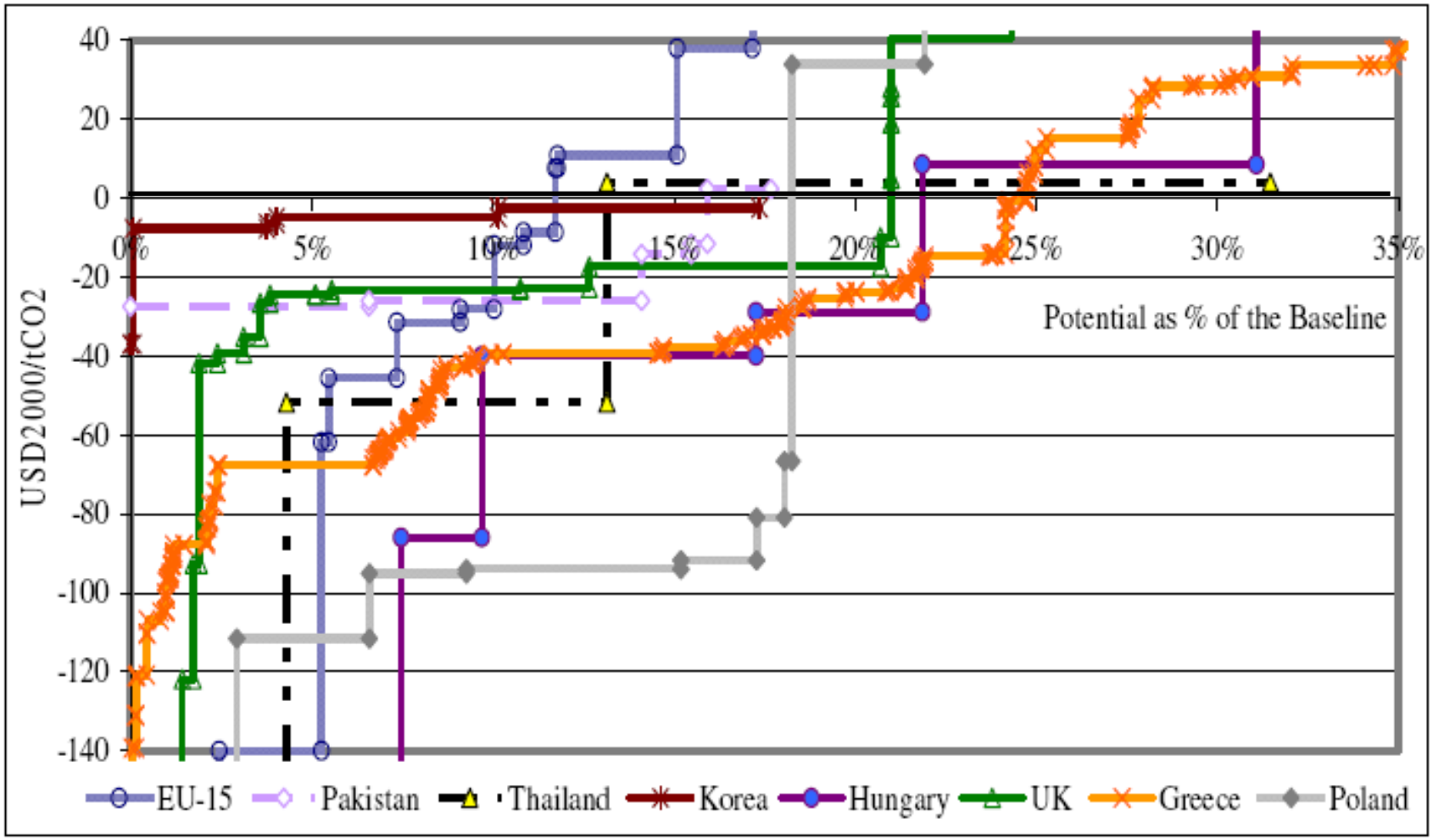
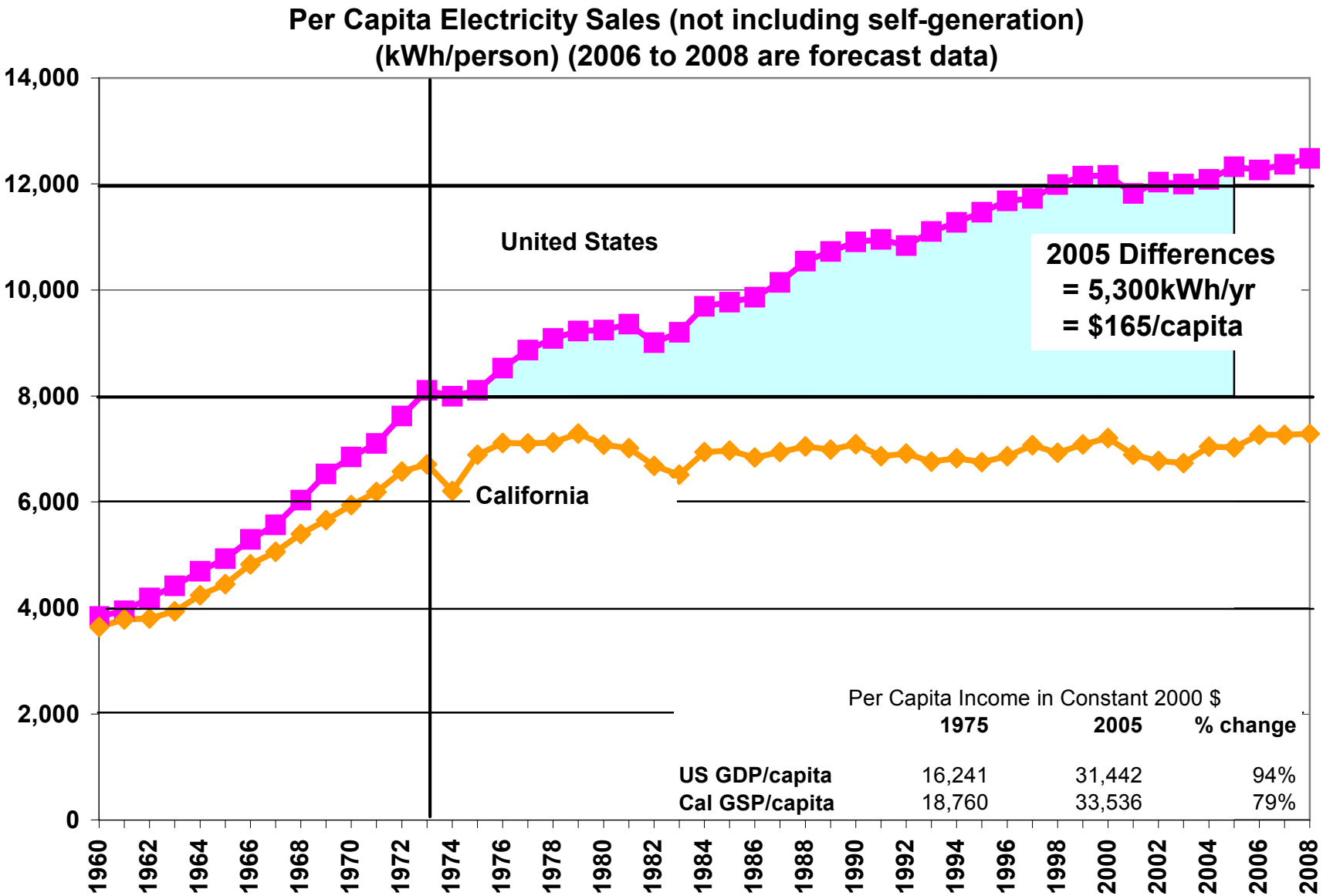
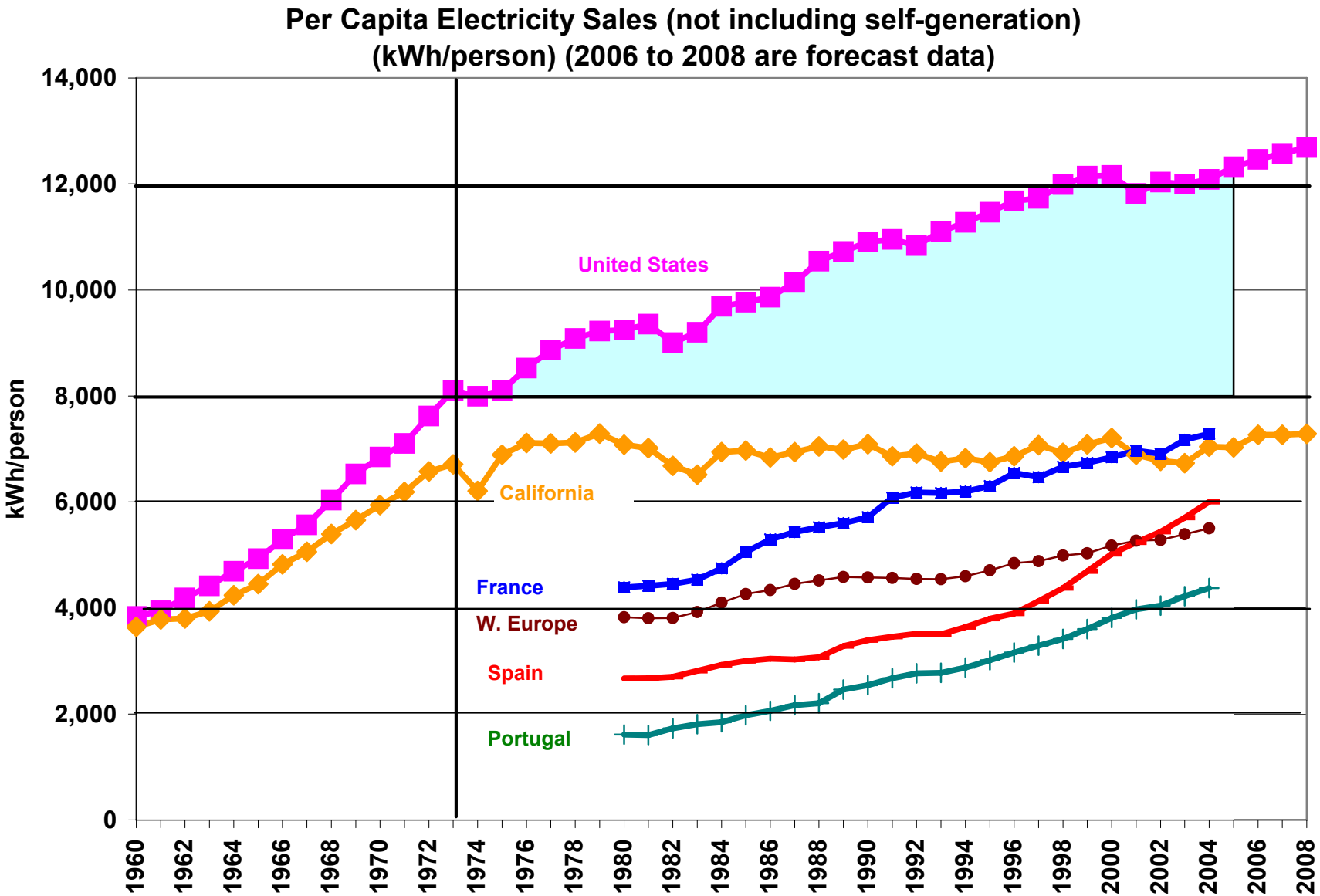


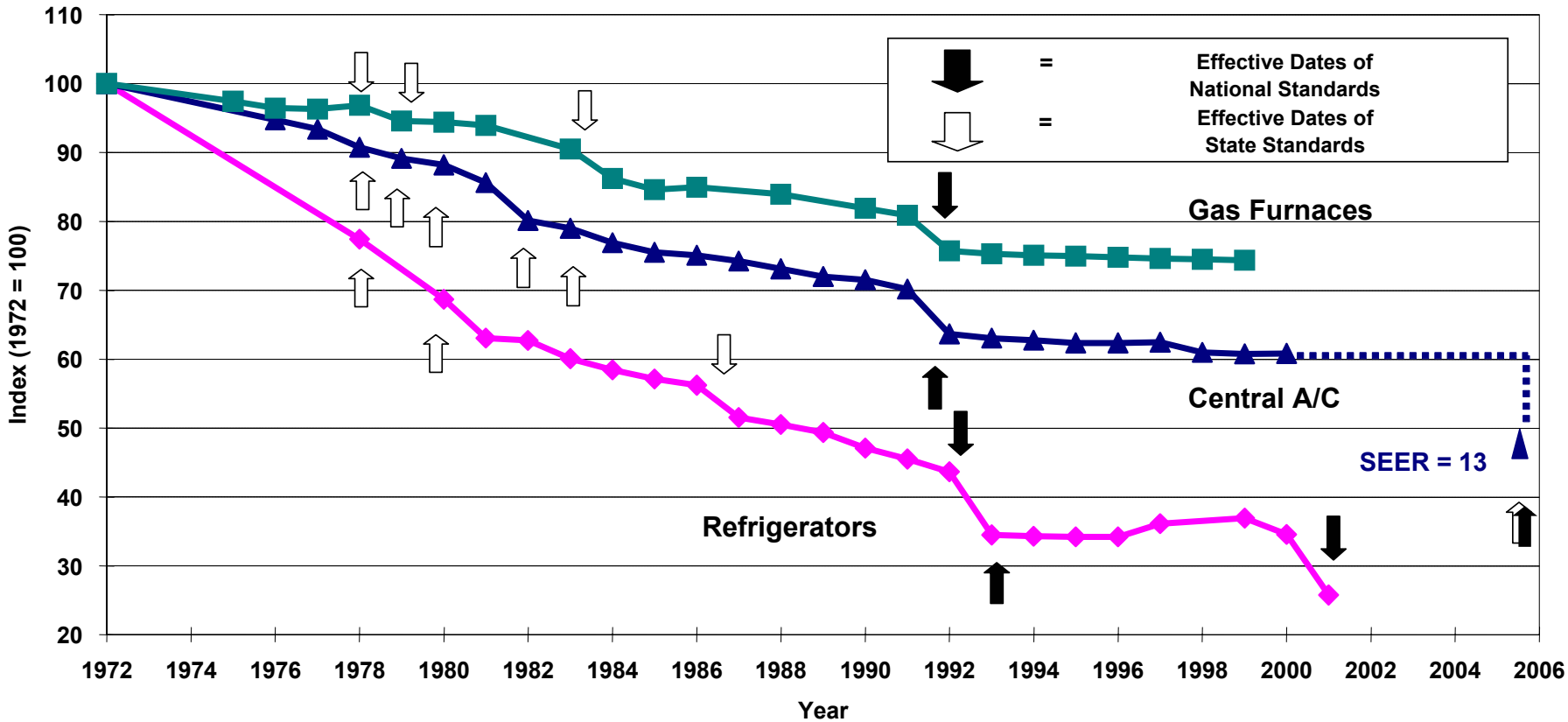
Figure 6.4: *Supply curves of conserved CO_2 for commercial and residential sector[1)] in 2020[2)] for different world regions*

p. 42, Final Draft IPCC 4th Assessment, Working Group III


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


Per Capita Electricity Sales (not including self-generation)
(kWh/person) (2006 to 2008 are forecast data)
kWh/person
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
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
United States
California
France
W. Europe
Spain
Portugal

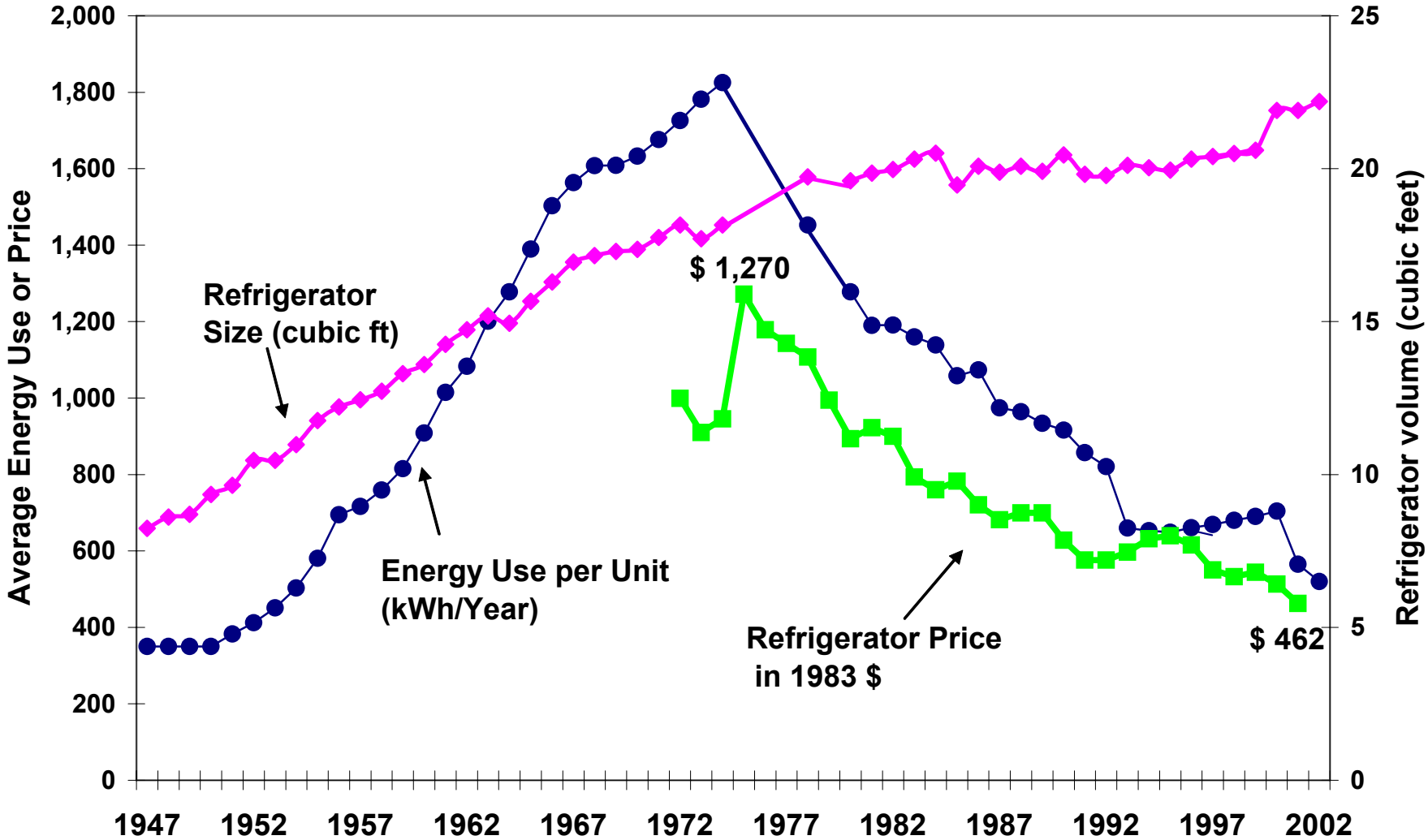
Impact of Standards on Efficiency of 3 Appliances



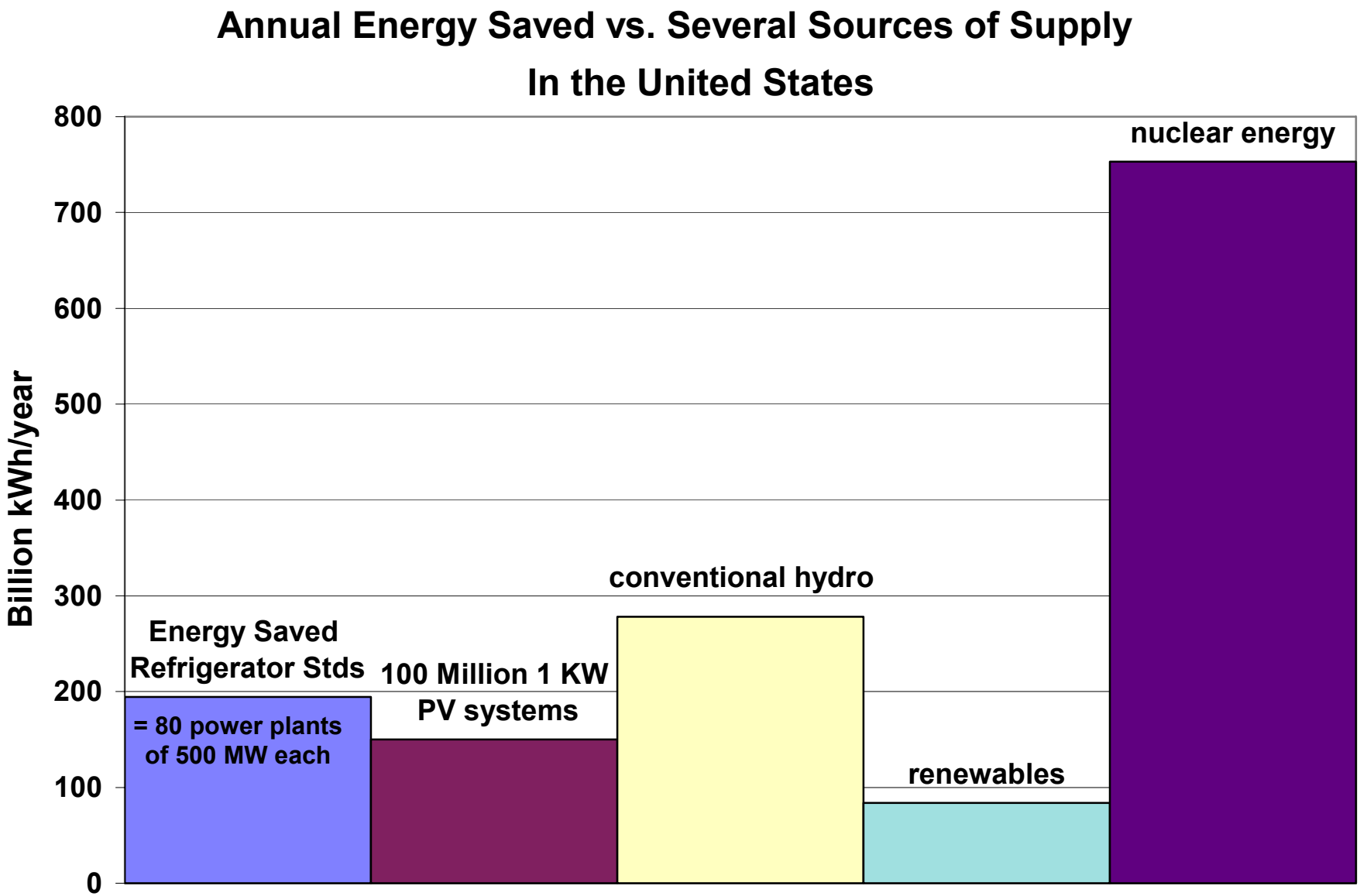
Source: S. Nadel, ACEEE,

in ECEEE 2003 Summer Study, www.eceee.org

New United States Refrigerator Use v. Time and Retail Prices

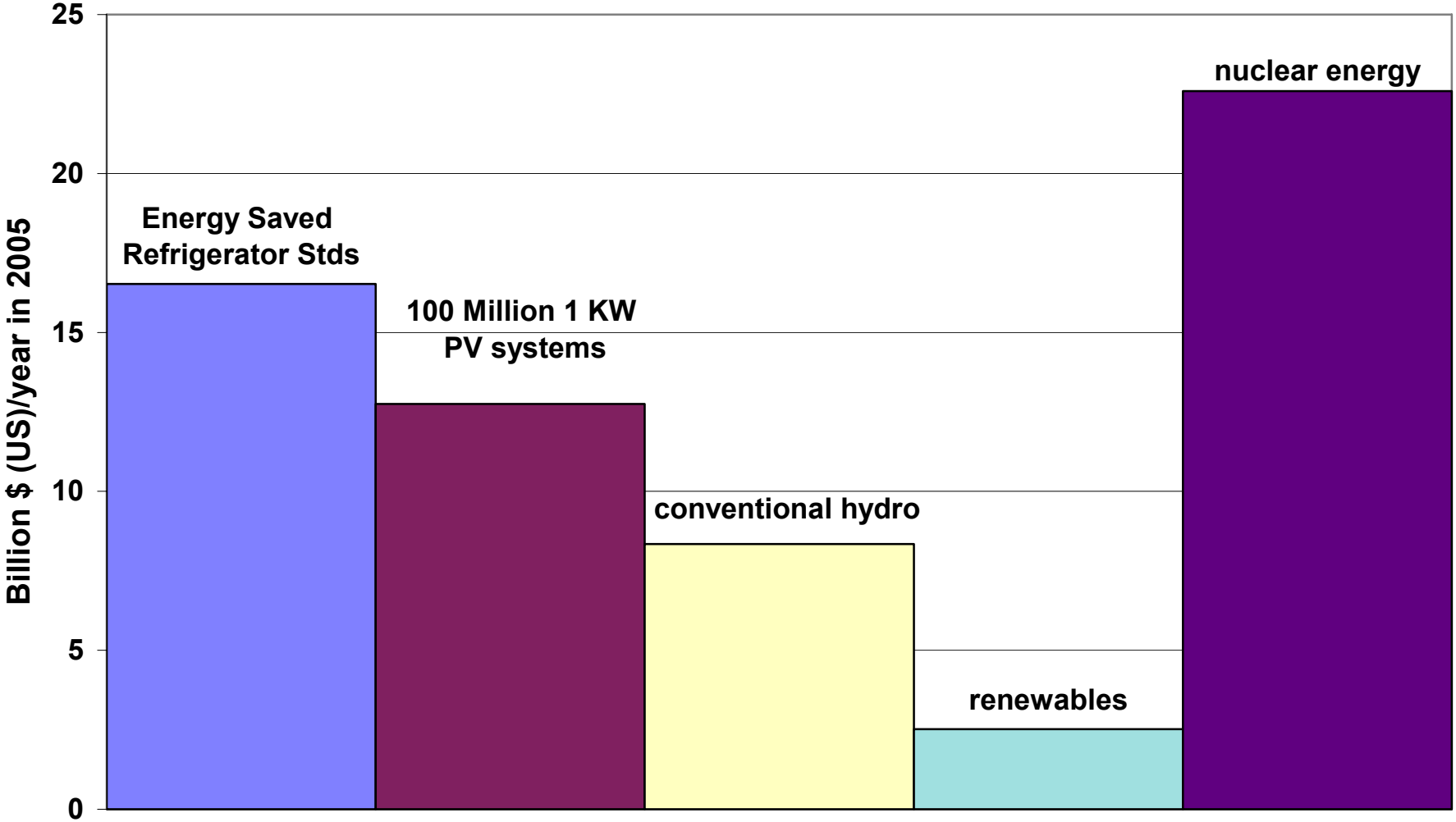


Source: David Goldstein


Annual Energy Saved vs. Several Sources of Supply
In the United States
Billion kWh/year
800
700
600
500
400
300
200
100
0
nuclear energy
conventional hydro
Energy Saved
Refrigerator Stds
= 80 power plants
of 500 MW each
100 Million 1 KW
PV systems
renewables

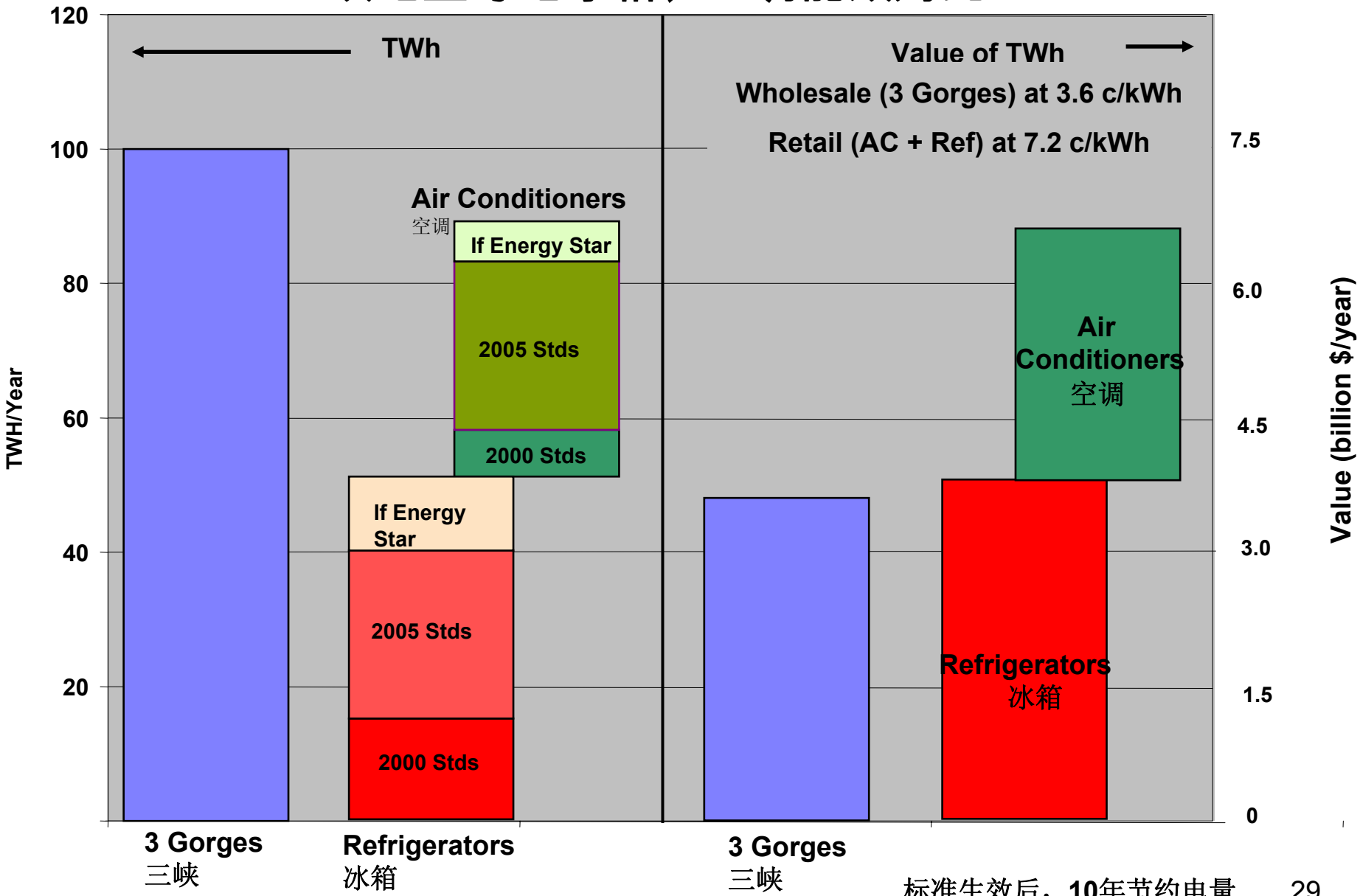
In the United States

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)



Comparison of 3 Gorges to Refrigerator and AC Efficiency Improvements

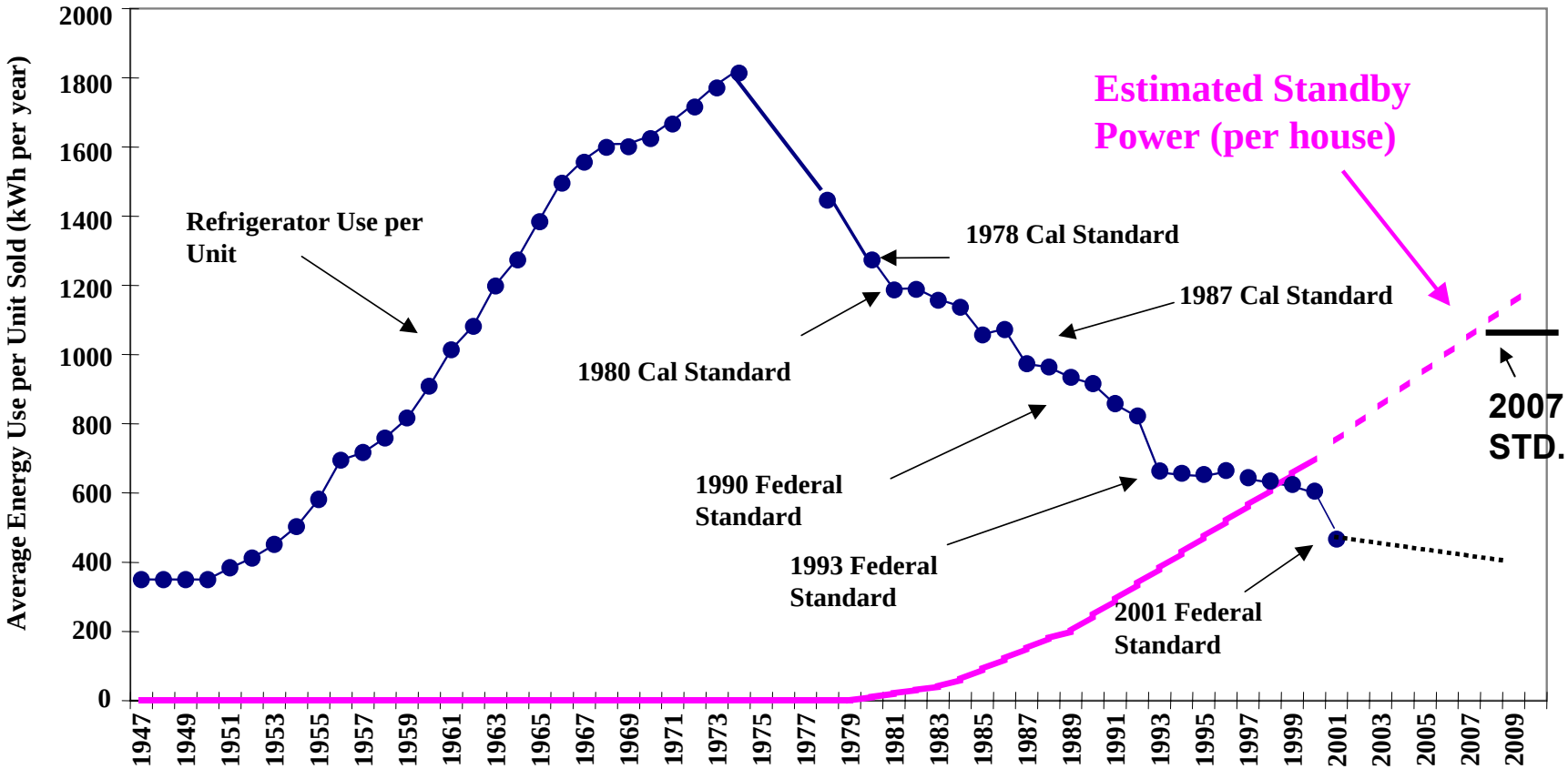
三峡电量与电冰箱、空调能效对比



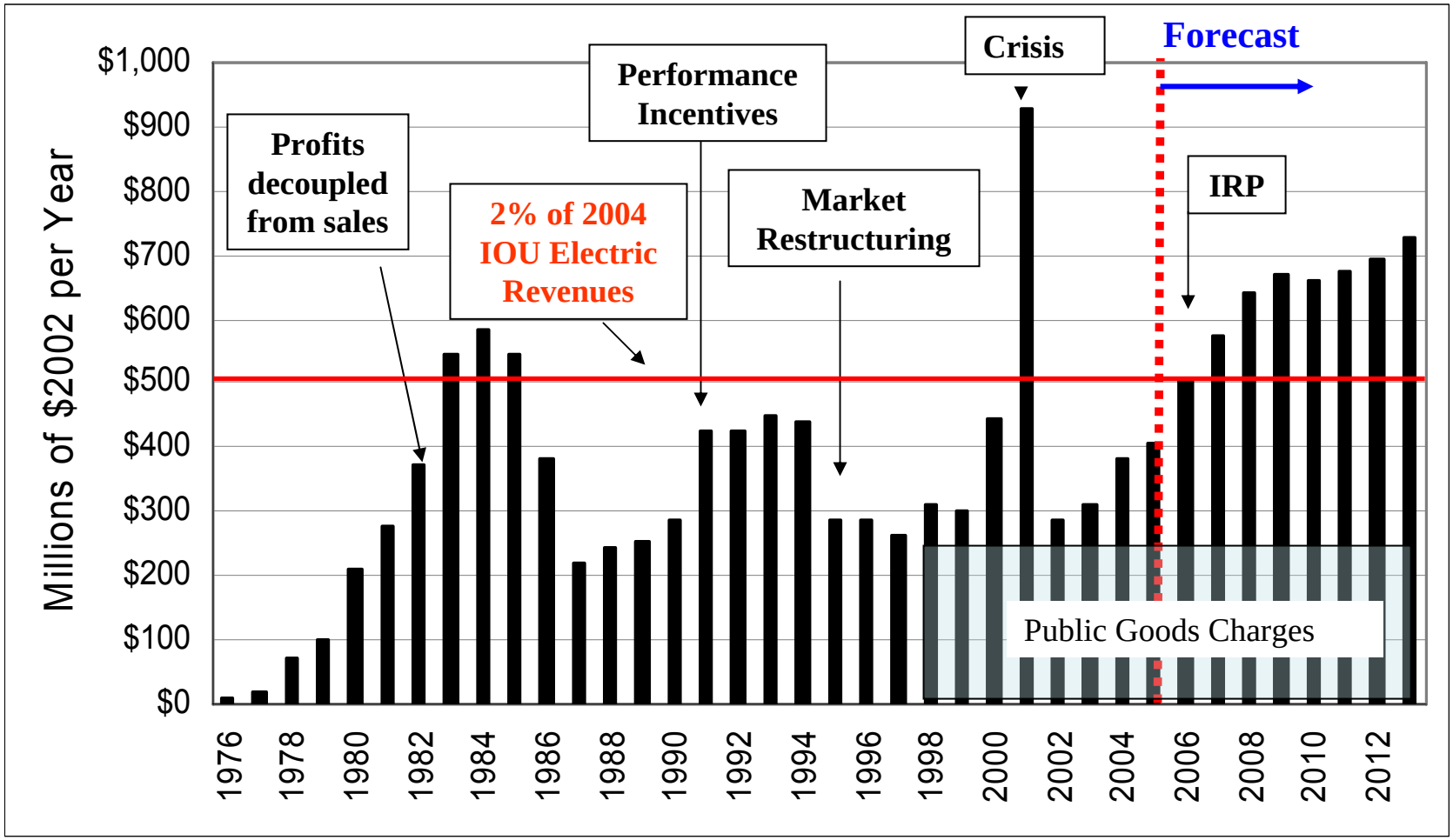
Savings calculated 10 years after standard takes effect. Calculations provided by David Fridley, LBNL

标准生效后，10年节约电量

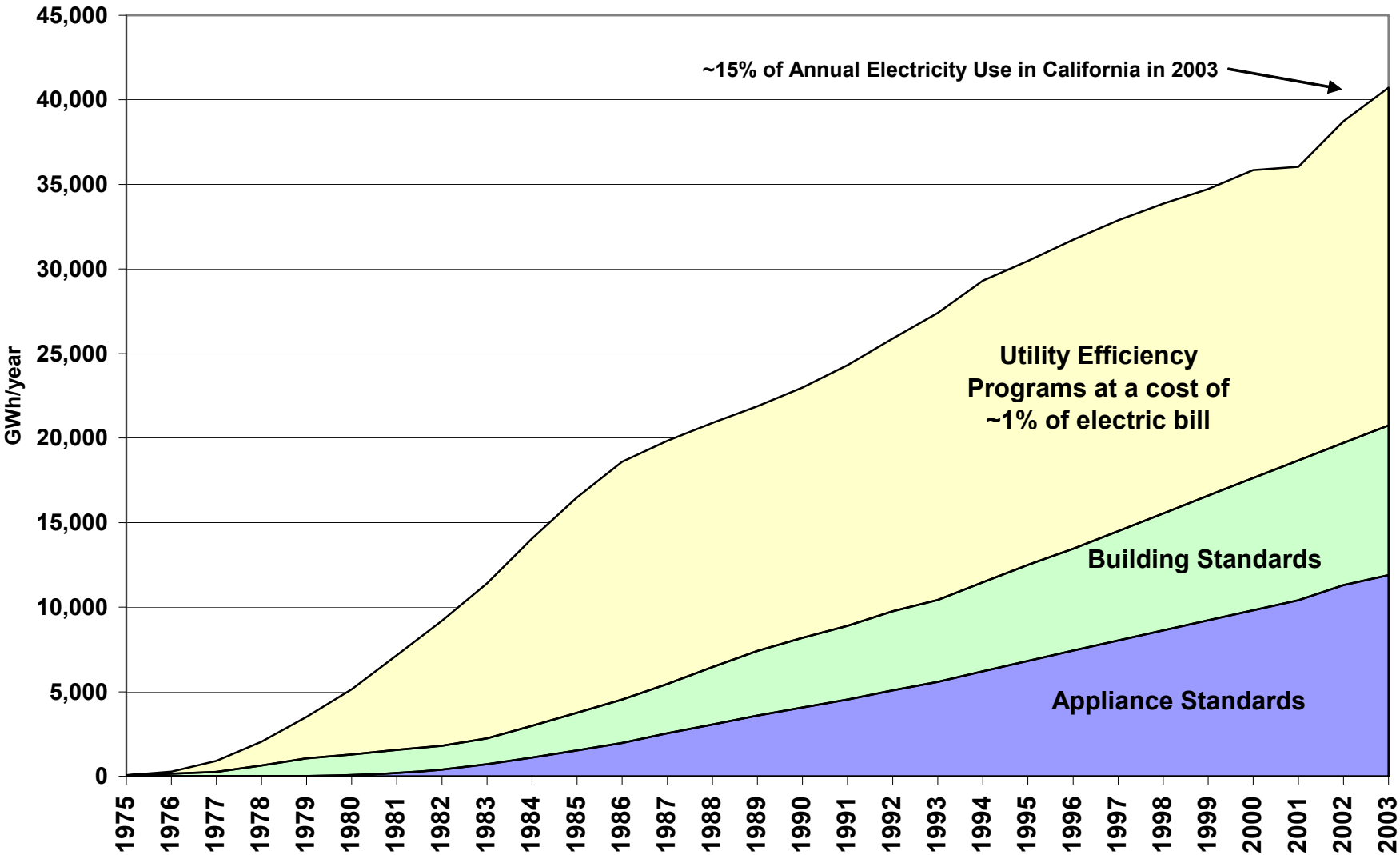
United States Refrigerator Use, repeated, to compare with Estimated Household Standby Use v. Time



California IOU's Investment in Energy Efficiency



Annual Energy Savings from Efficiency Programs and Standards



Cool Urban Surfaces and Global Warming

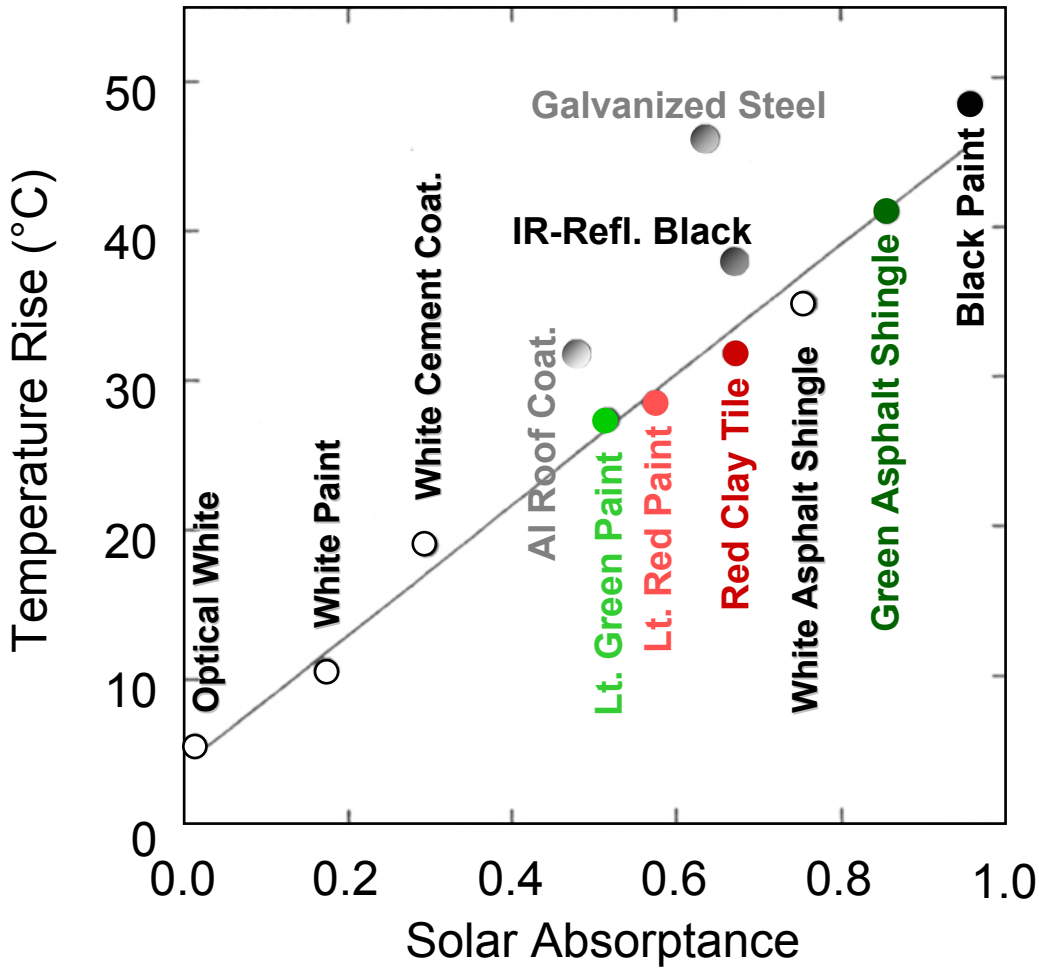
Hashem Akbari

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

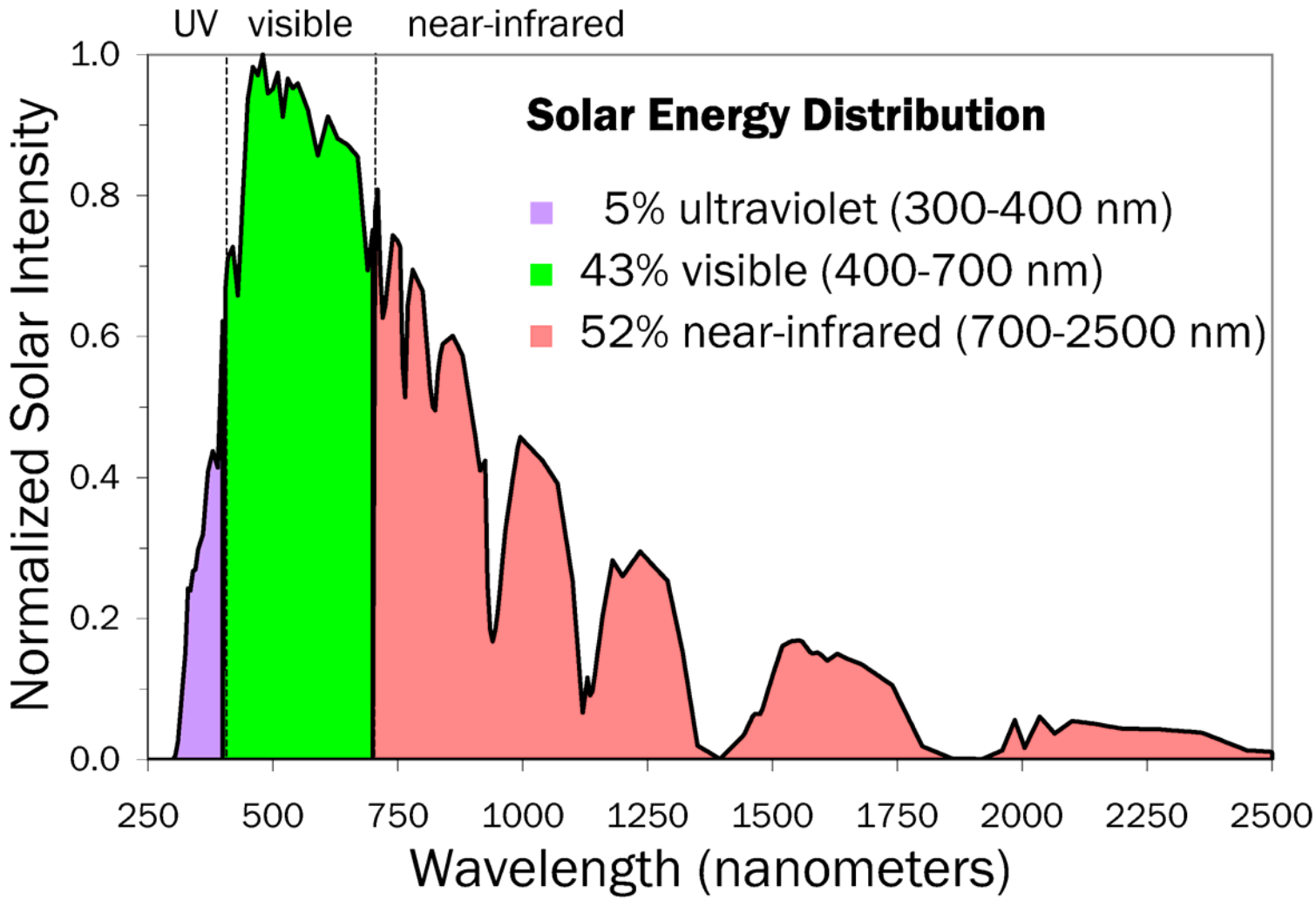
flat, white

pitched, white

New

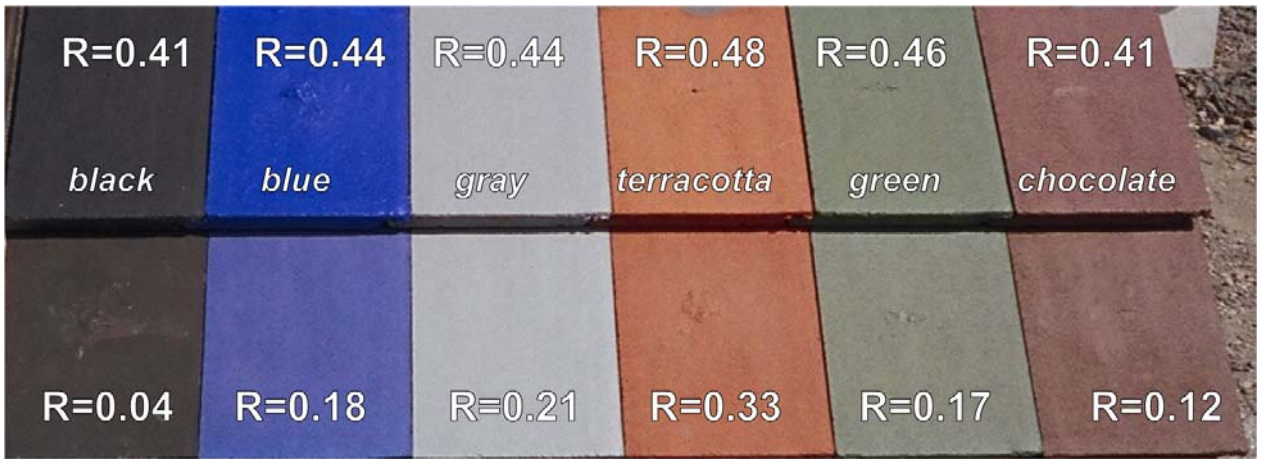
pitched, cool & colored

Cool Colors Reflect Invisible Near-Infrared Sunlight



Cool and Standard Color-Matched Concrete Tiles

Courtesy American Rooftile Coatings



cool

standard

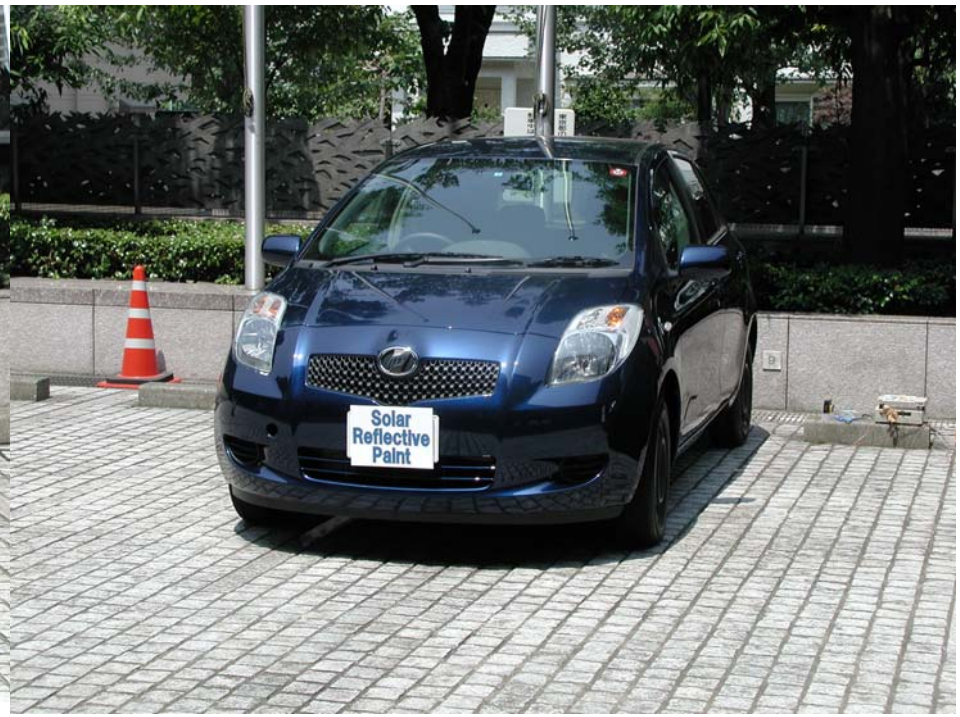
ΔR=0.37 ΔR=0.26 ΔR=0.23 ΔR=0.15 ΔR=0.29 ΔR=0.29

- 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

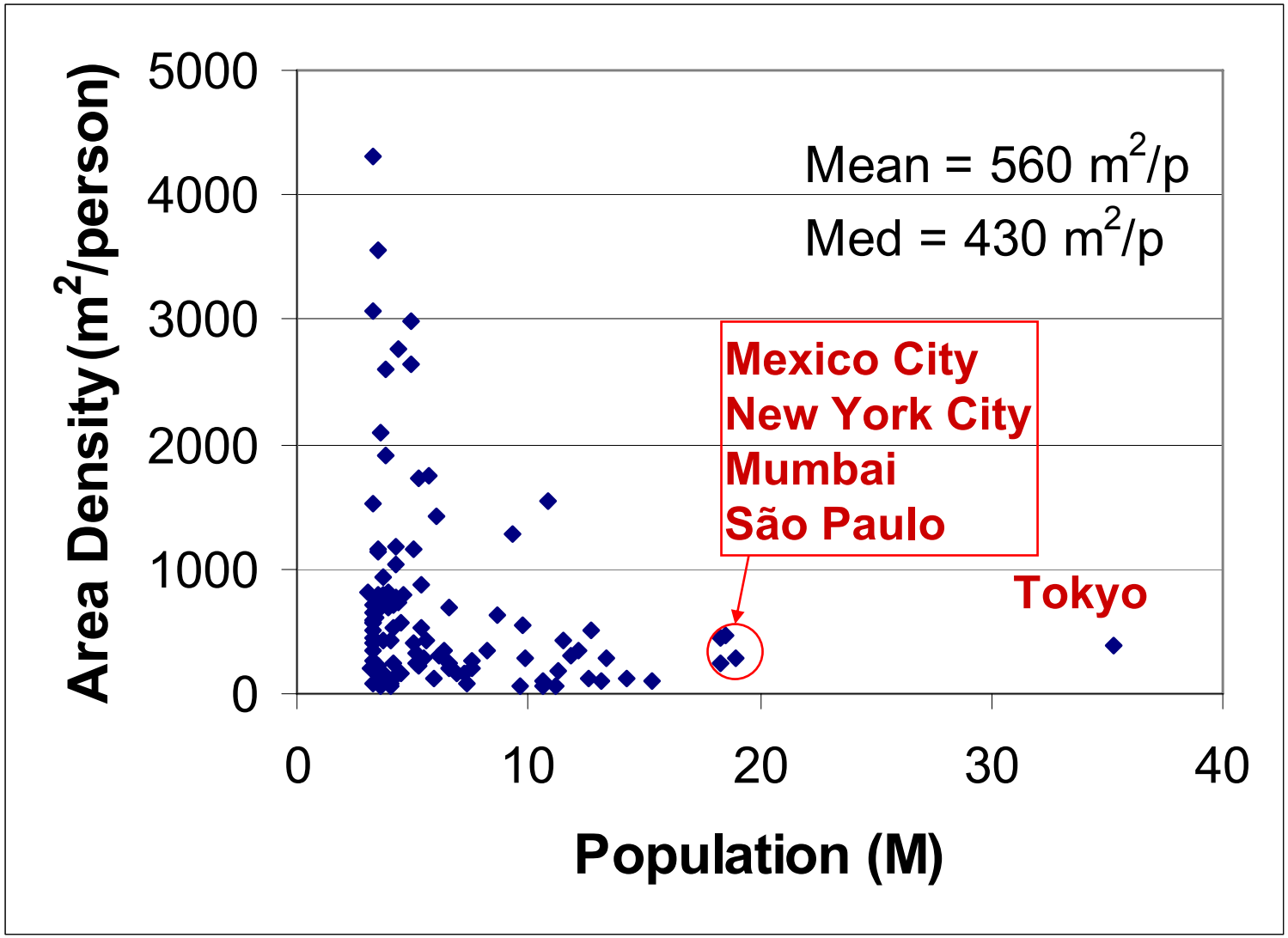


- **Toyota experiment (surface temperature 10K cooler)**
- **Ford and Fiat are also working on the technology**

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, temperate cities.

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]

- **2% of land is 3 x 10^12 m2 = area of a square of side s =1700 km.**

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**

- So urban area of 3 x 10**12 m2 x delta albedo of 0.1 = effective 100% white area of 0.3 m2, area of a square of side 550 km.

- **Equivalent area of snow (albedo = 0.85) = 0.35 x 10^12 m2 which = area of a square of side 600 km.**

The Effect of Increasing Urban Albedo by 0.1 (cntd) (Hanson et al.)

- Given 3 results:
  - Harte $\Delta T = 0.011K$
  - Hansen 0.016K
  - Our preliminary GISS run 0.002K
  - We shall adopt as an order of magnitude $\Delta T=0.01K$
  - This is disappointing compared to predicted global warming of say 3K, but still offsets 10 $GtCO_2$!!– see next slide.

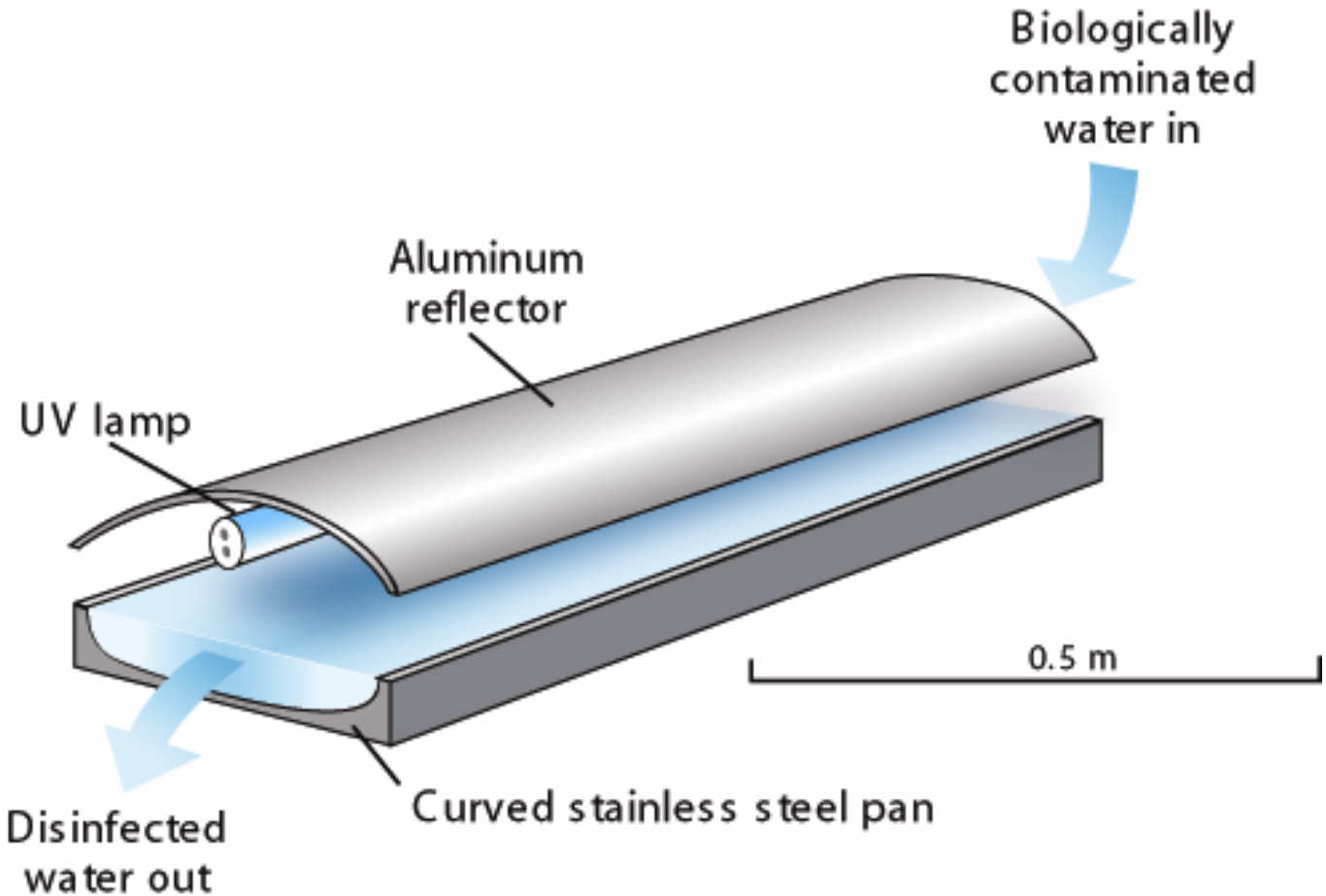
Carbon Equivalency

- Modelers estimate a warming of 3K in 60 years, so 0.05K/year
- Change of 0.1 in urban albedo will result in 0.01K, a delay of ~0.2 years in global warming
- World's current rate of CO_2 emissions = 25 G tons/year (4.1 tons/year per person)
- World's rate of CO_2 emissions averaged over next 60 years = 50 G tons/year
- **Hence 0.2 years delay is worth 10 Gt CO_2**

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

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 400 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 **200 MtCO2 eq.** per year
  - Primarily fire wood is used for this
  - With heat content = to 2 million barrels of petroleum per day

2. Switching from Kerosene Lighting to LED rechargeable Flashlights

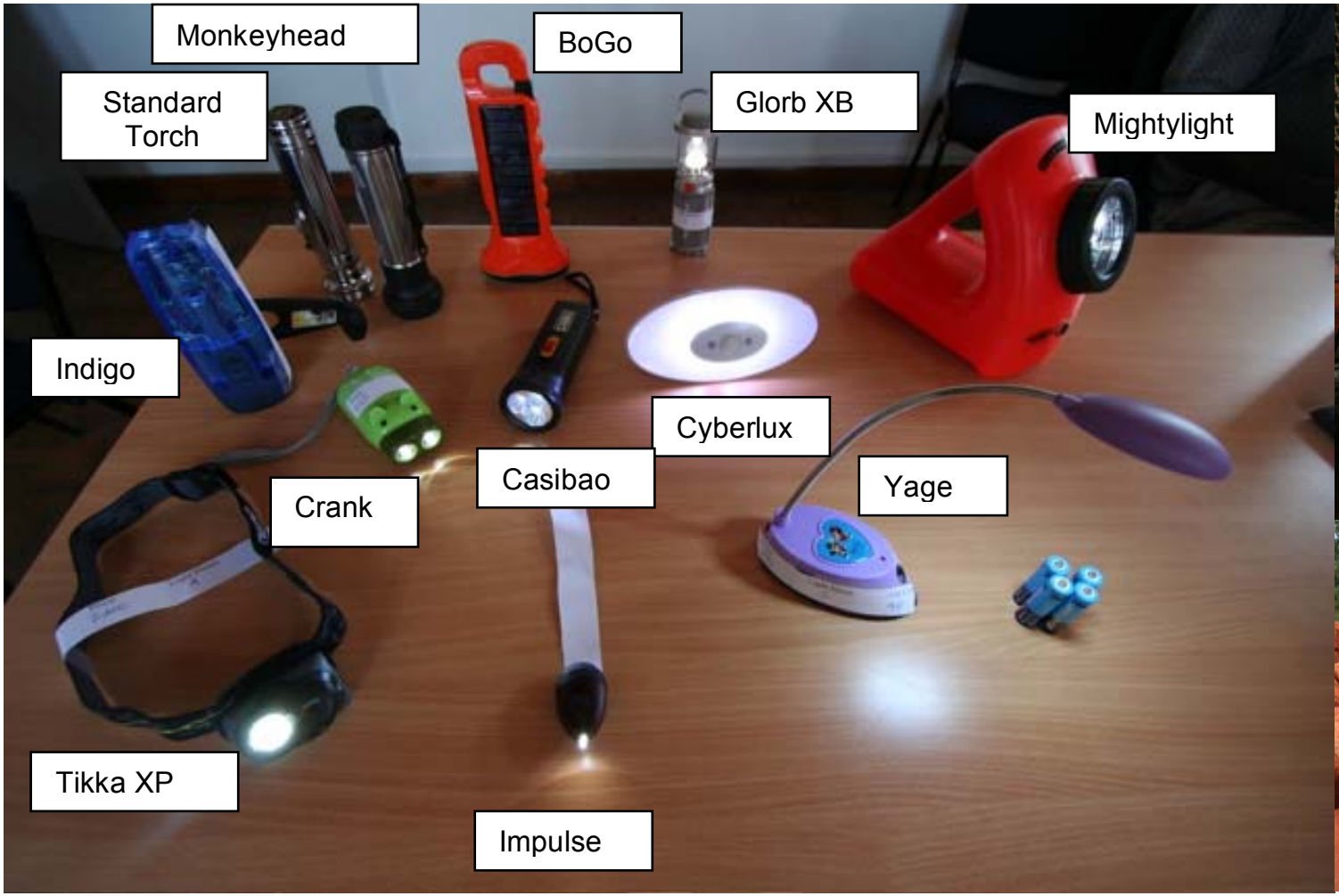
- 2 Billion people off of electricity grid use kerosene lanterns
- Rechargeable LED flashlights now cost less than $20
- Worldwide this will avoid another **200 MtCO2 eq.** per year

The total of **400 MtCO2 eq**. = **10%** of Harvey's reduction target in the building sector

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