From the Lab to the Marketplace to Standards
Hertz Foundation Symposium
San Jose, CA
3-17-2007

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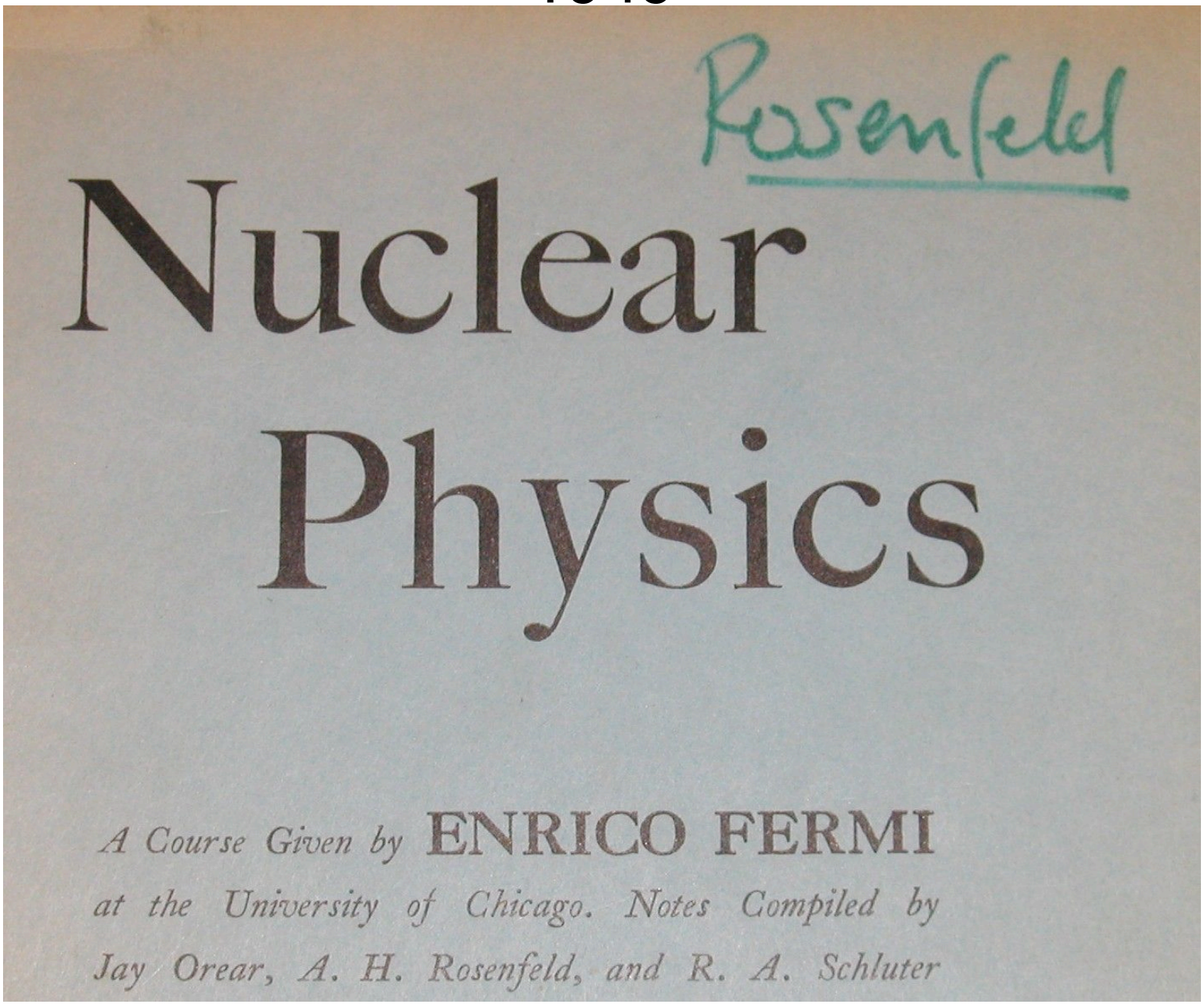
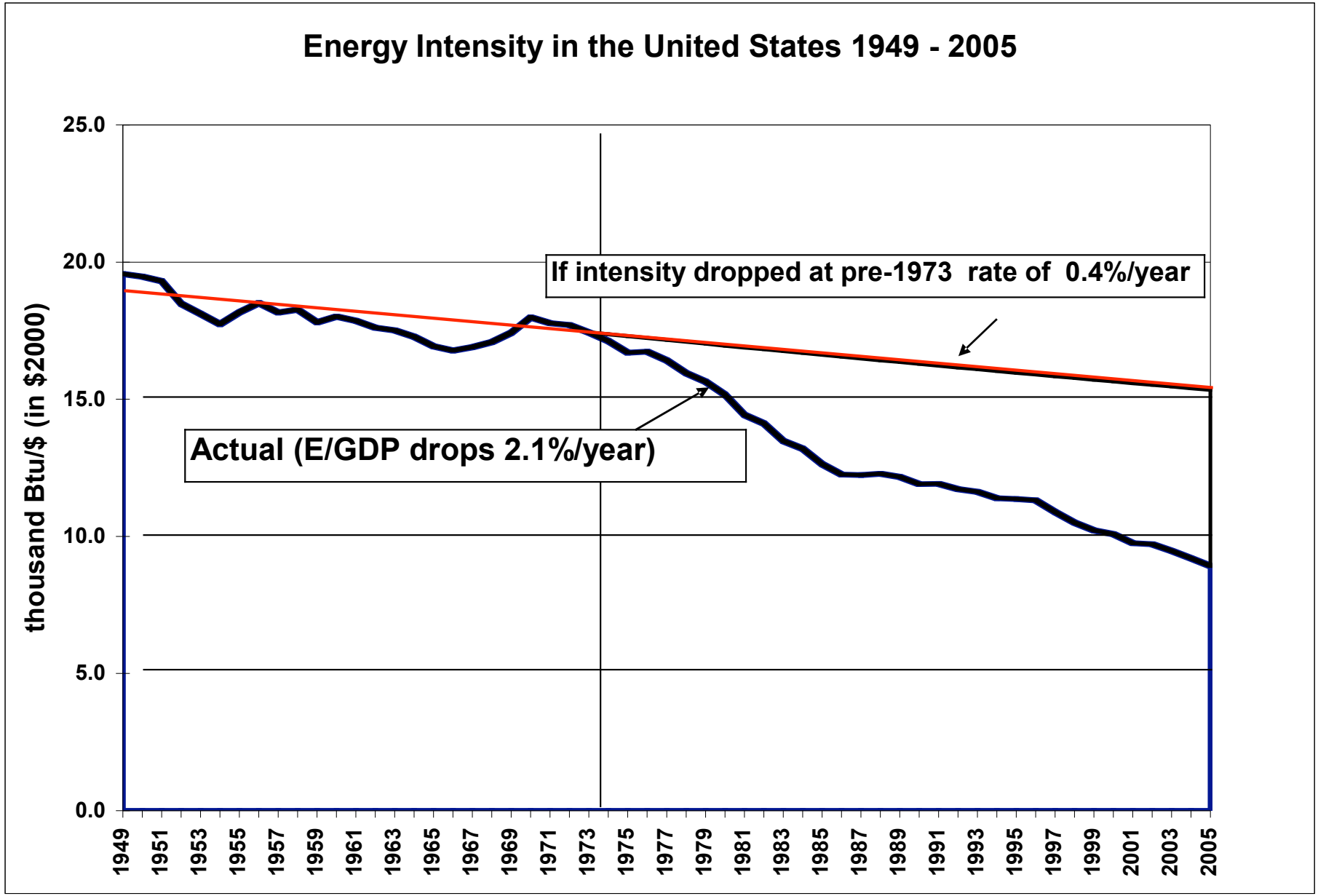
http://www.energy.ca.gov/commission/commissioners/rosenfeld.html

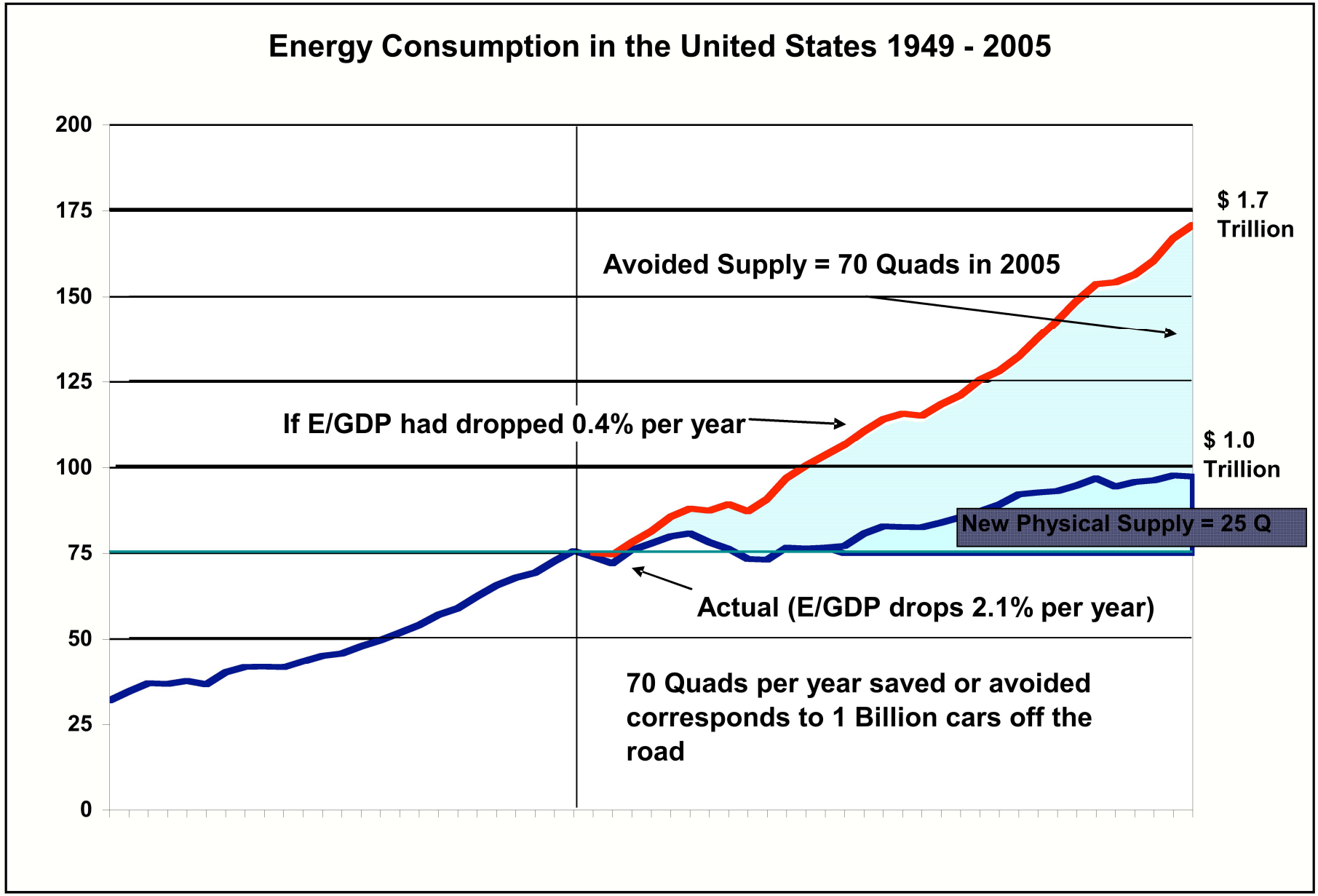
or just Google "Art Rosenfeld"

The Economist
JANUARY 27TH–FEBRUARY 2ND 2007
www.economist.com
Shake-up in Big Pharma
China's space blast
Europe's rotating slump
Serbia's encouraging election
Hating Hillary Clinton
LOW ENERGY LIG
The greening of America

1949


Rosenfeld
Nuclear
Physics
A Course Given by ENRICO FERMI
at the University of Chicago. Notes Compiled by
Jay Orear, A. H. Rosenfeld, and R. A. Schluter


Energy Intensity in the United States 1949 - 2005
thousand Btu/$ (in $2000)
25.0
20.0
15.0
10.0
5.0
0.0
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
If intensity dropped at pre-1973 rate of 0.4%/year
Actual (E/GDP drops 2.1%/year)


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

Environmental Equivalent of Avoiding 70 Quads

- 70 Quads = 33 Mbod (Million barrels of oil per day)
  = 40% of World oil production of 80 Mbod

- 70 Quads = 1 Billion cars off the road, impressive since there are only 600 million cars on the road

How Much of The Savings Come from Efficiency?

- Easiest to tease out is cars
  - In the early 1970s, only 14 miles per gallons
  - Now about 21 miles per gallon
  - If still at 14 mpg, we'd consume **75 billion gallons more** and pay **$225 Billion more** at 2006 prices
  - But we still pay **$450 Billion per year**
  - If California wins the "Schwarzenegger-Pavley" suit, and it is implemented nationwide, we'll save **another $150 Billion per year**
- Commercial Aviation improvements save another **$50 Billion per year**
- Appliances and Buildings are more complex
  - We must sort out true efficiency gains vs. structural changes (from smokestack to service economy).

How Much of The Savings Come from Efficiency (cont'd)?

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

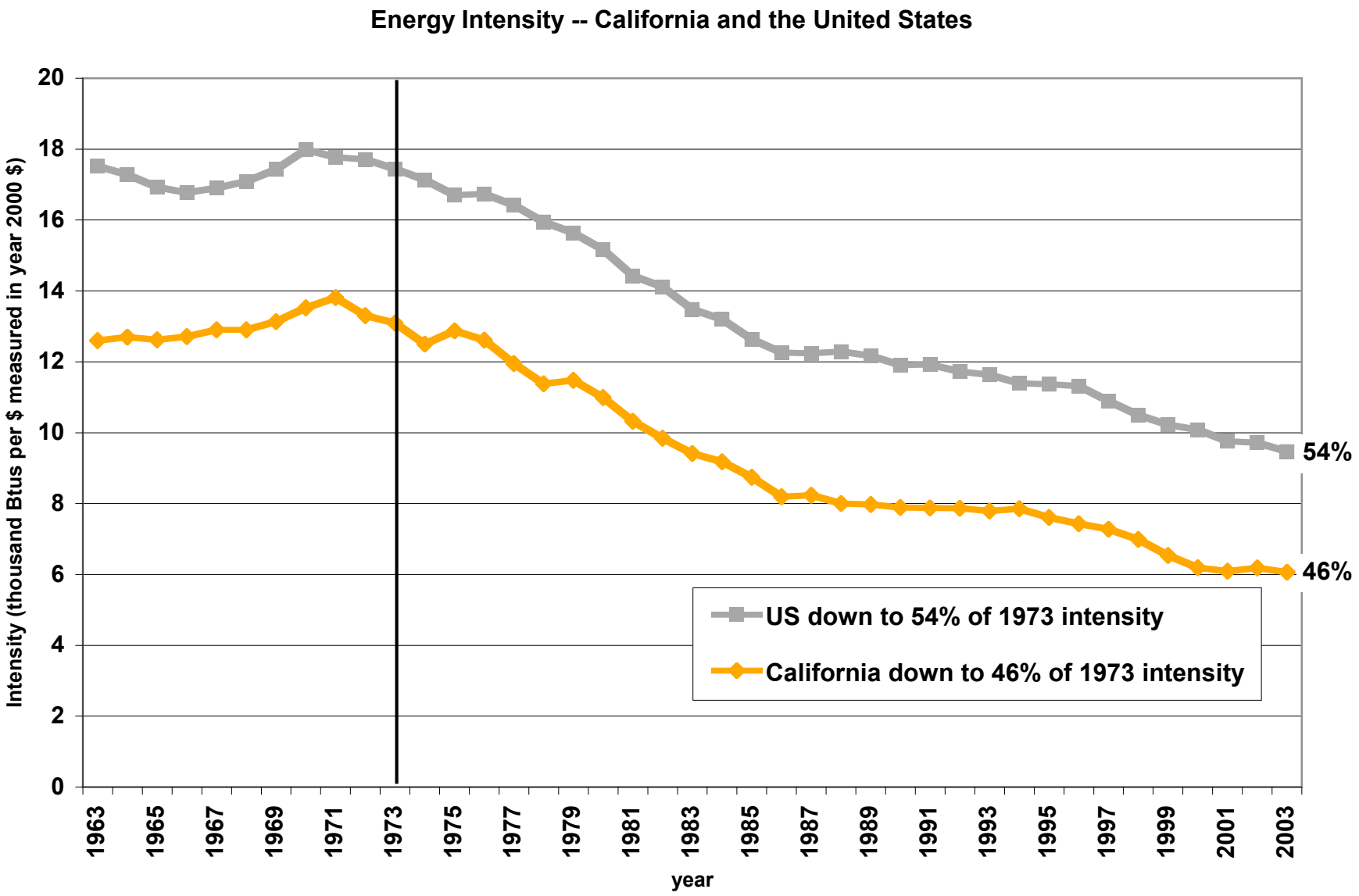
	Billion $
Space Heating	**40**
Air Conditioning	**30**
Refrigerators	**15**
Fluorescent Tube Lamps	**5**
Compact Floursecent Lamps	**5**
Total	**95**

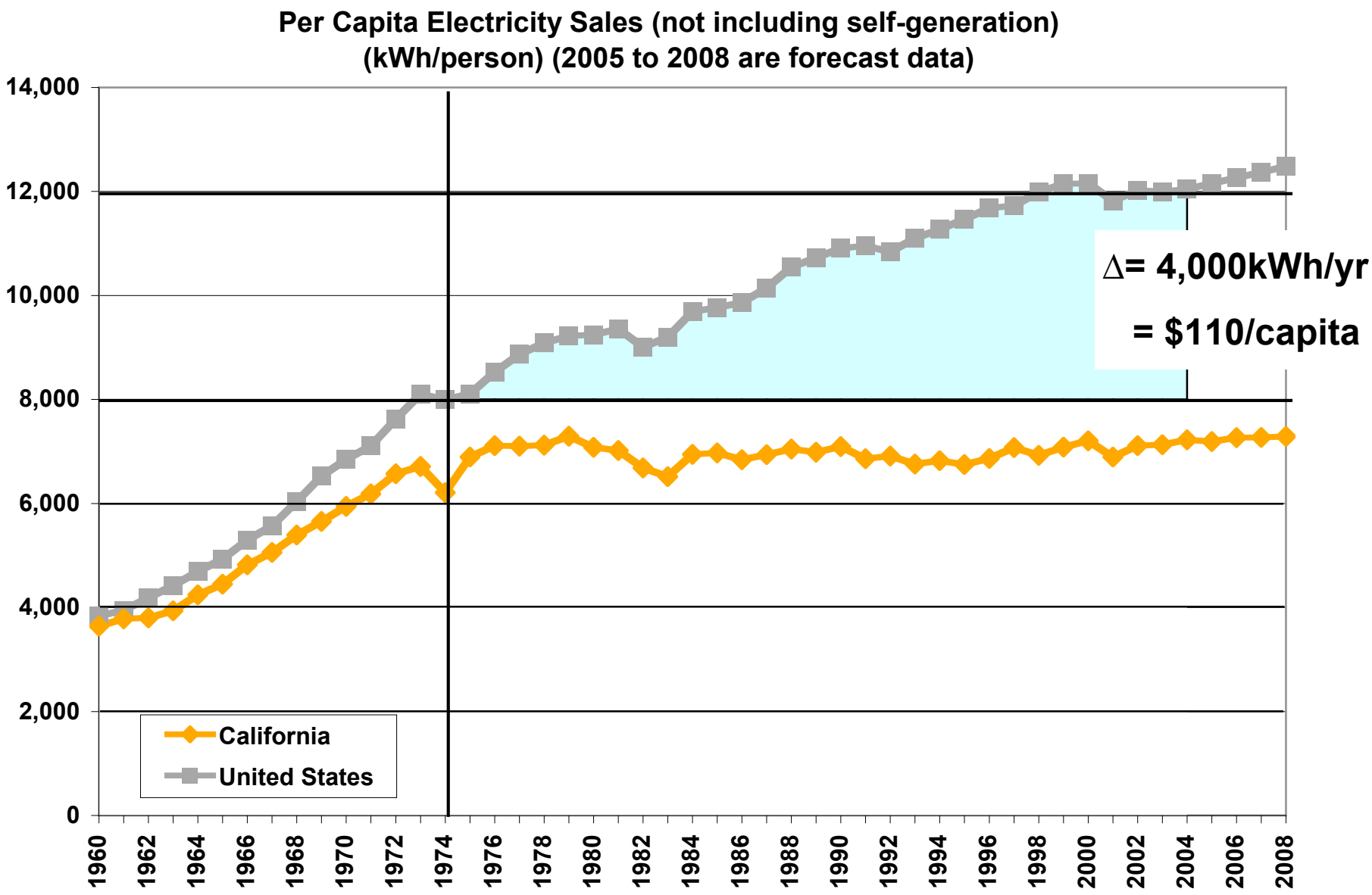
- Beginning in 2007 in California, reduction of "vampire" or stand-by losses
  - This will save $10 Billion when finally implemented, nation-wide
- Out of a total **$700 Billion**, a crude summary is that 1/3 is structural, 1/3 is from transportation, and 1/3 from buildings and industry.

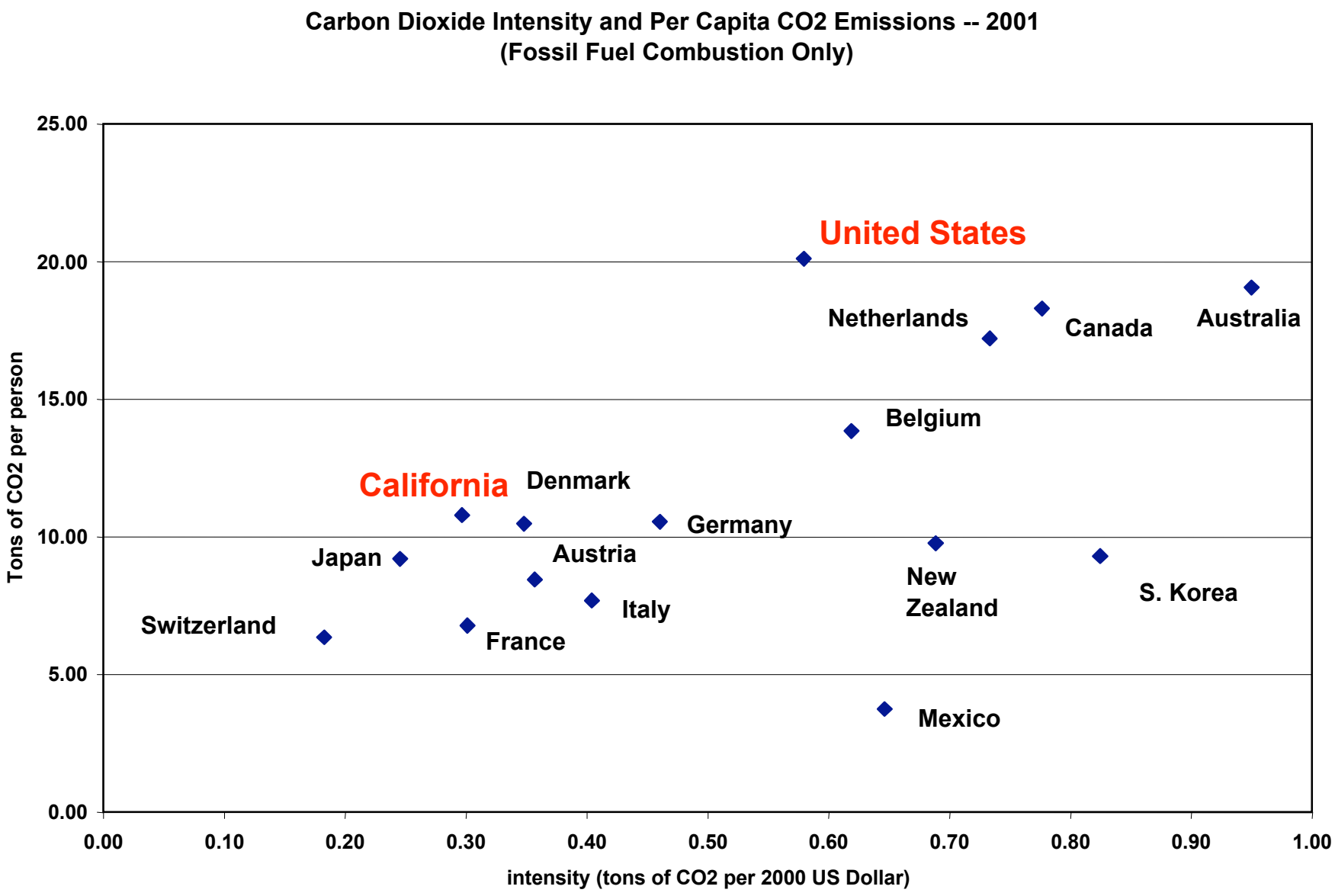
A supporting analysis on the topic of efficiency from Vice-President Dick Cheney

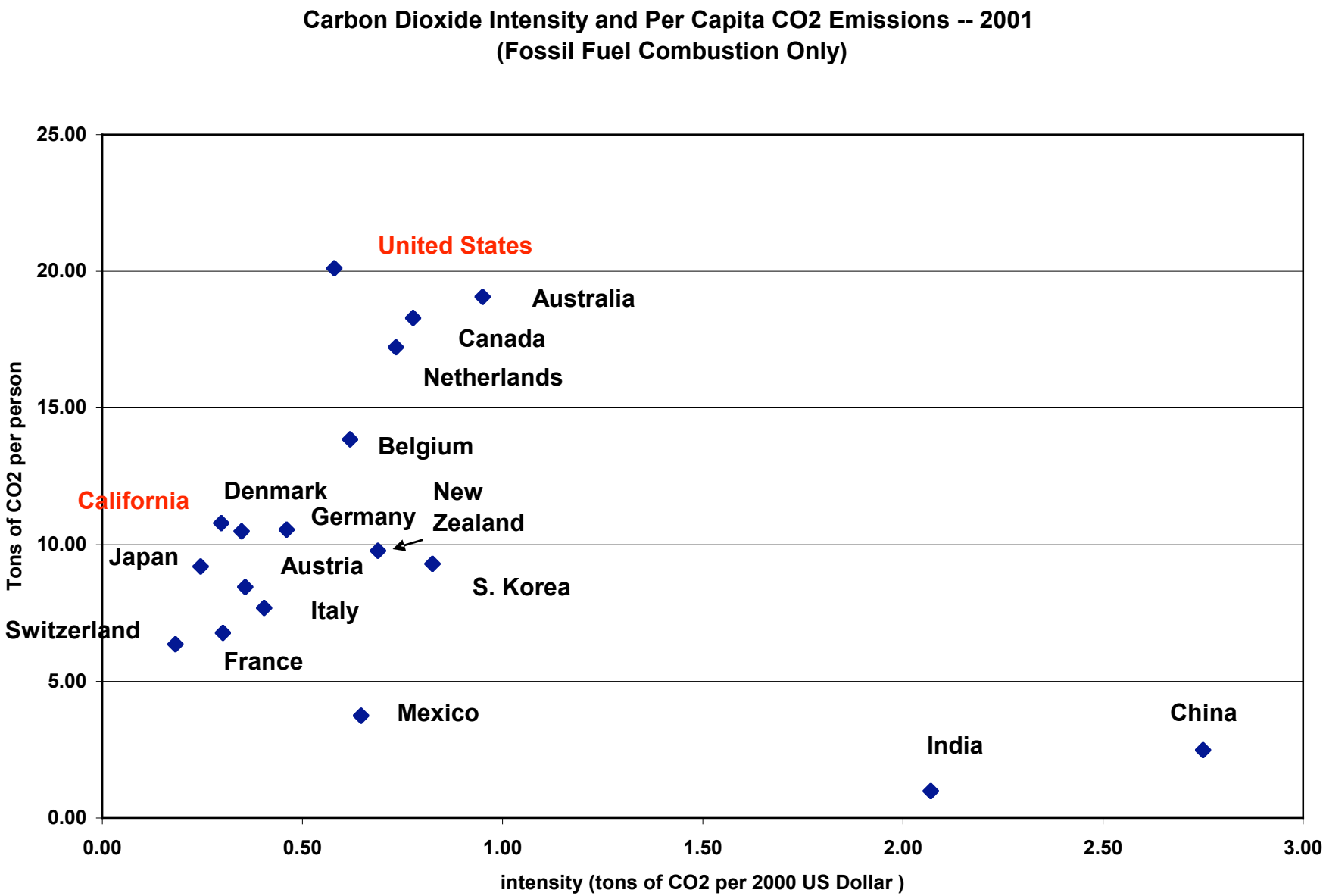
- "Had energy use kept pace with economic growth, the nation would have consumed 171 quadrillion British thermal units (Btus) last year instead of 99 quadrillion Btus"
- "About a third to a half of these savings resulted from shifts in the economy. The other half to two-thirds resulted from greater energy efficiency"

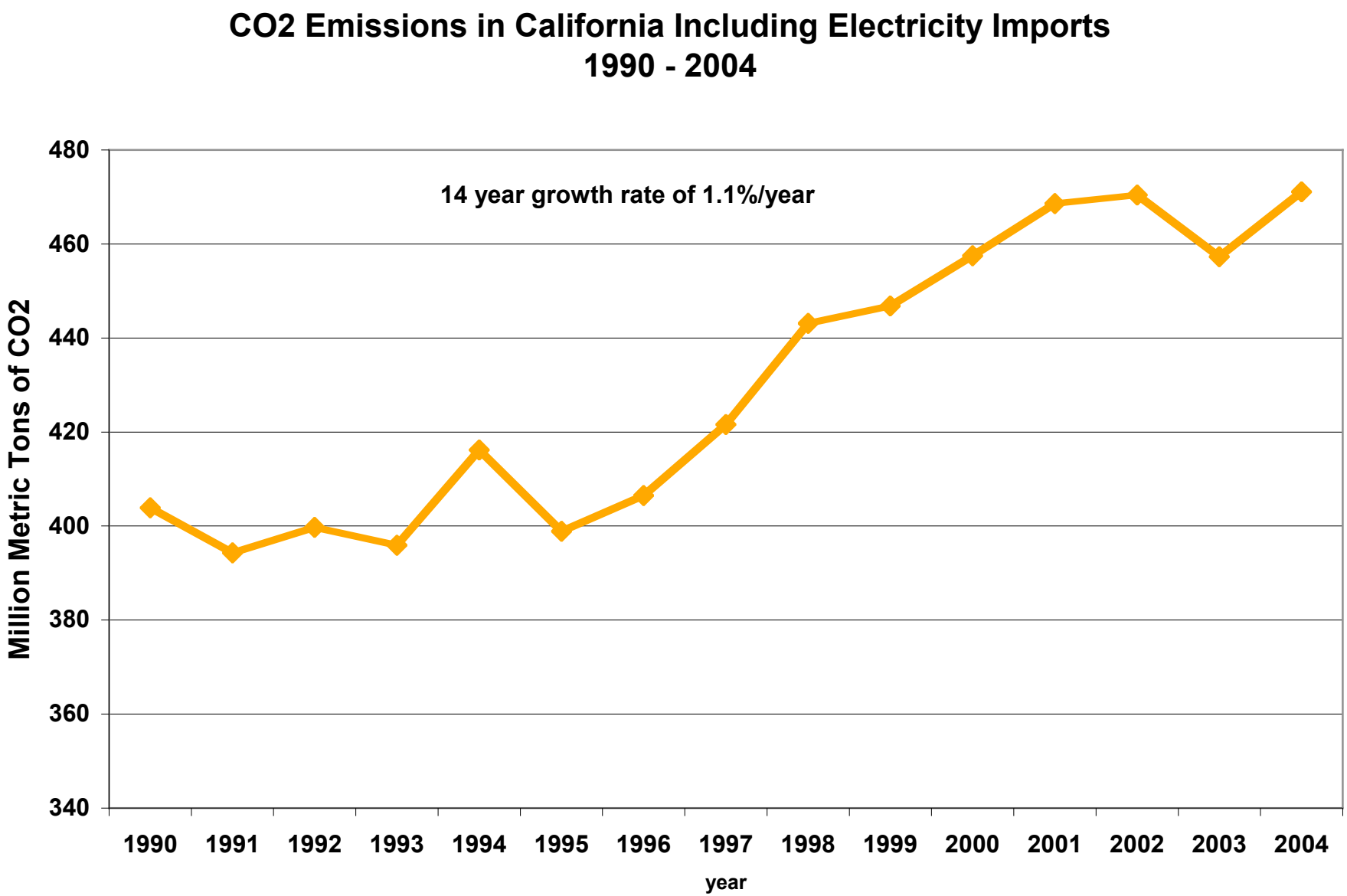
Source: National Energy Policy: Report of the National Energy Policy Development Group, Dick Cheney, et. al., page 1-4, May 2001


Energy Intensity -- California and the United States
Intensity (thousand Btus per $ measured in year 2000 $)
20
18
16
14
12
10
8
6
4
2
0
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
year
54%
46%
US down to 54% of 1973 intensity
California down to 46% of 1973 intensity

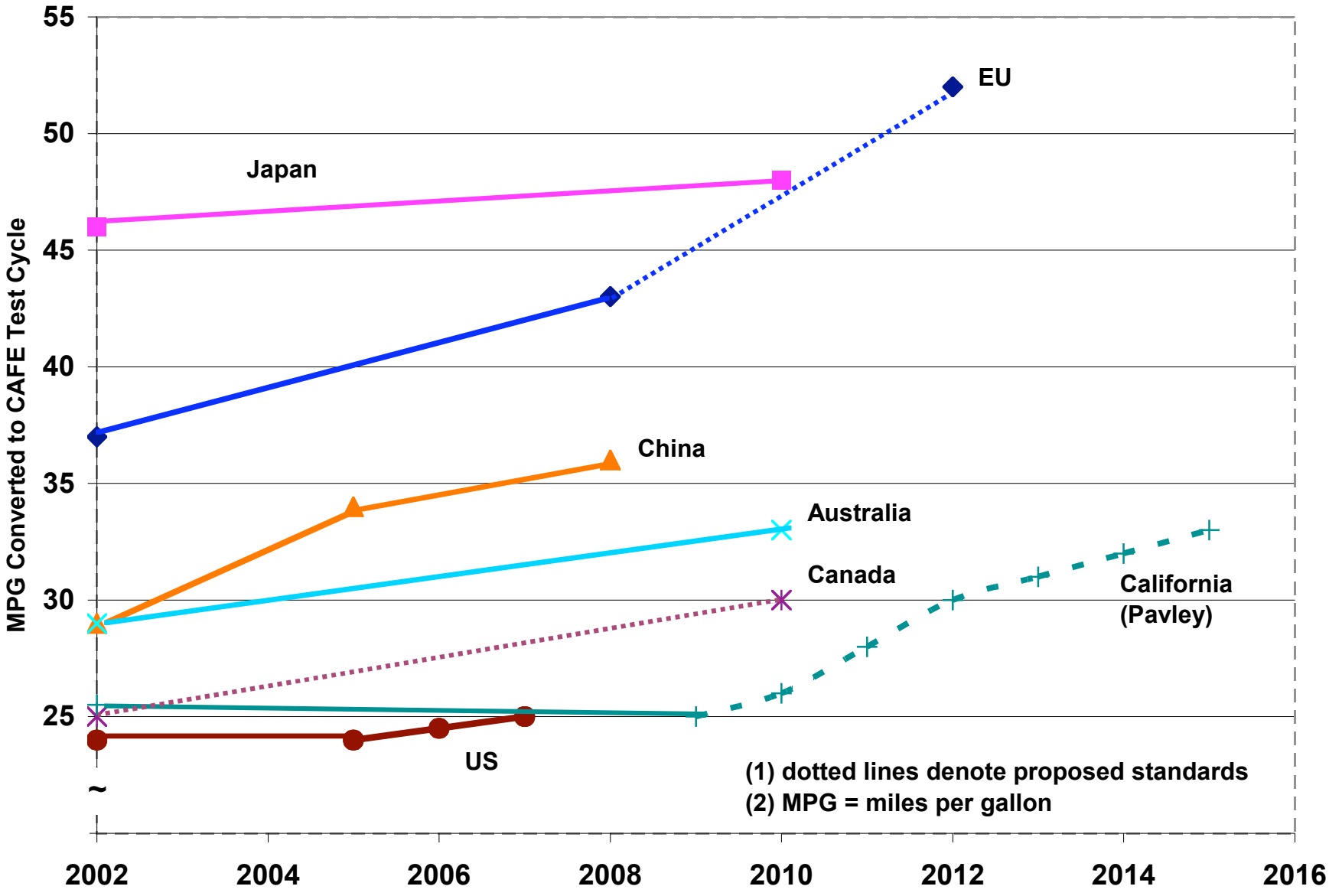

Per Capita Electricity Sales (not including self-generation)
(kWh/person) (2005 to 2008 are forecast data)
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1960
1962
1964
1966
1968
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
California
United States
Δ= 4,000kWh/yr
= $110/capita

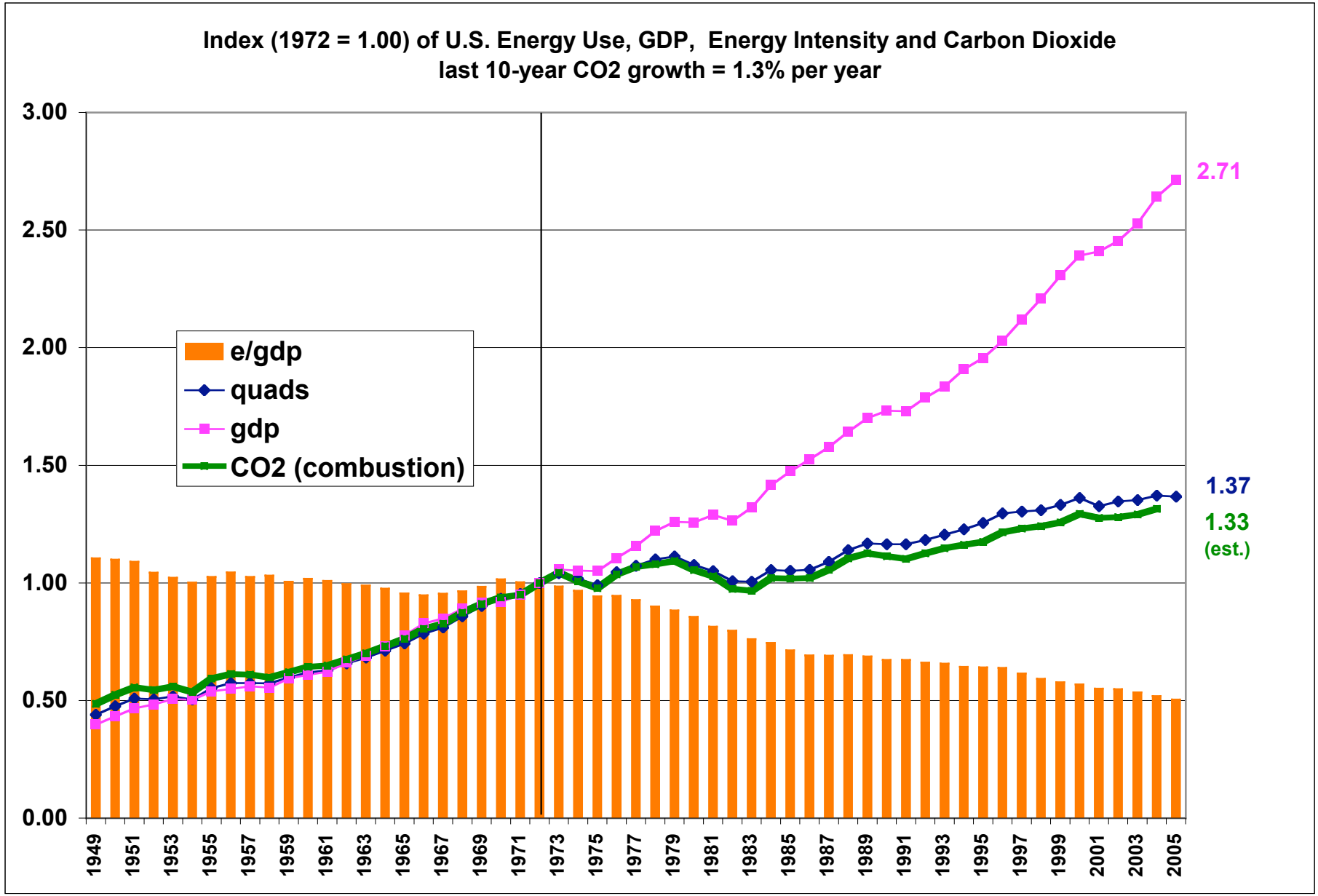

Carbon Dioxide Intensity and Per Capita CO2 Emissions -- 2001
(Fossil Fuel Combustion Only)
Tons of CO2 per person
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.10
0.20
0.30
0.40
0.50
0.60
0.70
0.80
0.90
1.00
intensity (tons of CO2 per 2000 US Dollar)
United States
Netherlands
Canada
Australia
Belgium
California
Denmark
Germany
Japan
Austria
New Zealand
S. Korea
Italy
Switzerland
France
Mexico

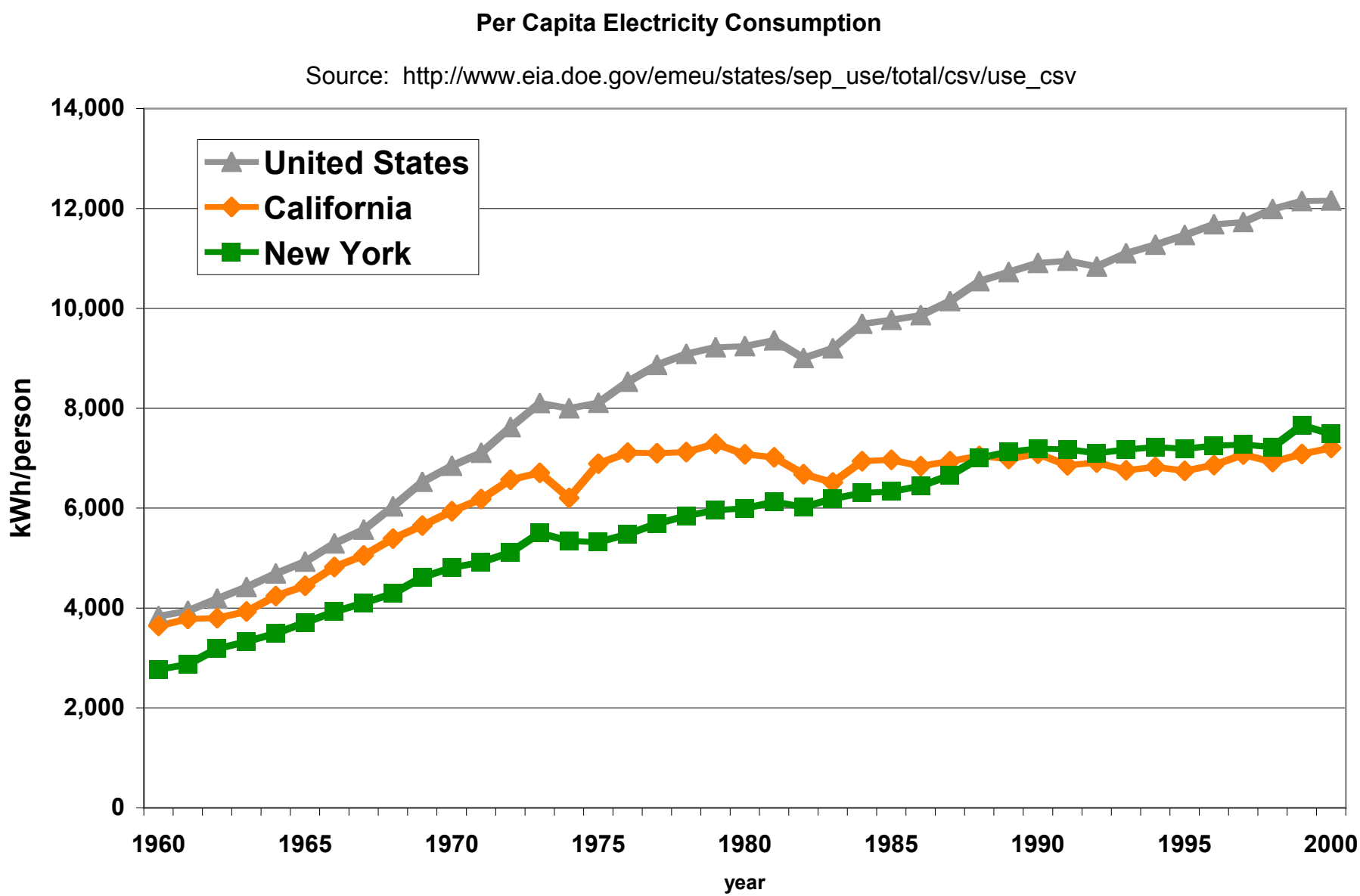

Carbon Dioxide Intensity and Per Capita CO2 Emissions -- 2001
(Fossil Fuel Combustion Only)
Tons of CO2 per person
25.00
20.00
15.00
10.00
5.00
0.00
0.00
0.50
1.00
1.50
2.00
2.50
3.00
intensity (tons of CO2 per 2000 US Dollar)
United States
Australia
Canada
Netherlands
Belgium
California
Denmark
Germany
New Zealand
Japan
Austria
S. Korea
Italy
Switzerland
France
Mexico
India
China

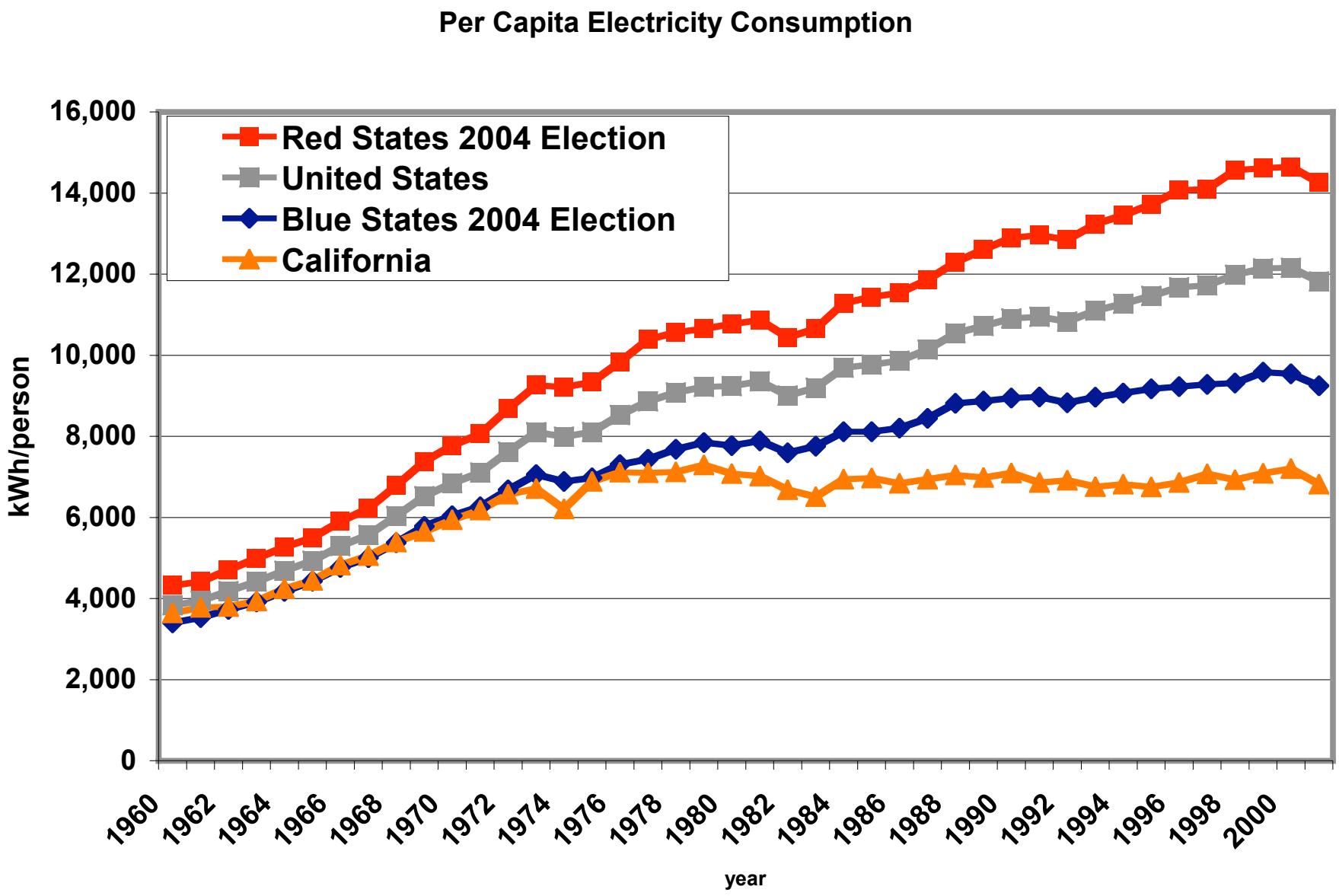

CO2 Emissions in California Including Electricity Imports
1990 - 2004
14 year growth rate of 1.1%/year
Million Metric Tons of CO2
480
460
440
420
400
380
360
340
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
year

Comparison of Fuel Economy – Passenger Vehicles

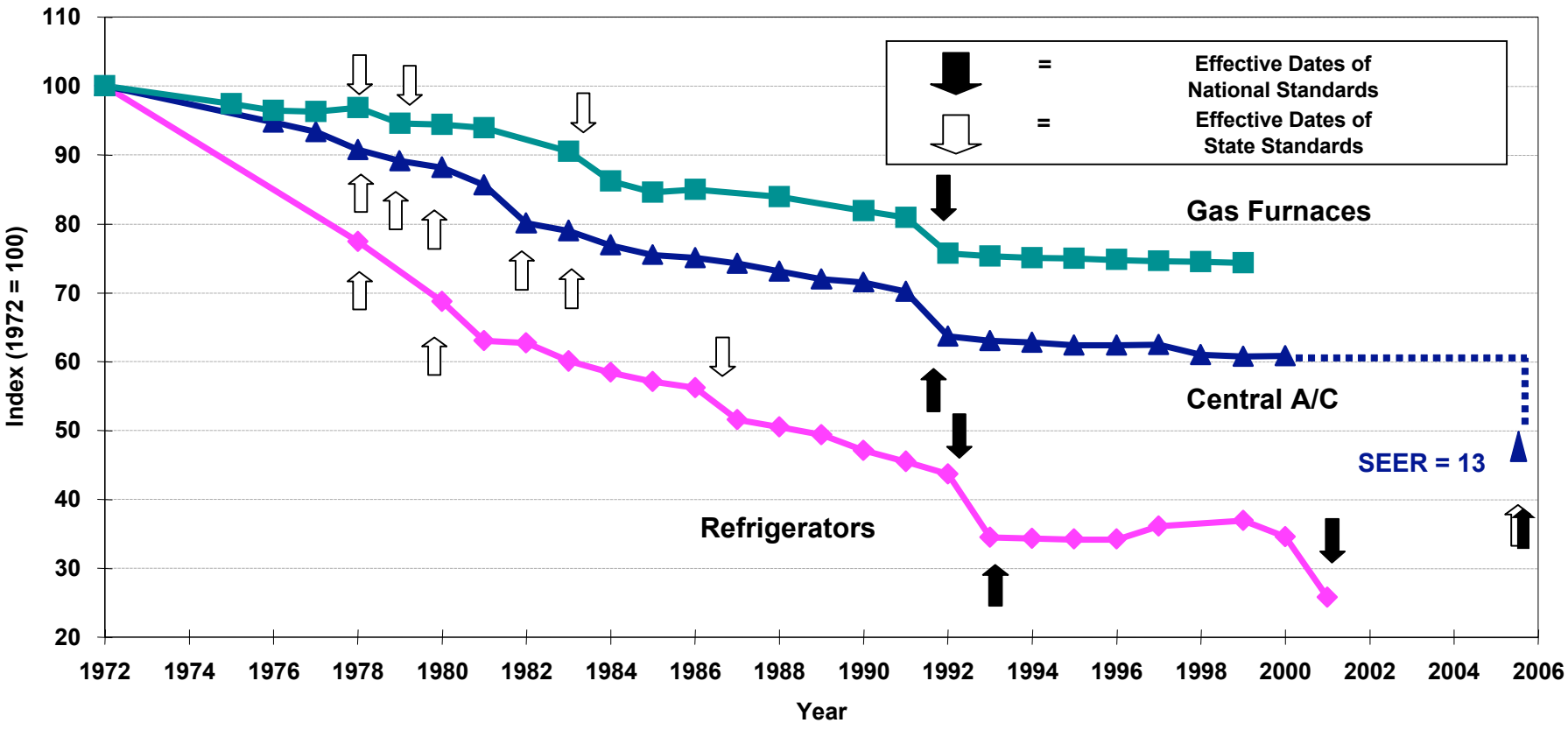



Index (1972 = 1.00) of U.S. Energy Use, GDP, Energy Intensity and Carbon Dioxide
last 10-year CO2 growth = 1.3% per year
3.00
2.50
2.00
1.50
1.00
0.50
0.00
e/gdp
quads
gdp
CO2 (combustion)
2.71
1.37
1.33
(est.)
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005


Per Capita Electricity Consumption
Source: http://www.eia.doe.gov/emeu/states/sep_use/total/csv/use_csv
United States
California
New York
kWh/person
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
year


Per Capita Electricity Consumption
Red States 2004 Election
United States
Blue States 2004 Election
California
kWh/person
16,000
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
year

Impact of Standards on Efficiency of 3 Appliances



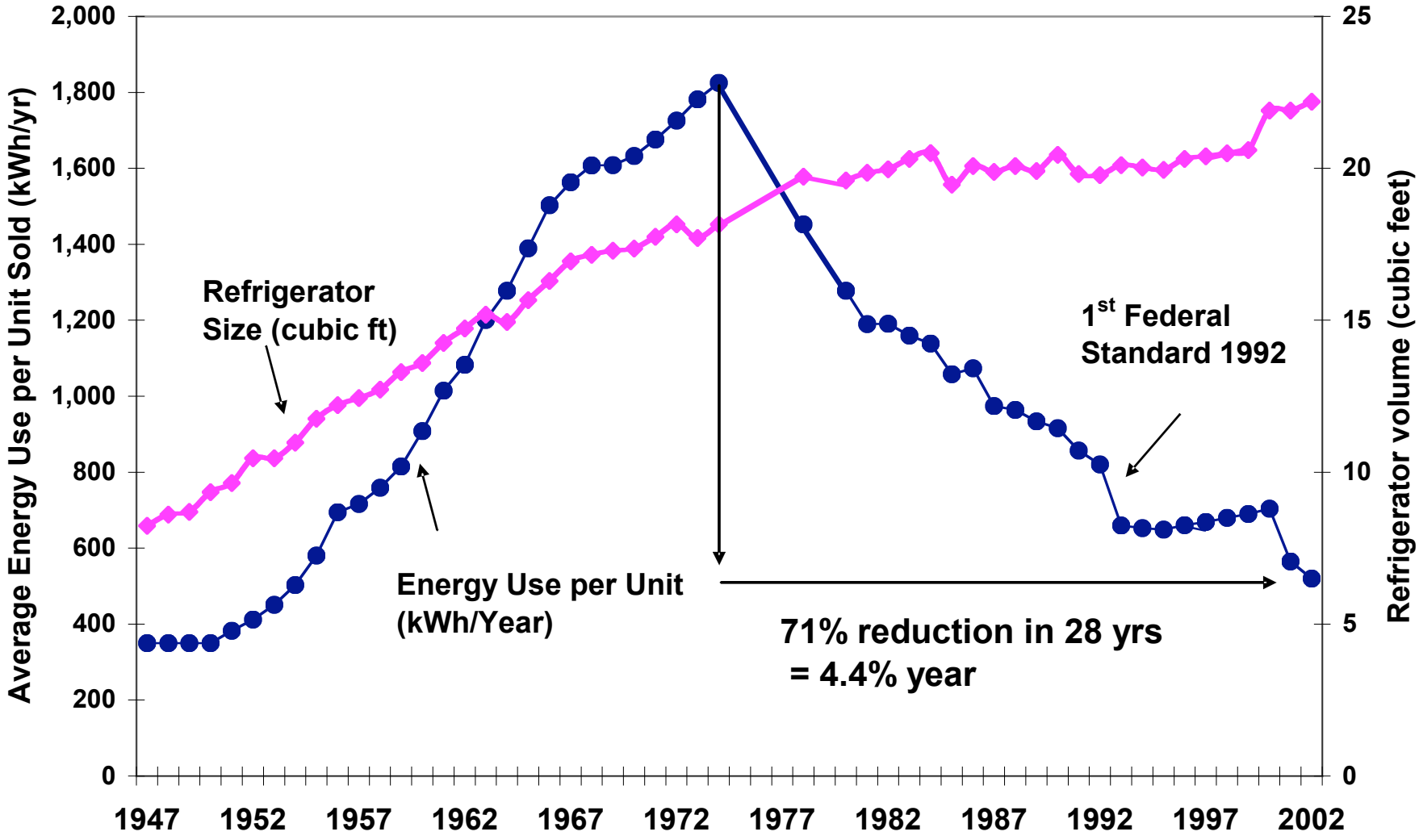
Source: S. Nadel, ACEEE,

in ECEEE 2003 Summer Study, www.eceee.org

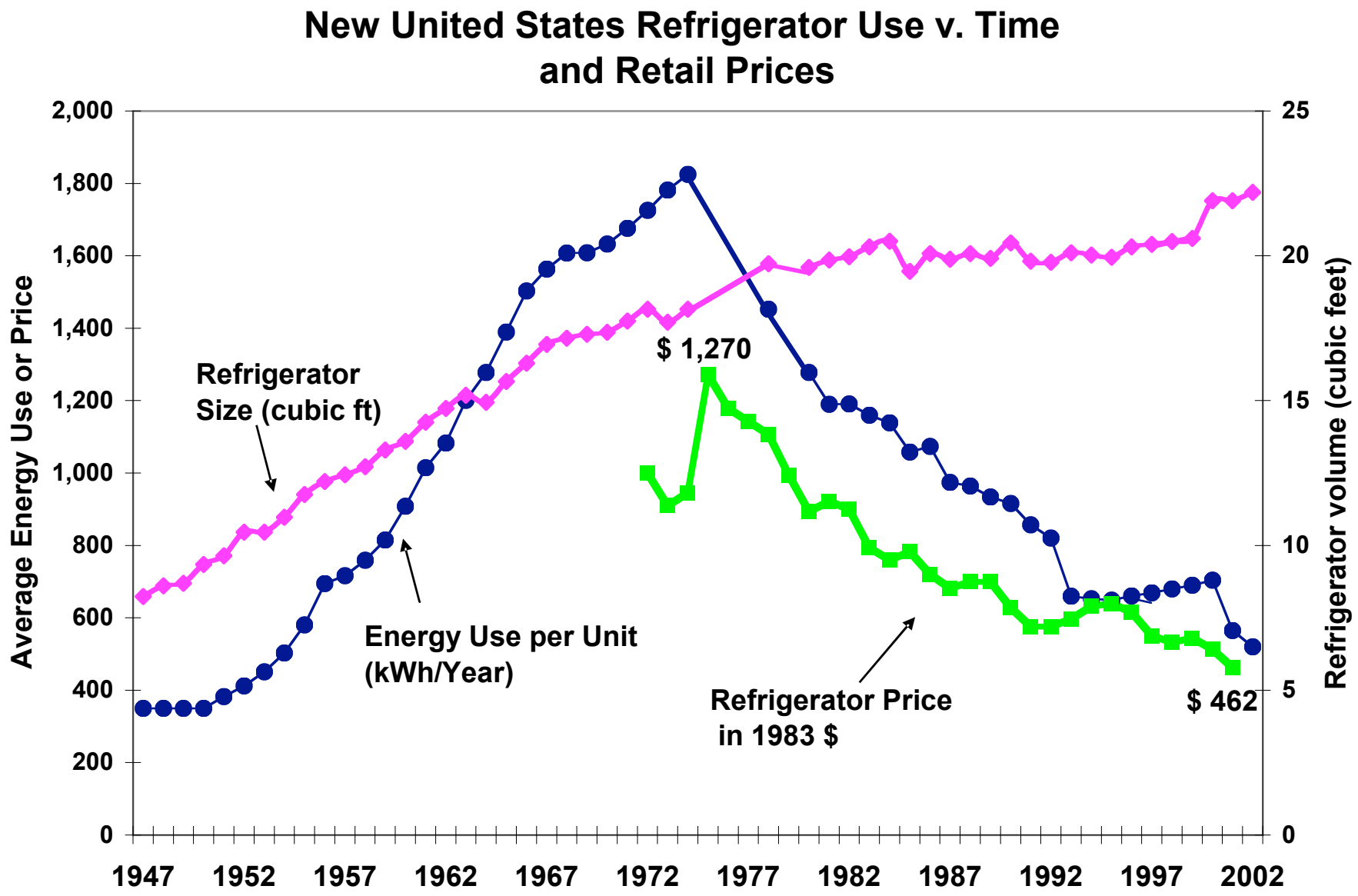
Impact on Lighting of Building + Appliance Standards

- **United States Best Practice measured in Watts/Sq. Ft. of Commercial Building floor area.**
- **In 1974 = 4 Watts/Sq. Ft.**
- **In 2006 = 0.8 Watts/Sq. Ft.**
- **An Enlightened reduction to 1/5**
- **Drivers: Standards, electronic ballasts, and currently, "scotopic" (blue-ish) color, all thanks to LBNL and Sam Berman.**

New United States Refrigerator Use v. Time

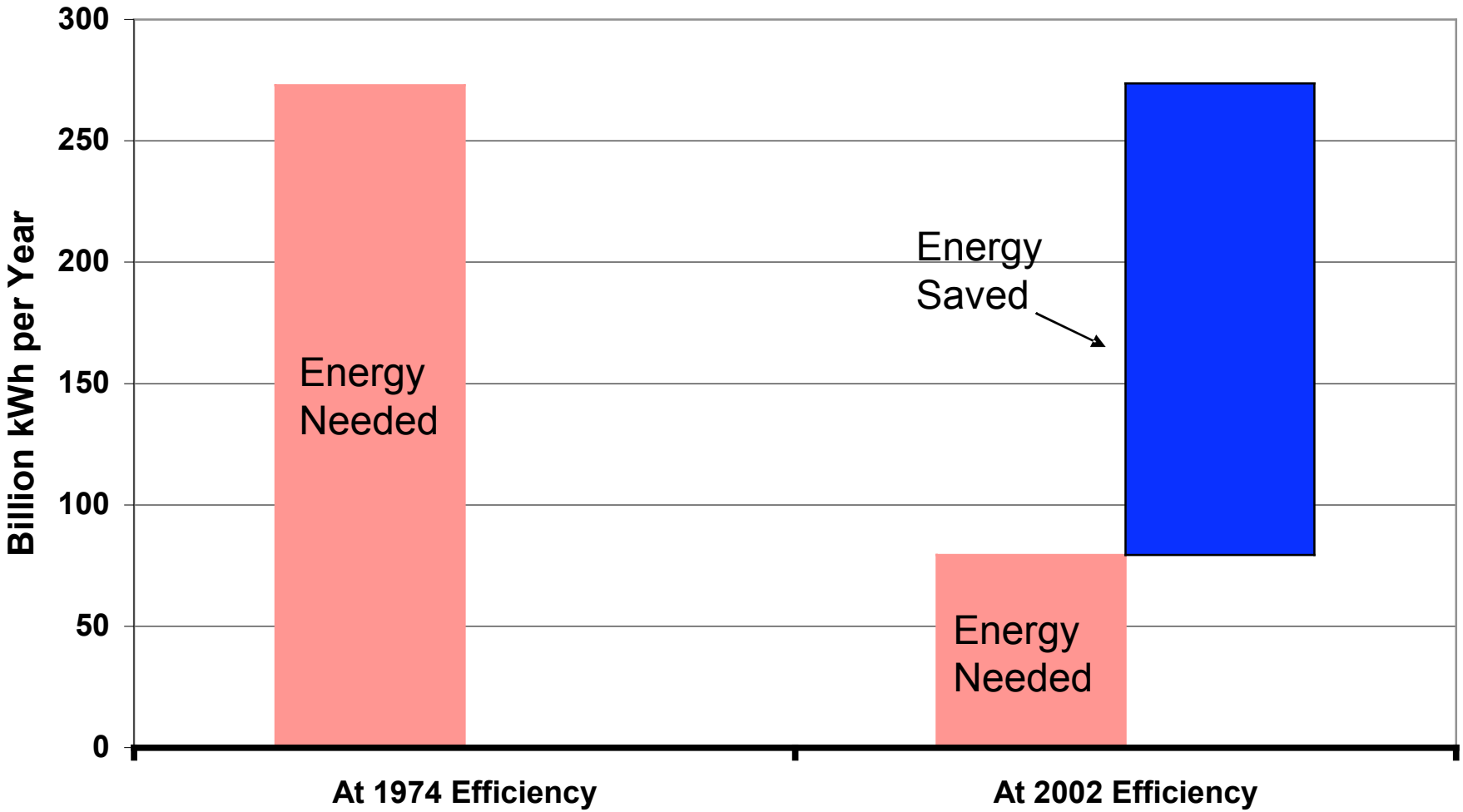


Source: David Goldstein

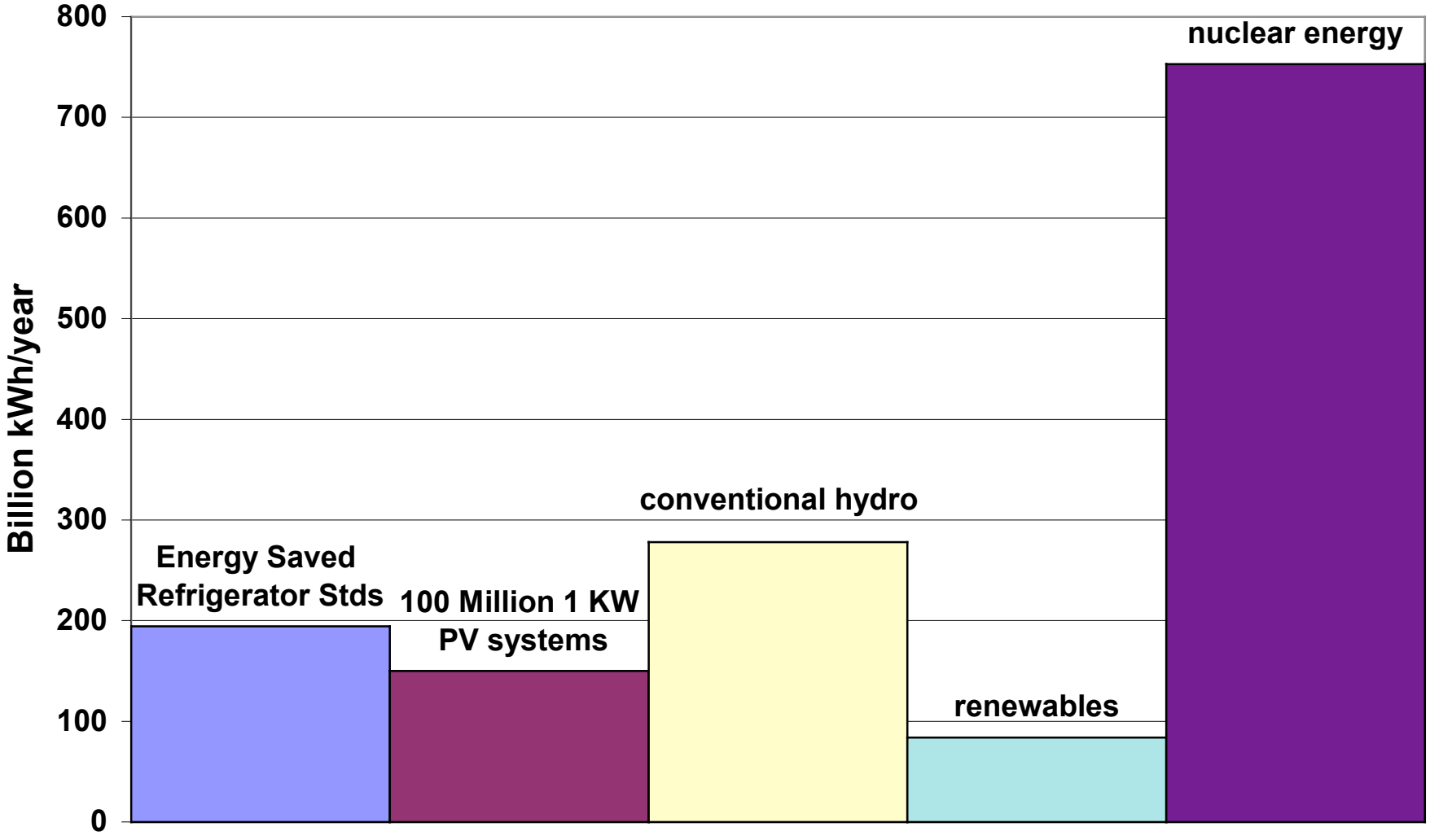


Source: David Goldstein

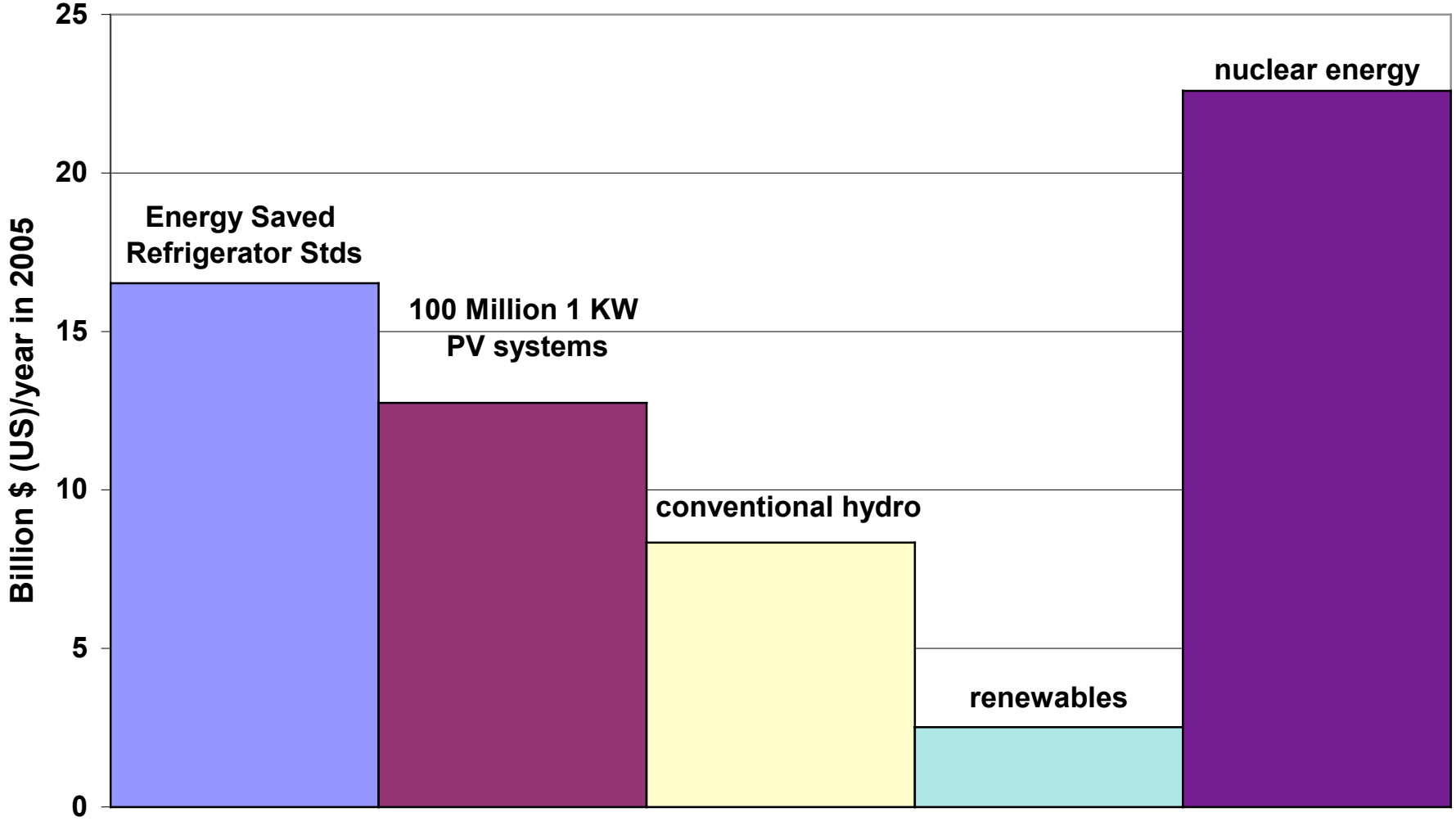
New Refrigerator Energy Use: 71% will be saved when stock completely turns over to 2001 Standards



Annual Energy Saved vs. Several Sources of Supply

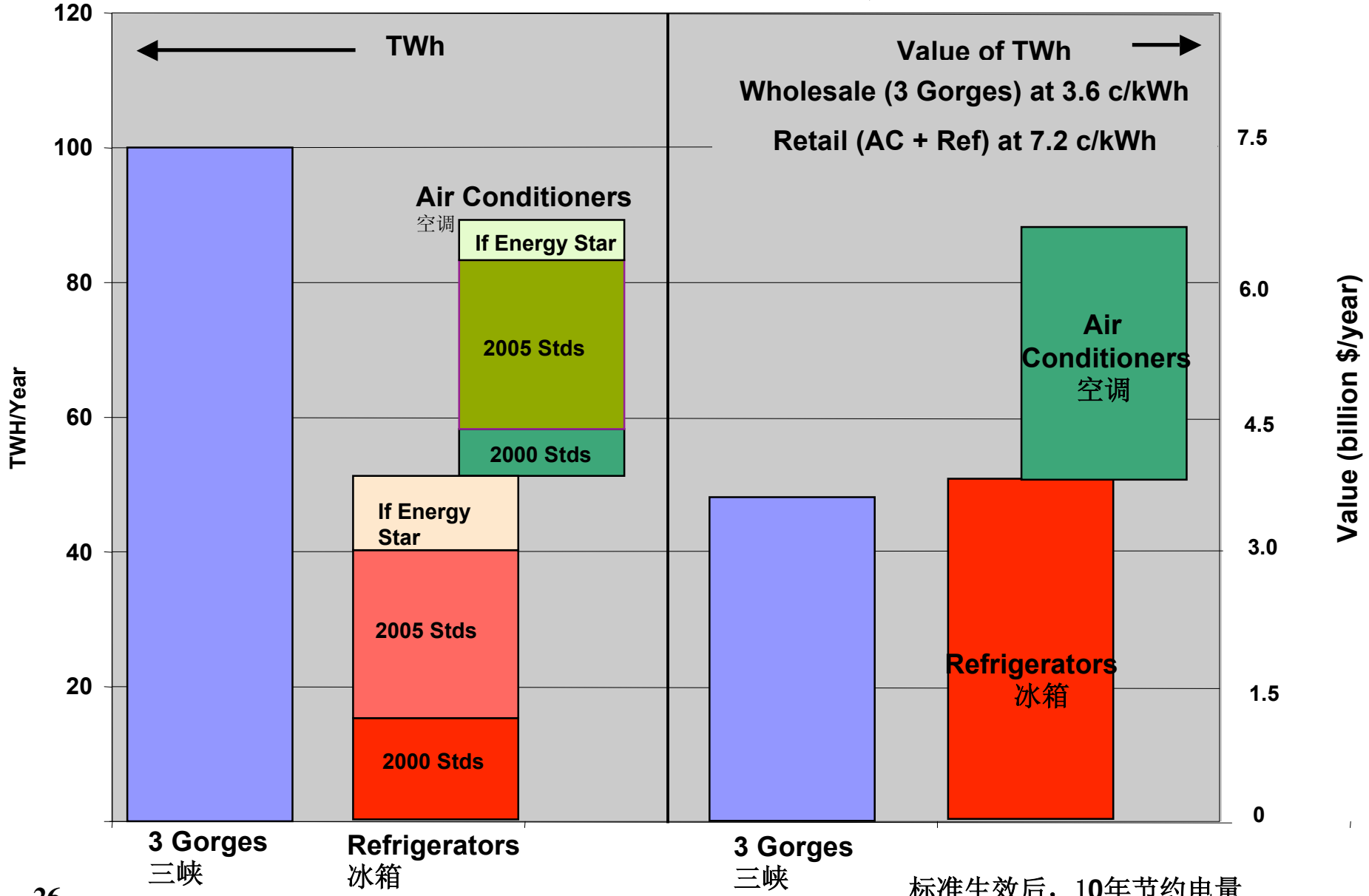


Value of Energy to be Saved (at 8.5 cents/kWh, retail price) vs. Several Sources of Supply in 2005 (at 3 cents/kWh, wholesale price)



Comparison of 3 Gorges to Refrigerator and AC Efficiency Improvements

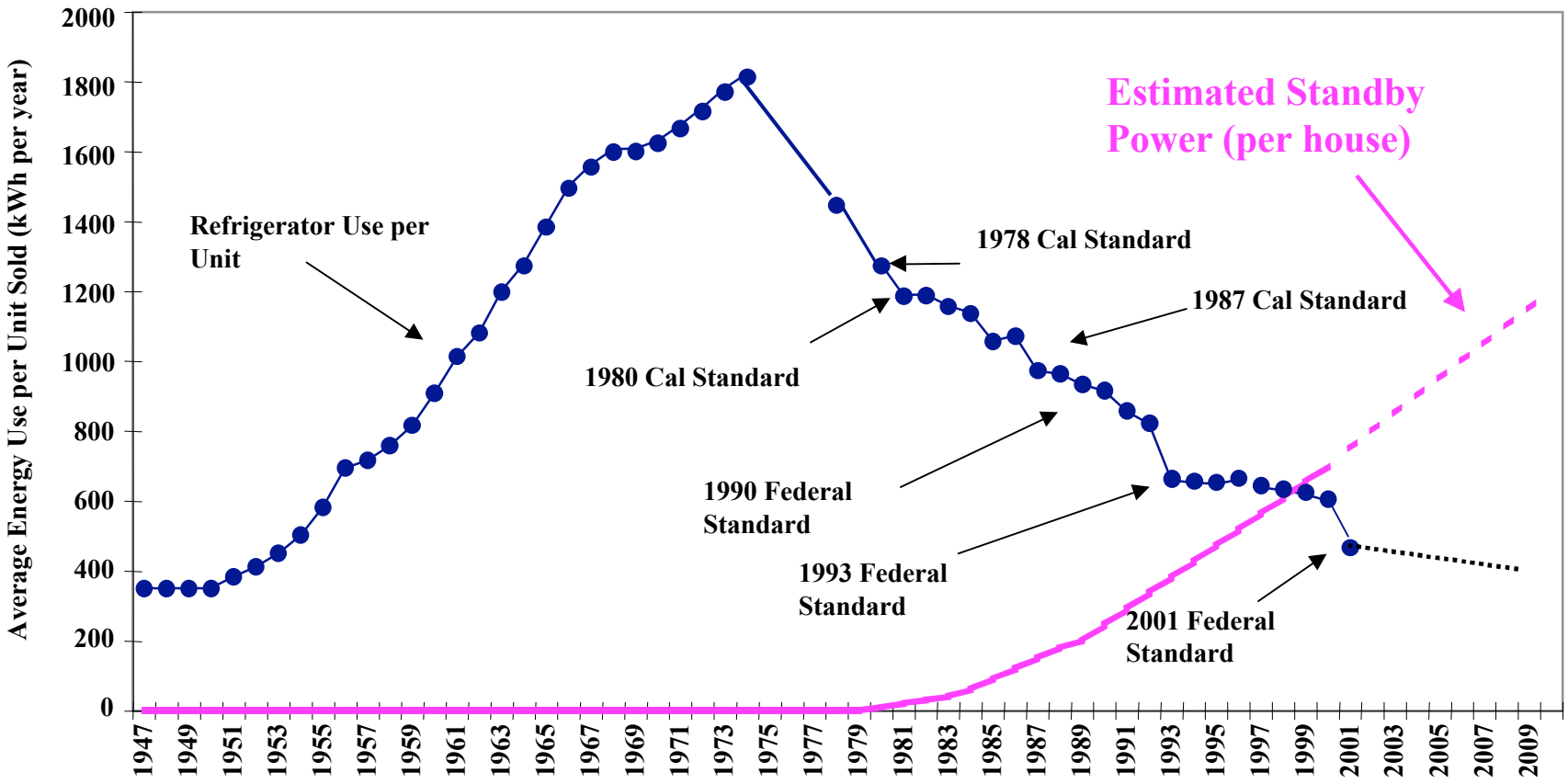
三峡电量与电冰箱、空调能效对比

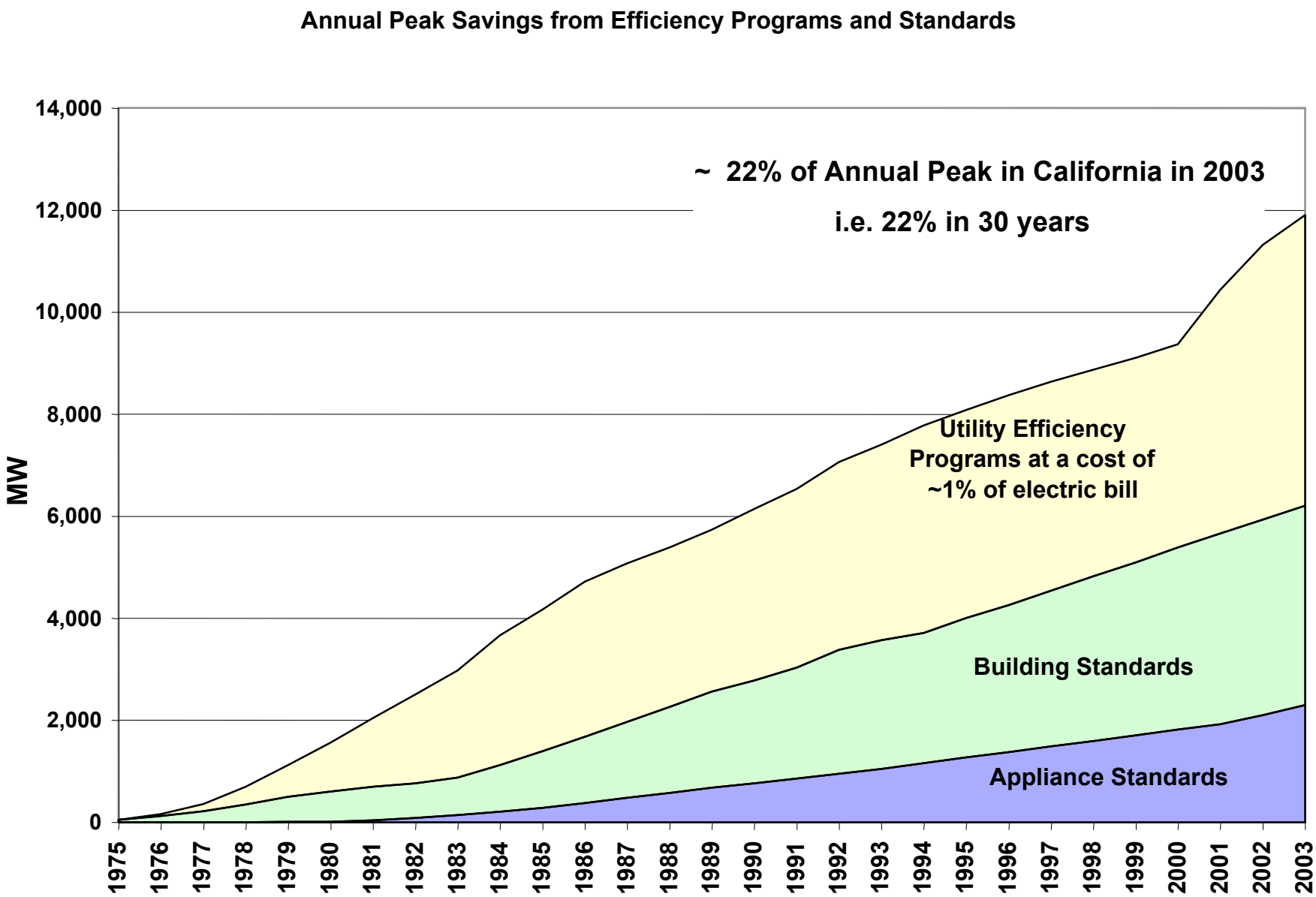


标准生效后，10年节约电量

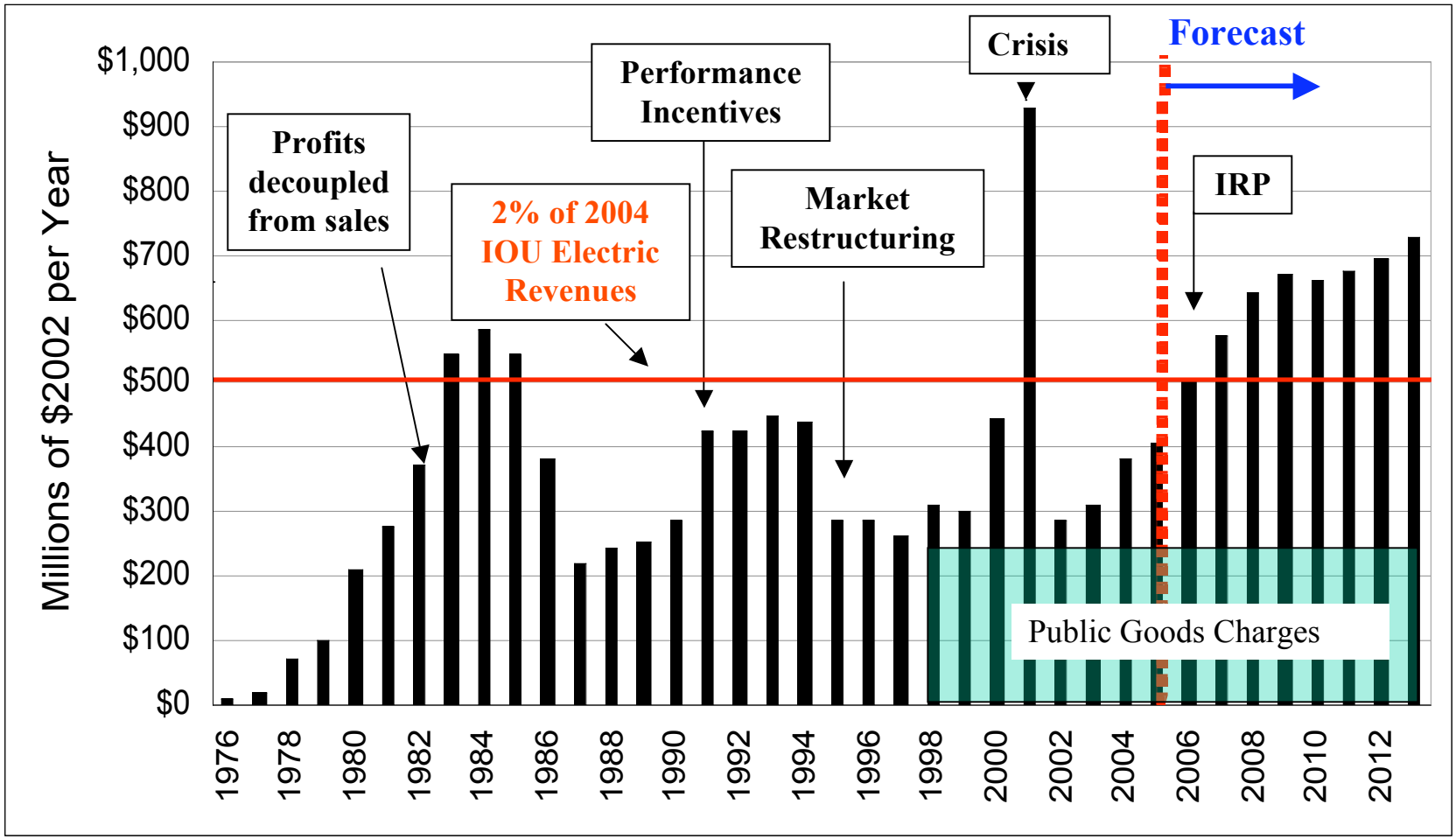
Savings calculated 10 years after standard takes effect. Calculations provided by David Fridley, LBNL

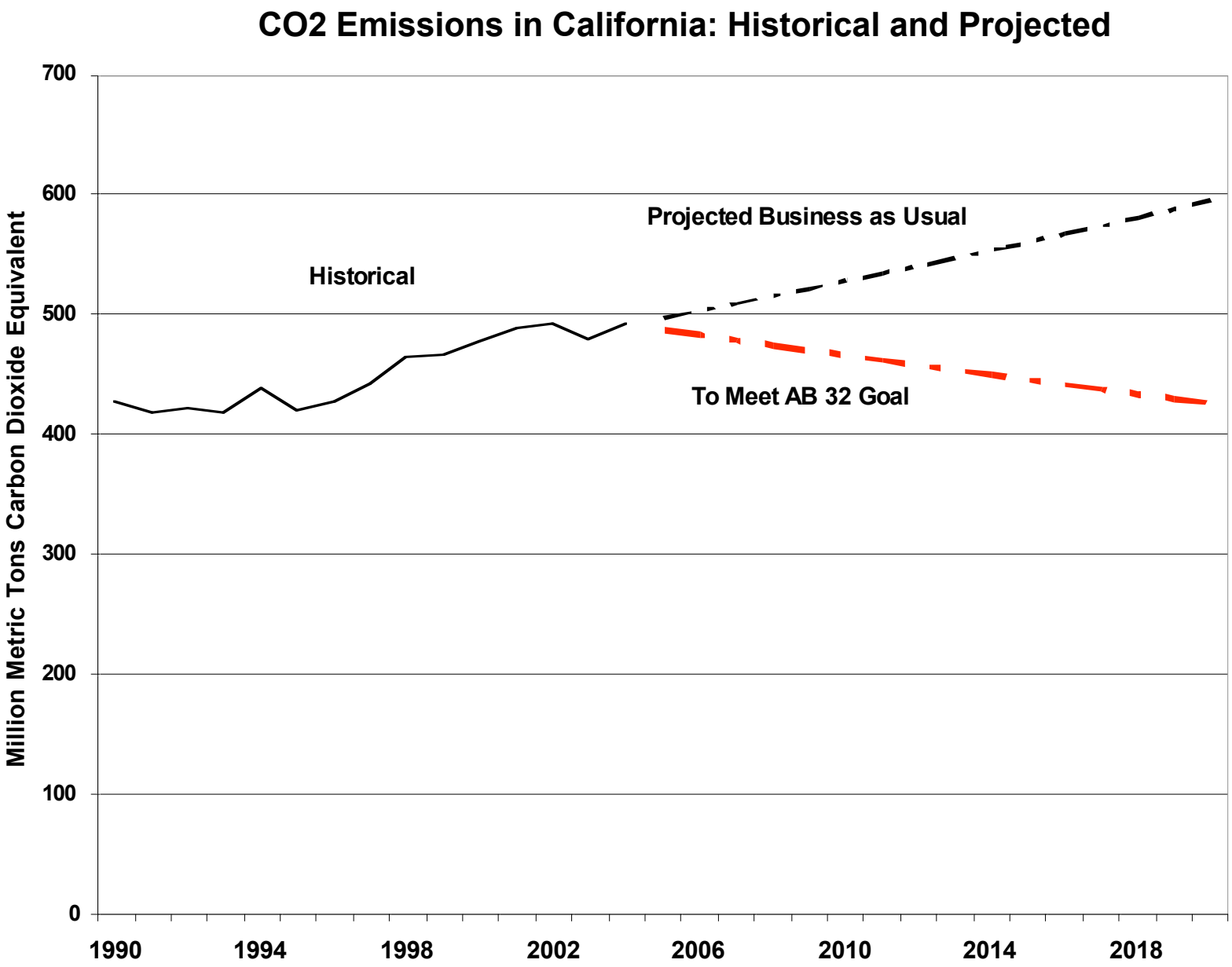
United States Refrigerator Use, repeated, to compare with Estimated Household Standby Use v. Time




Annual Peak Savings from Efficiency Programs and Standards
~ 22% of Annual Peak in California in 2003
i.e. 22% in 30 years
Utility Efficiency Programs at a cost of ~1% of electric bill
Building Standards
Appliance Standards
MW
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

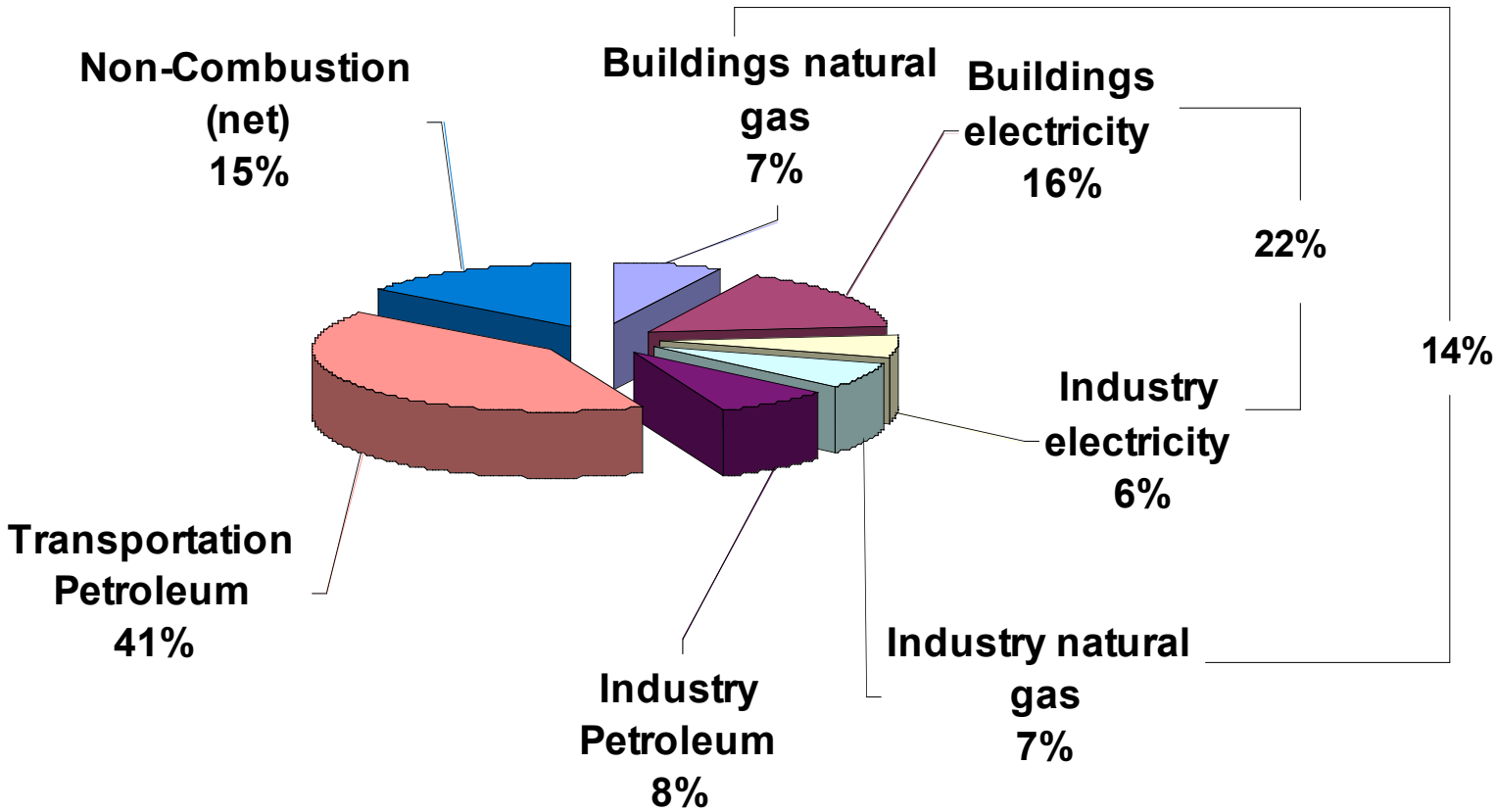
California IOU's Investment in Energy Efficiency




CO2 Emissions in California: Historical and Projected
Million Metric Tons Carbon Dioxide Equivalent
700
600
500
400
300
200
100
0
1990
1994
1998
2002
2006
2010
2014
2018
Historical
Projected Business as Usual
To Meet AB 32 Goal

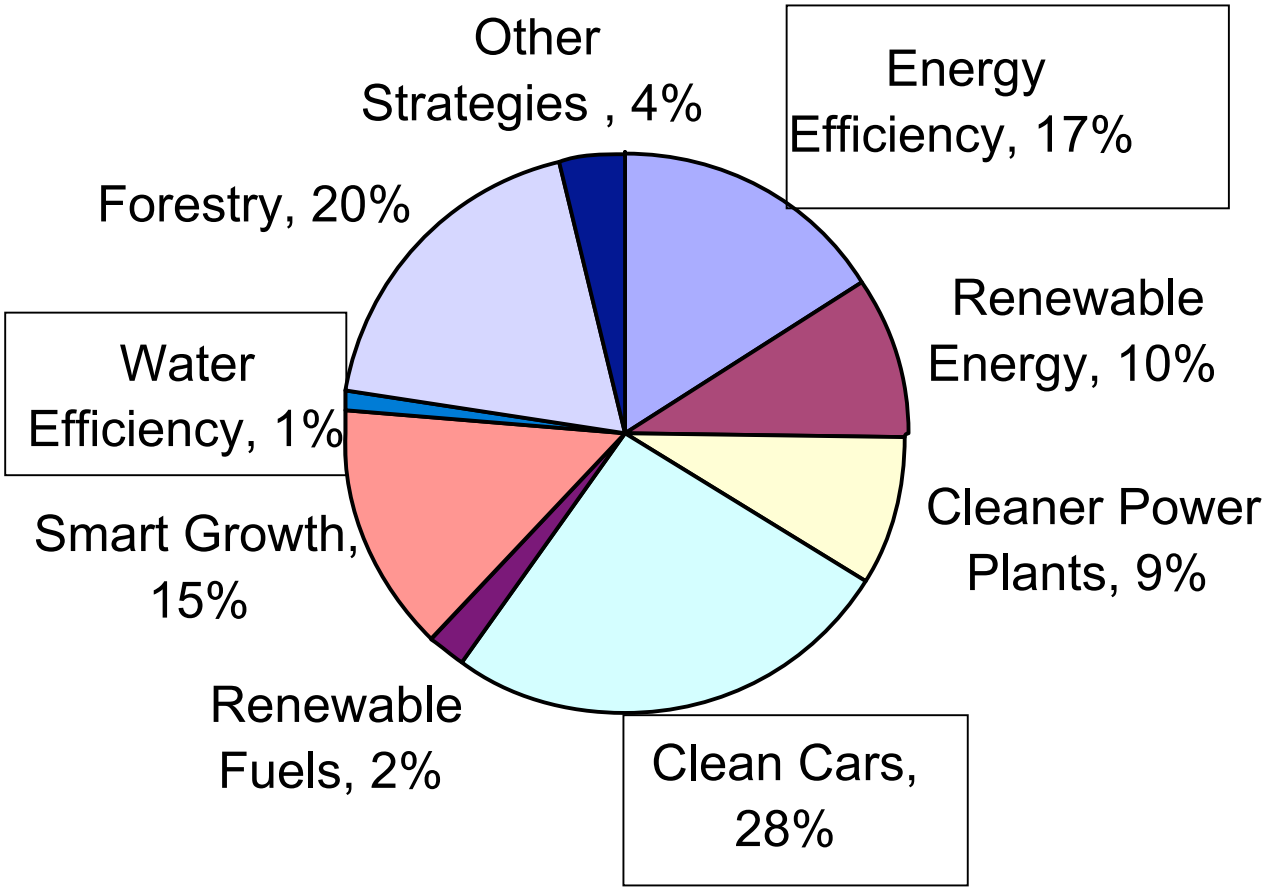
Emissions of CO_2 in California by End Use in 2004

Total Emissions = 490 Million metric tons CO_2 equivalent



Strategies for Meeting California's CO2 Goals in 2020

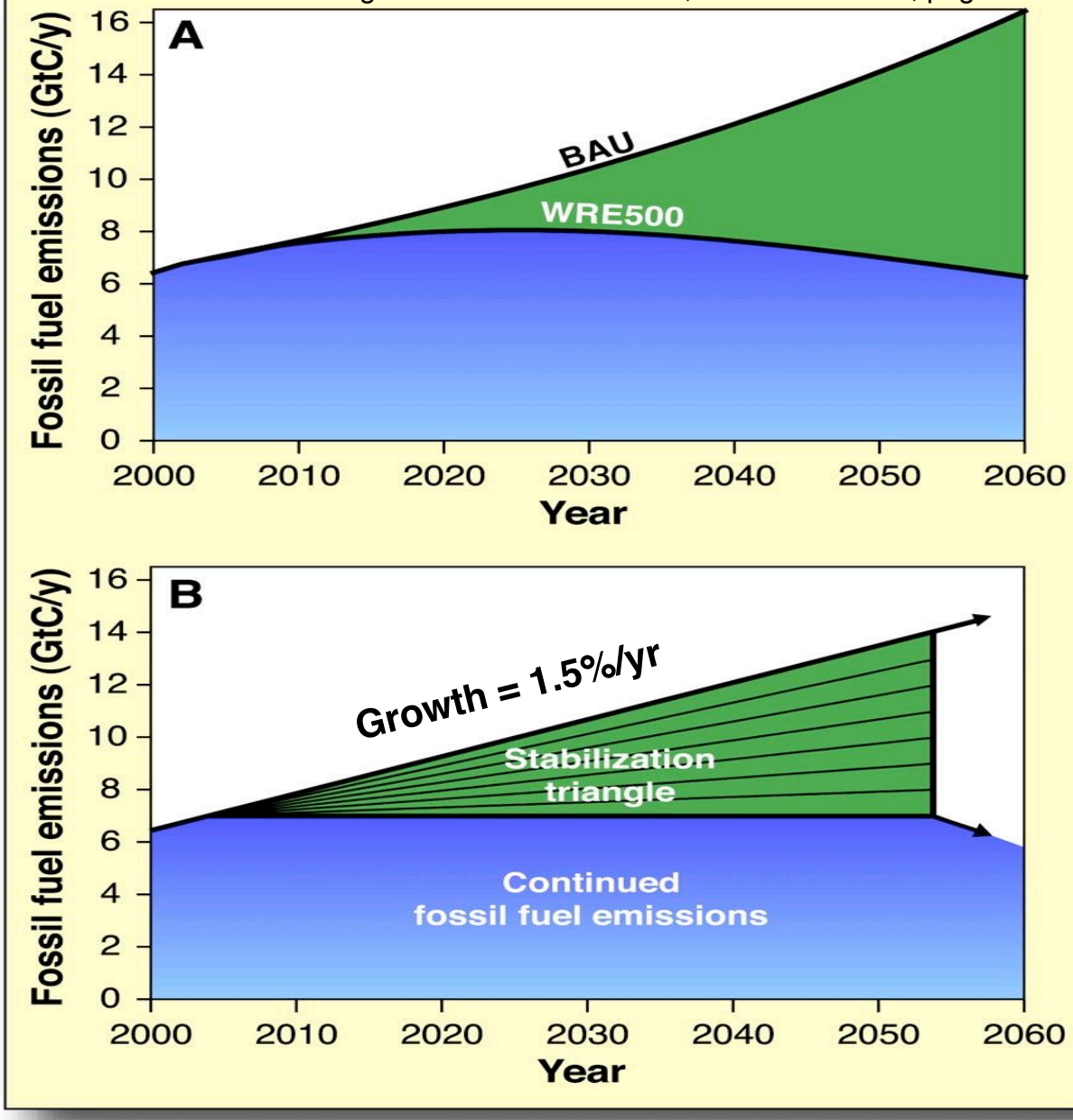
Total Reductions = 174 Million metric Tons CO2 equivalent



Initiatives in Efficiency

- "Fleet" Average for Lighting Efficiency to reduce incandescent share
  - Measured in lumens/watt
- Air conditioning standards
  - U.S. split into regions based on type of weather
  - Hot/dry west differs from warm/wet southeast
  - With peak load as the focus, not seasonal efficiency— "SEER"
- White roofs on existing buildings
- Benchmarking of Commercial Buildings
  - Fine tuning of energy management systems

Source: Stabilization Wedges: Pacala and Socolow, Science Vol 305, page 968

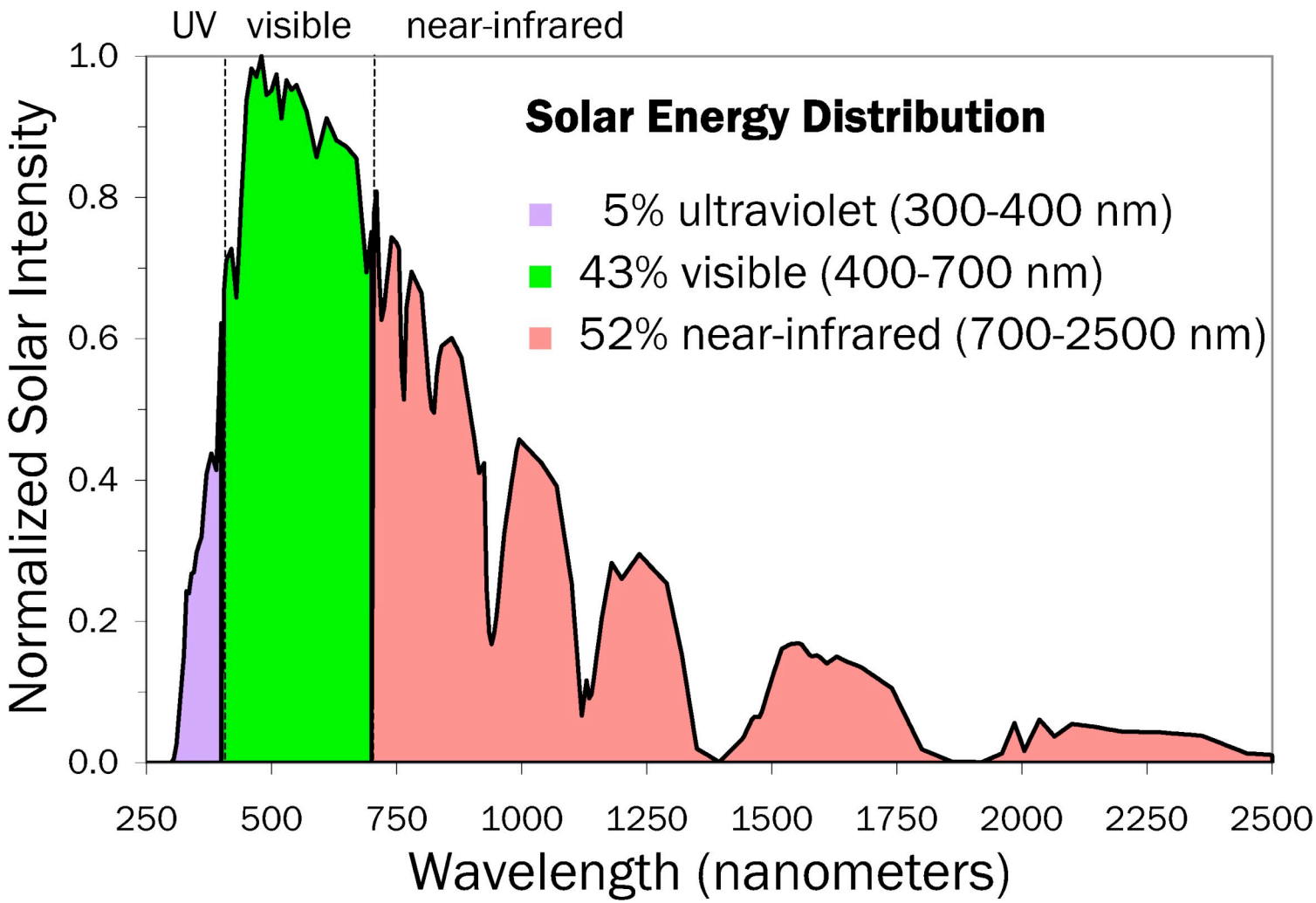


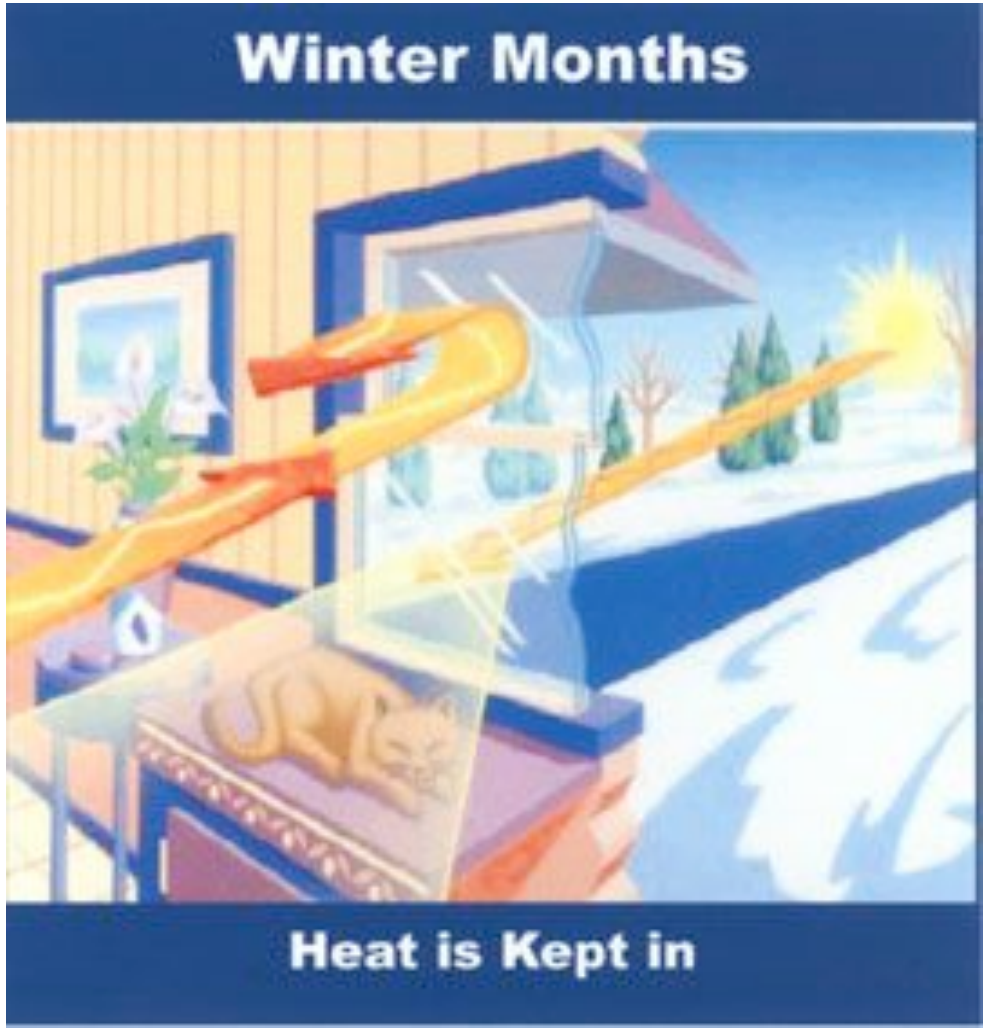
Illuminating Space vs. the Street

Heat Mirror Windows – Steve Selkowitz, LBNL

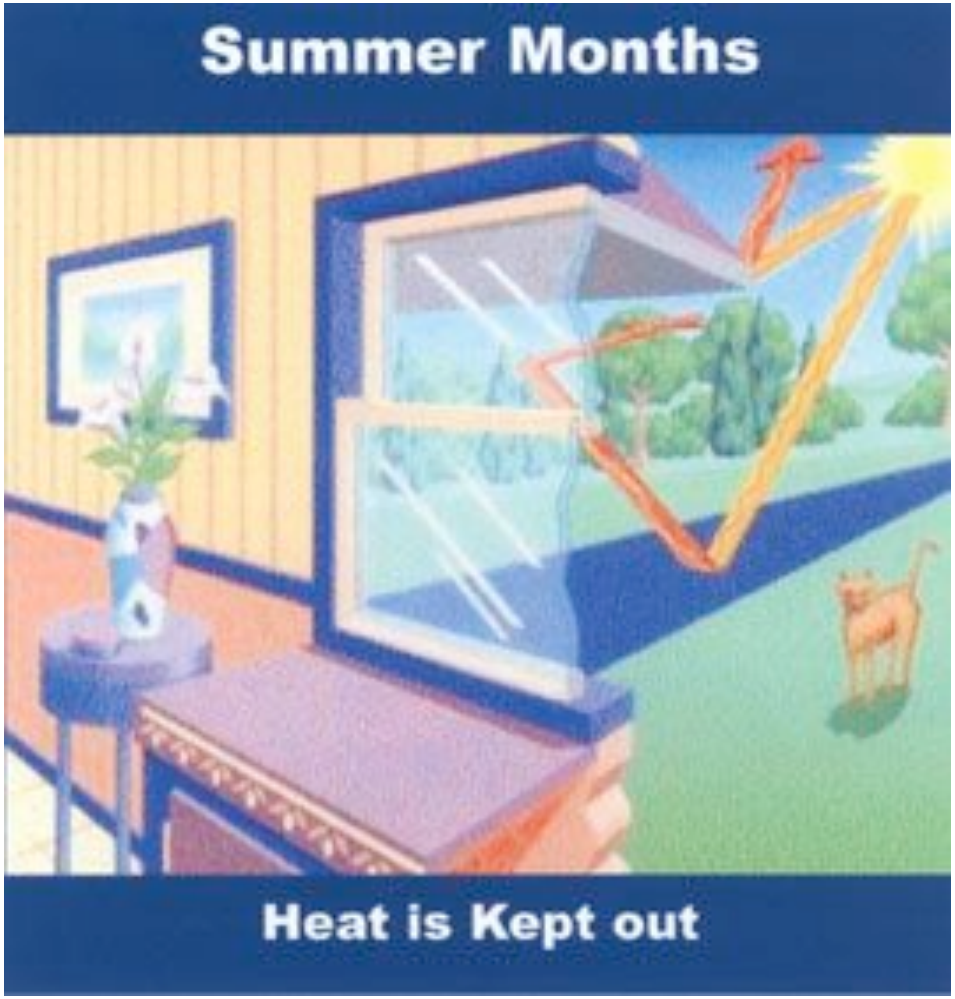
- Low Emissivity films are required by building standards world-wide. They reflect far infrared radiation. Retain indoor heat in winter, reflect outdoor heat in summer. They double the R-value of double glazing, and the inside pane is warm to the touch – more comfortable
- Before low-E, windows were 30% of the heat load of a home – now 15%.
- During a Montana winter, a north-facing low-E window, facing a snowy sunlit slope, is a net energy gainer.
- "Selective film are required for Commercial Buildings in California. They reflect far- and near-infrared radiation, and halve the solar gain though windows; including car windshields in BMW's etc.
- **Modern windows save ~1 Mbod of oil equivalent, = Alaskan oil.**

Cool Colors Reflect Invisible Near-Infrared Sunlight



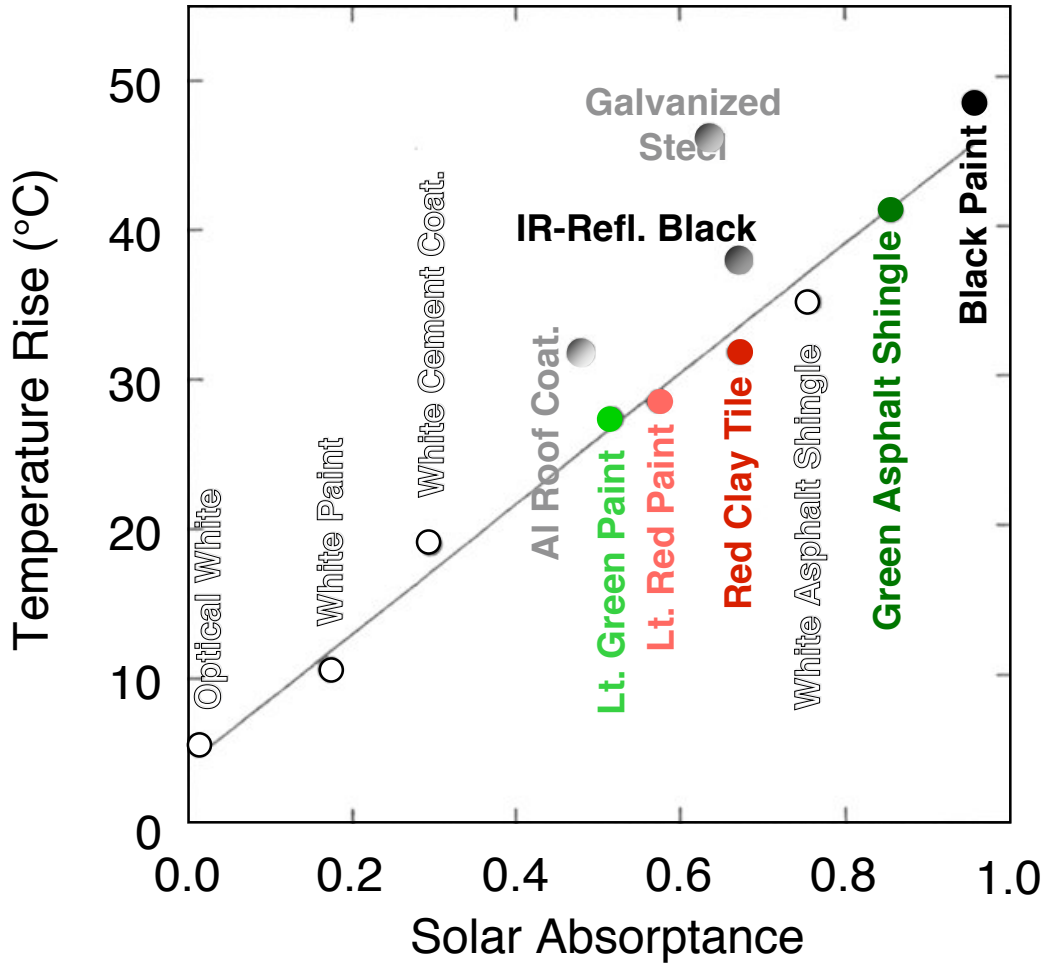


http://www.nwhi.net/Vinyl_Windows/Low_E_Glass.htm

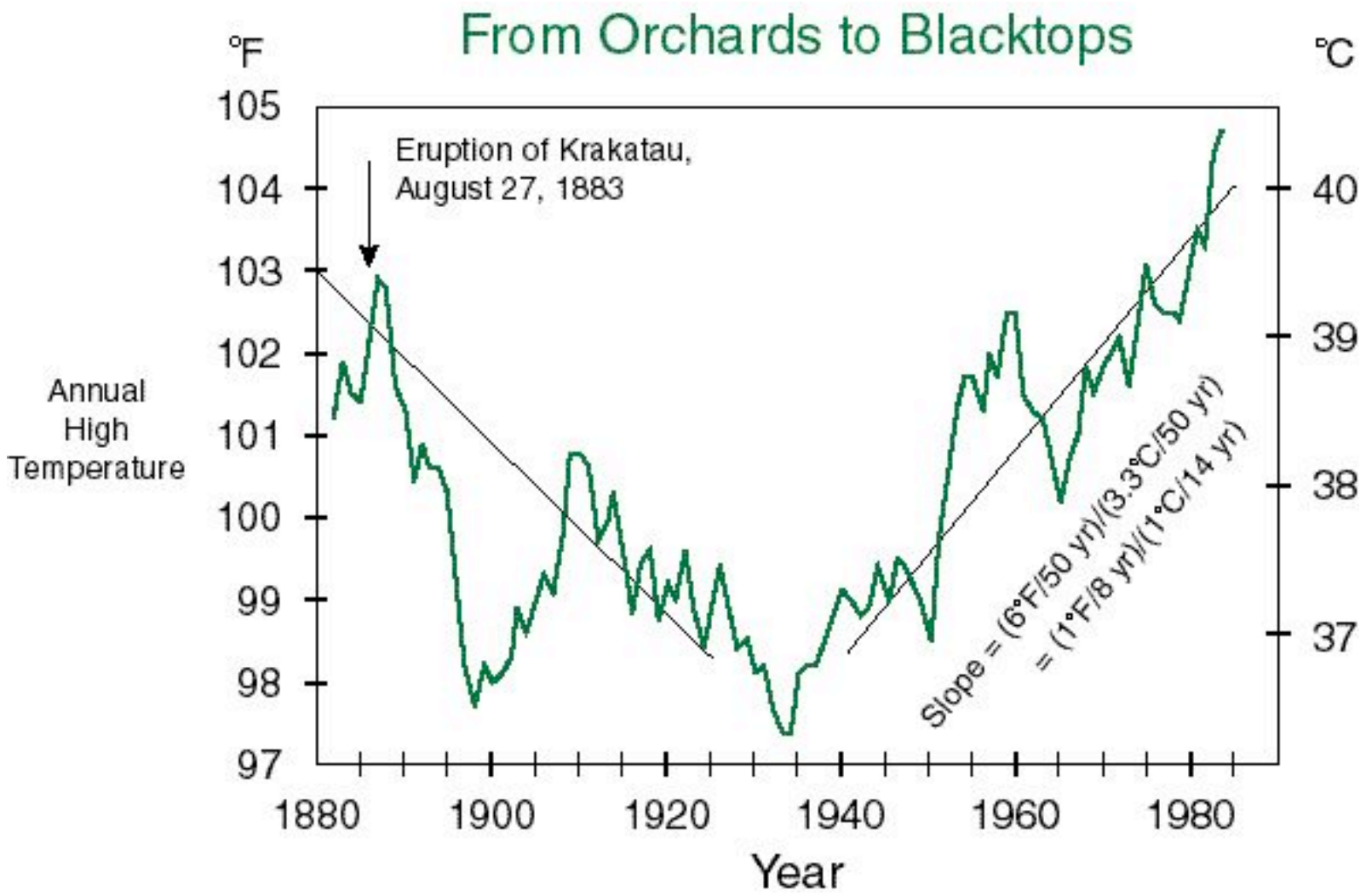


http://www.nwhi.net/Vinyl_Windows/Low_E_Glass.htm

Temperature Rise of Various Materials in Sunlight
Dr. Hashem Akbari, LBNL Heat Island Group



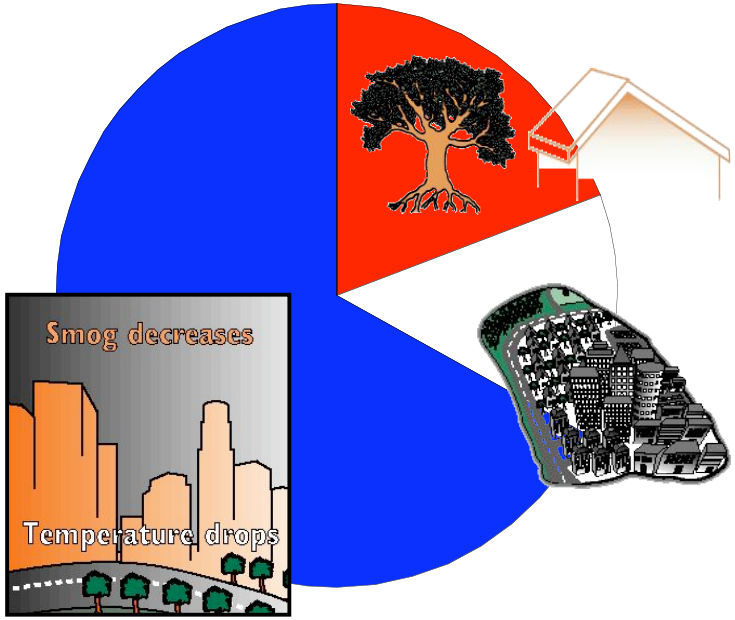
Temperature Trends in Downtown Los Angeles



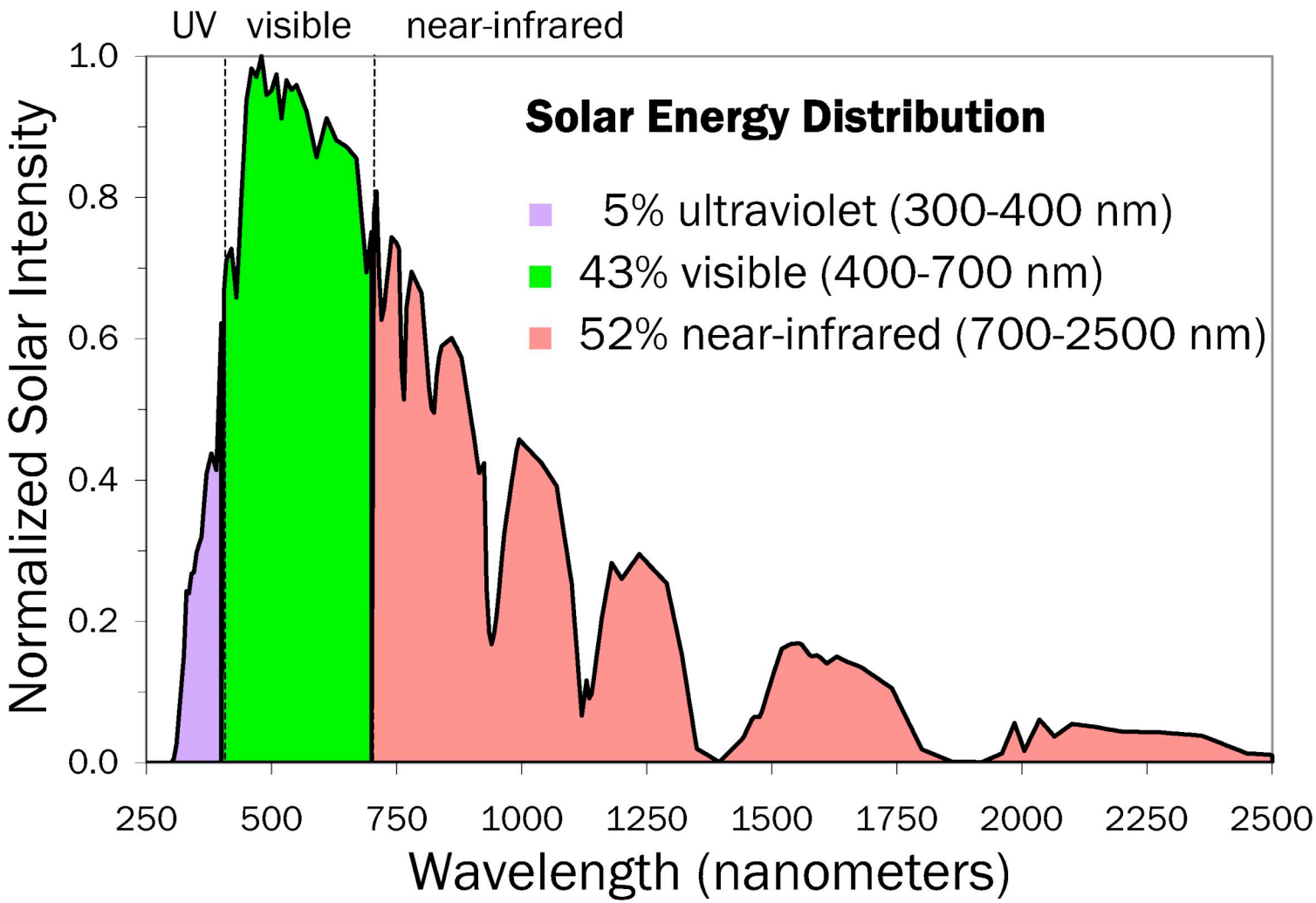
Potential Savings in LA

- **Savings for Los Angeles**
  - Direct, $200M/year
  - Indirect, $140M/year
  - Smog, $360M/year

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



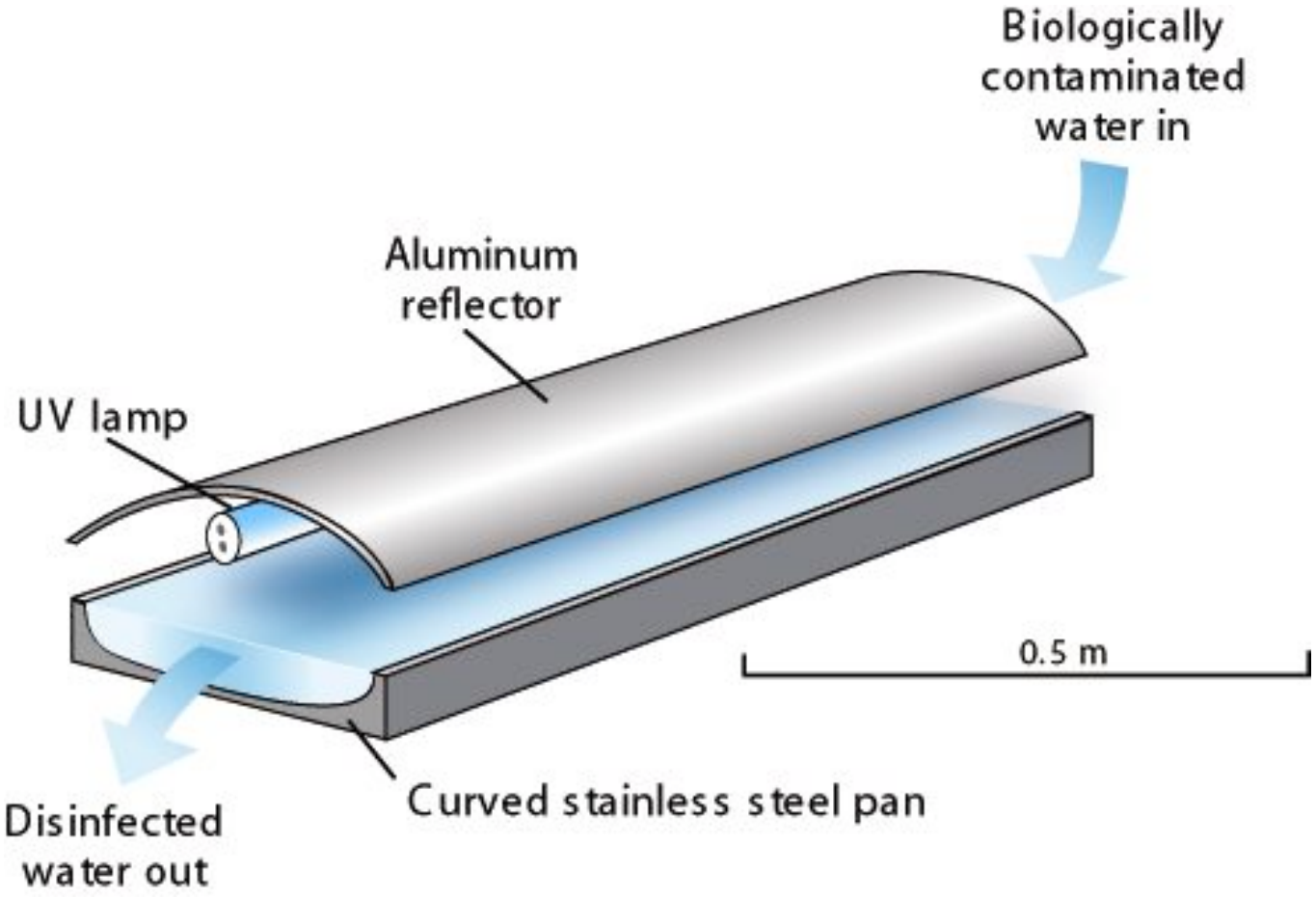
Cool Colors Reflect Invisible Near-Infrared Sunlight



From Cool Color Roofs to Cool Color Cars

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

UV Water Purification



Kothapeta (Dec. 2005) commissioning test

Source: Dr. Ashok Gadgil, LBNL

Typical interior layout of the WaterHealth Community System Installation in Kothapeta

Source: Dr. Ashok Gadgil, LBNL

Ultra Violet Water Purification for Villages in Developing World

Ashok Gadgil at LBNL points out if UV treatment replaces boiling 10 tons of water per day, each system avoids 3 tons of CO_2 per day. An American car emits only 4 tons of CO_2 per YEAR

UVW meets / exceeds WHO and US EPA purification criteria

- Energy efficient: 60 watts disinfects 1 ton / hour
- **Low cost: price, including profit, is under 1 cent (US)/gallon**
- Reliable, Mature components
- Can treat un-pressurized water
- Rapid throughput: 12 seconds under lamp
- Low maintenance: once every three months
- >50 units now operating in India and Philippines, adding one village/week
- http://www.waterhealth.com/
- ***If 1 Billion villagers can avoid boiling 10 liters/day of water (by burning kerosene), the avoided CO_2 is equivalent to 5 million barrels/day of gasoline, which is more than half of all US gasoline use.***

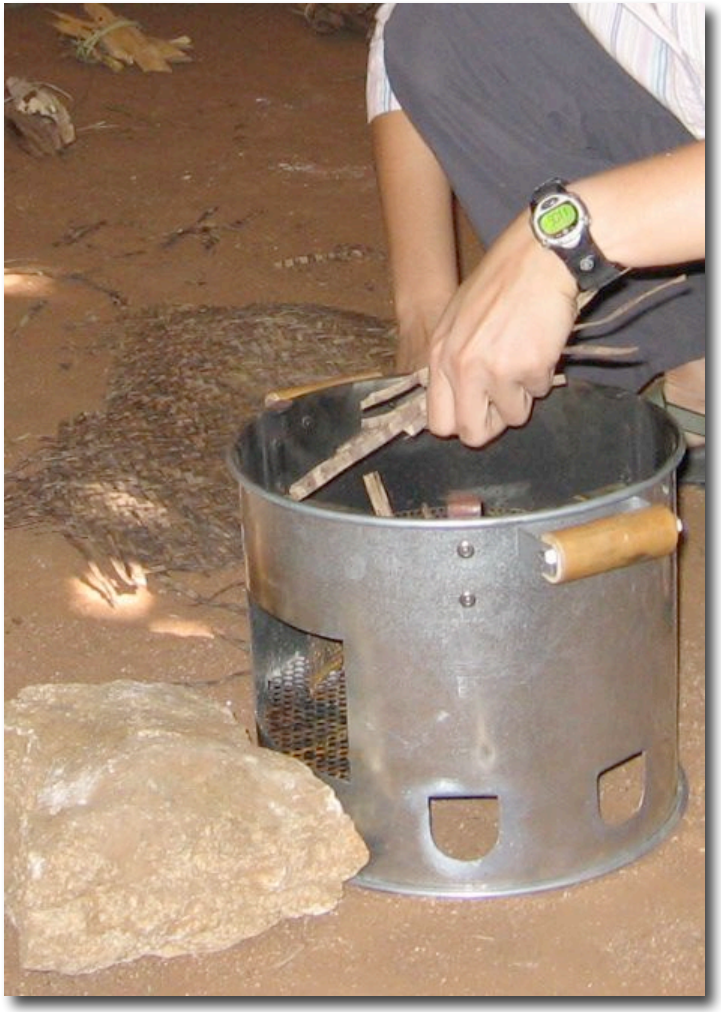
Dr. Ashok Gadgil's Darfur Cookstove Project

In Nov.-Dec. 2005, he visited Darfur camps, and showed that with a $10 metal stove, and training to use it, only half the fuelwood is needed.

The stove saves fuelwood worth $160 annually for a refugee family

Since that time, Ashok Gadgil has improved stove efficiency by another factor of two

http://www.osti.gov/bridge/servlets/purl/878538-hMpqN3/878538.PDF



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http://www.ifc.org/led

LEDs Powered with Photovoltaics

- Evan Mills at LBNL points out the following:
- If 1.6 billion people could replace kerosene lamps with LEDs, emissions would drop by the equivalent of 1.3 million barrels of petroleum per day
- http://eetd.lbl.gov/emills/PUBS/Fuel_Based_Lighting.html
- The above estimate was for residential lamps only
- Including commercial uses, Mills estimates > 2 Mbod
- For comparison, U.S. gasoline use is 9 Mbod

Hurricane lanterns

- Teachers grading homework with light levels 1% of western standards

Tanzania (teachers' home)

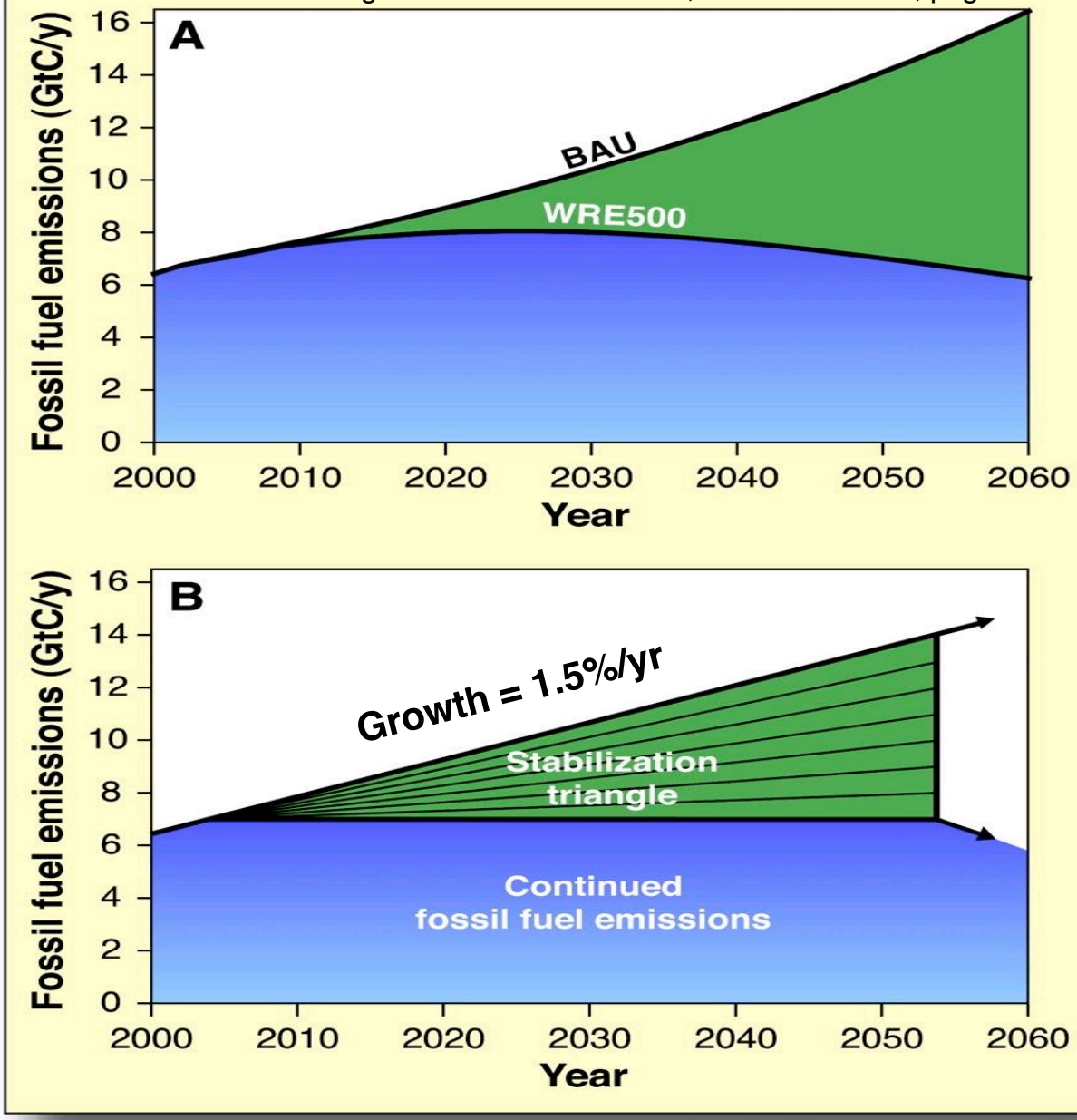
Productive uses

Tanzania: fruit seller - flame [left]; 1-watt white LED [right]

Productive uses: big market driver

Tanzania: shoe seller - flame [left]; 1-watt white LED [right]

Source: Stabilization Wedges: Pacala and Socolow, Science Vol 305, page 968



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- This talk available on my web page
- Just Google

“Art Rosenfeld”