Energy Efficient Technologies and Policies and Their Impact on Climate Change - Lessons from US and California

Workshop on Balancing Energy, Development and Climate Priorities in India

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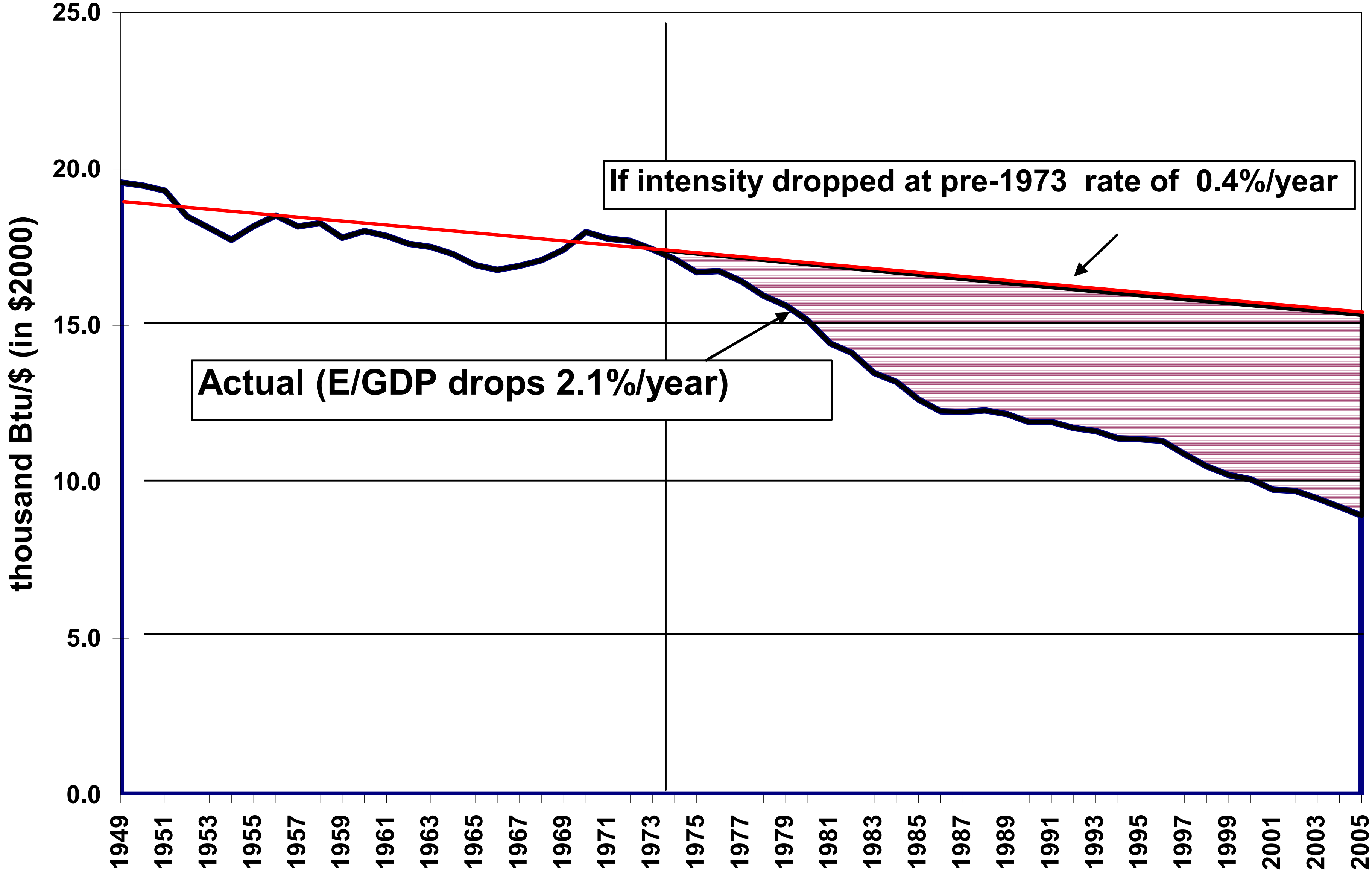
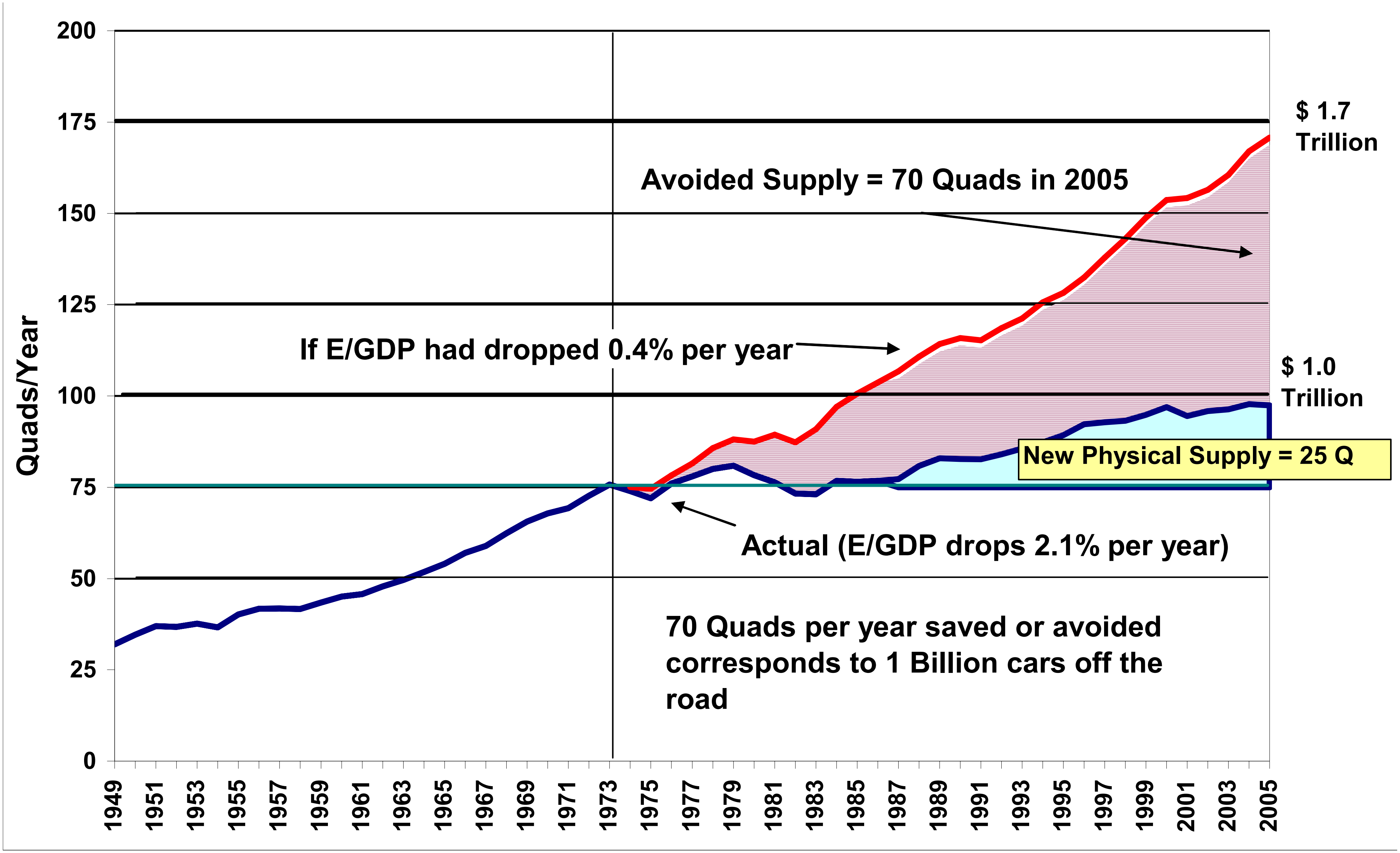
Energy Intensity in the US (1949 – 2005)



Energy Use in the US (1949 – 2005)



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).

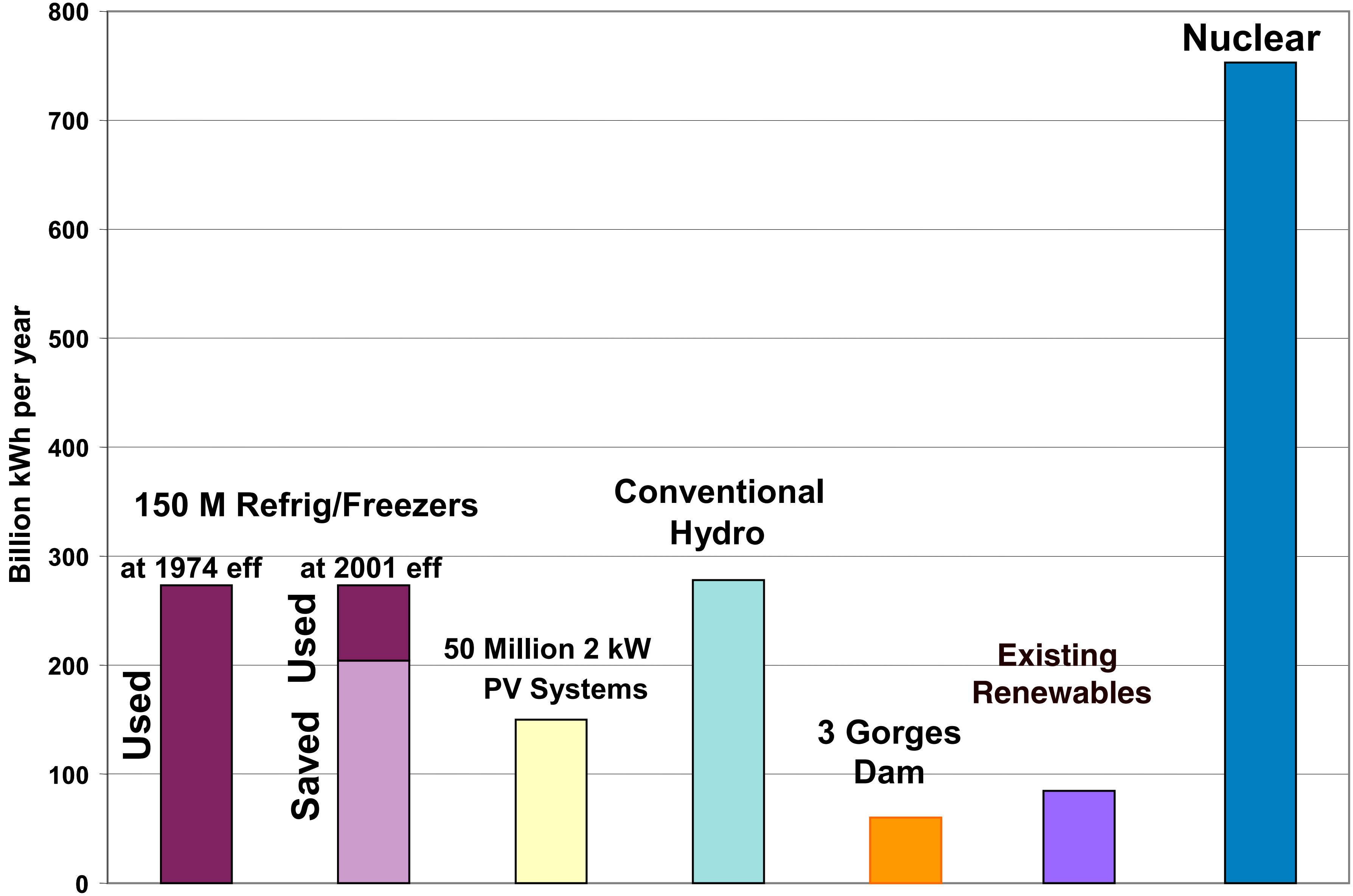
How Much of The Savings Come from Efficiency (cont'd)?

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

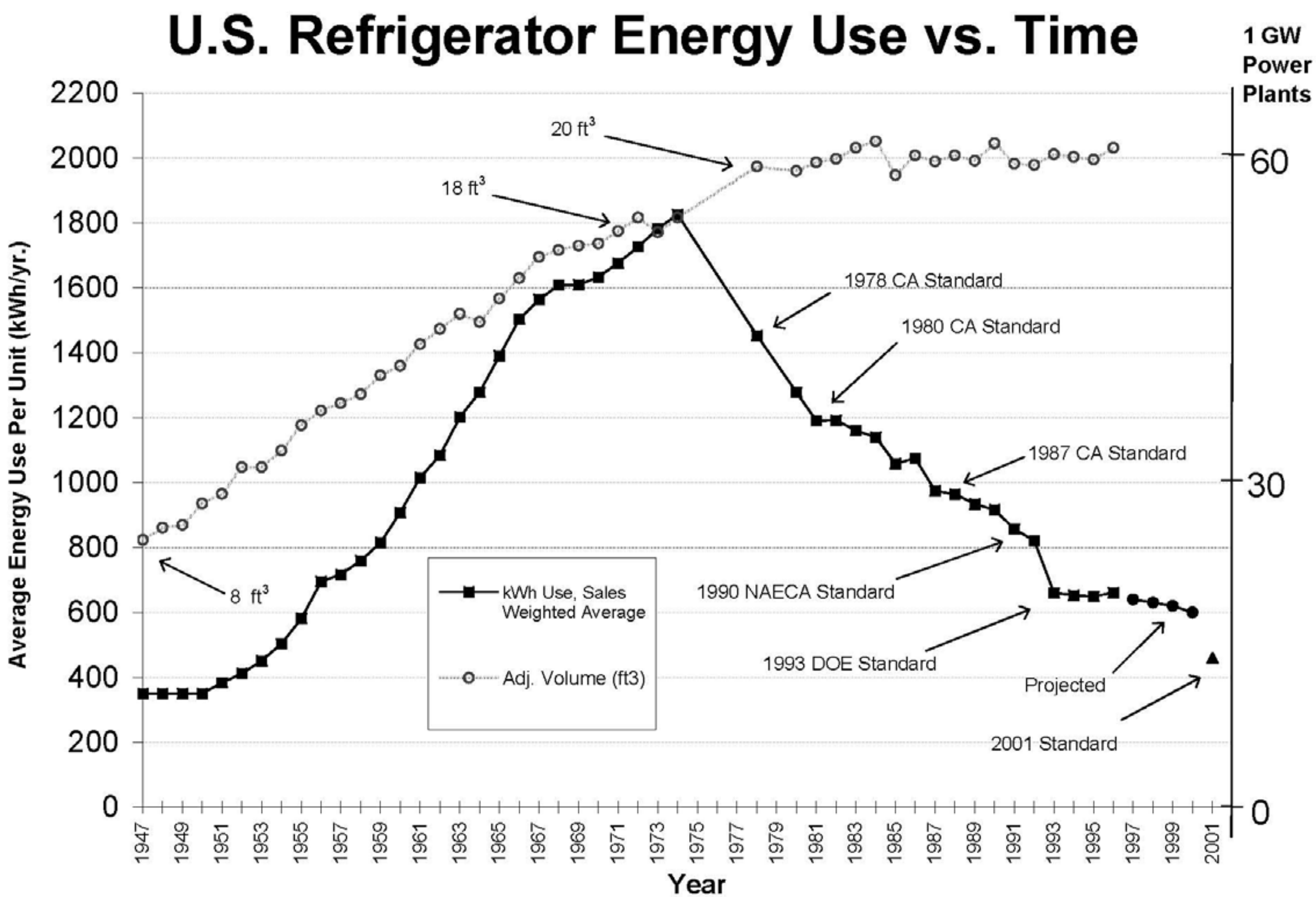
	Billion $
Space Heating	**40**
Air Conditioning	**30**
Refrigerators	**15**
Fluorescent Tube Lamps	**5**
Compact Floursecent Lamps	**5**
Total	**95**

- 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 transportation, and 1/3 is buildings and industry.

Stacking Energy Savings From Refrig. Stds. Against Energy Supply - 1

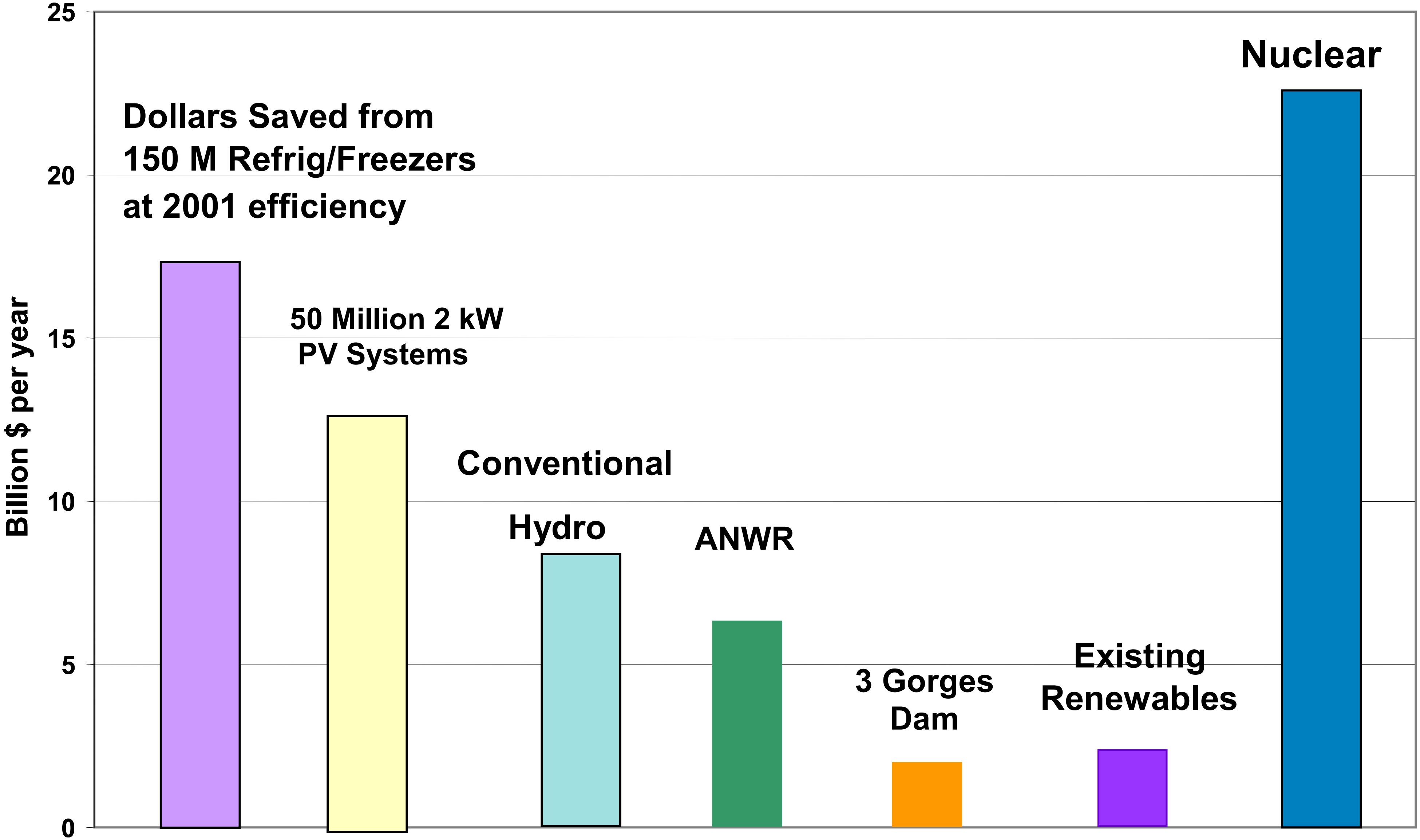


Stacking Energy Efficiency From Refrig. Stds. Against Energy Supply - 2



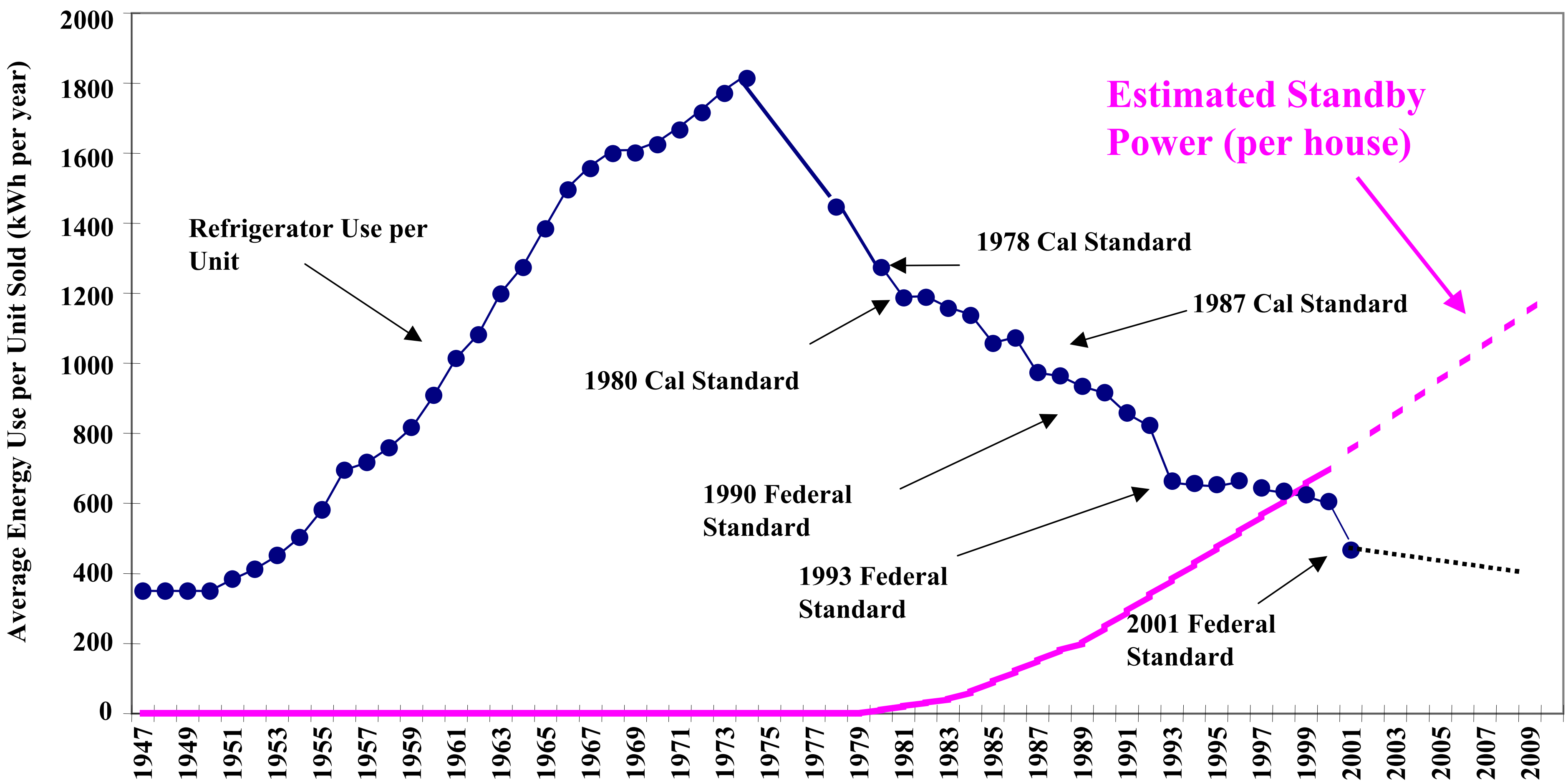
Source: Geller-Goldstein Szilard Lecture, Physics and Society 28 No. 2, 1999, American Physical Society, College Park

Stacking Energy Efficiency From Refrig. Stds. Against Energy Supply - 3

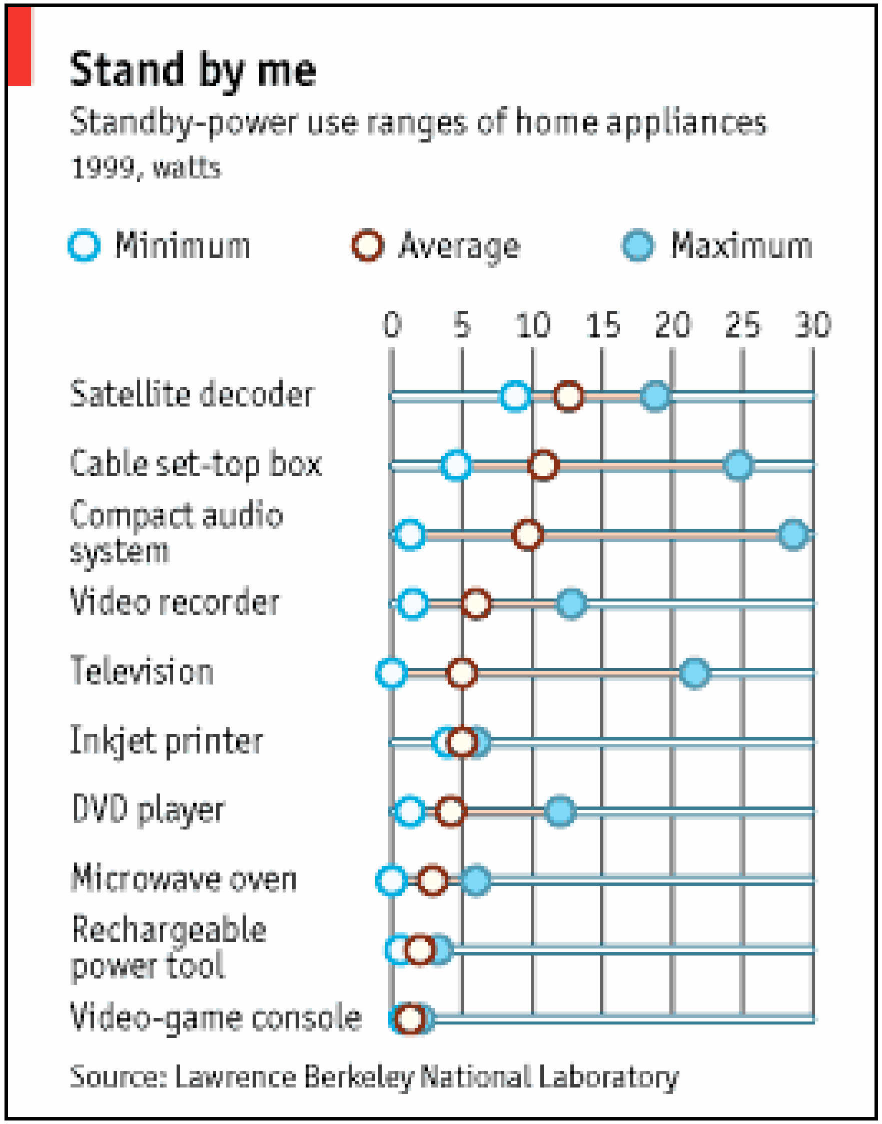


$0.085/kWh retail electricity cost; $0.03/kWh whole sale electricity cost

United States Refrigerator Use Compare with Estimated Household Standby Use



Standby Power (Electronic Vampires)



Energy Efficiency Economics

TABLE 1 Economics of Three New Energy Efficiency Technologies and Appliance Standards. (A 1994 update of Tables 1 & 4 of Ref. 17)

	Research & Development				Standards
	High frequency ballasts vs core coil ballasts	**Compact fluorescent lamps (1) vs incadescents**	**Low-E (R-4) windows vs. double glazed windows per small window (10 ft^2)**	**Total**	**Refrigerators and freezers '76 base case vs '92 CA Stds.**
1. Unit cost premium(2)					
a. Wholesale	$8	$5	$10		$100
b. Retail	($12)	($10)	($20)		($170)
2. Characteristics					
a. % energy saved	33%	75%	50%		60%
b. Useful life(3)	10 years	3 years	20 years		20 years
c. Simple payback time (SPT)(4)	0.8 year	0.5 year	2.9 years		1.3 year
3. Unit lifetime savings					
a. Gross energy	1330 kWh	440 kWh	10 MBtu		20,720 kWh
b. Gross $(5)	$100	$33	$70		$1550
c. Net $ [3b–1a]	$92	$28	$60(6)		$1450
d. Gross equivalent gallons(7)	106	35	69		1660
e. Miles in 25 mpg car	2660	880	1720		41,440
4. Savings 1985–1993					
a. 1993 sales	25 M	42 M	20 M		6 M
b. Sales 1985 through 1993	54 M	147 M	96 M		50 M
c. Cum. net savings [4b × 3c]	$5.0 B	$4.1 B	$5.8 B	$15B/8yr	$73 B

Energy Efficiency Economics (Contd.)

5. Savings at saturation[8]					
a. U.S. units	600 M	750 M	1400 M		125 M
b. U.S. annual sales	60 M	250 M	70 M		6 M
c. Annual energy savings [5b × 3a]	80 BkWh	110 BkWh	0.3 Mbod		130 BkWh
d. Annual net $ savings [5b × 3c][9]	$6 B	$7 B	$4 B	$17 B/yr	$9 B
e. Equivalent power plants[10]	16 "plants"	22 "plants"		38	26 "plants"
f. Equivalent offshore platforms[10]	45 "platforms"	60 "platforms"	35 "platforms"	140	70 "platforms"
g. Autos offset[11]	16 M	22 M	12 M	50 M	26 M
6. Project benefits					
a. Advance in commercialization	5 years	5 years	5 years		5 years
b. Net project savings [6a × 5d]	$28 B	$35 B	$21 B	$84 B	$45 B
7. Cost of DOE for R&D	$3M	$0[12]	$3M	$6M	$2M
8. Benefits/R&D cost [6b/7]	9,000:1		7000:1	14,000:1	23,000:1

From: "The Role of Federal Research and Development in Advancing Energy Efficiency," Statement of Arthur H. Rosenfeld before James H. Scheuer, Chairman, Subcommittee on Environment, Committee on Science, Space, and Technology, U.S. House of Representatives, April 1991. Available from Center for Building Science, LBL, (510) 486–4834.

(1) Calculations for CFLs based on one 16-watt CFL replacing thirteen 60-watt incandescents burning about 3300 hours/year, assuming that a CFL costs $9 wholesale, or $5 more than the wholesale cost of thirteen incandescents. For retail we take a lamp cost of $18.

(2) Unit cost premium is the difference between one unit of the more efficient product (e.g. one high-frequency ballast) and one unit of the existing product (e.g. one core-coil ballast).

(3) Useful life is the assumed calendar life of the product (as opposed to operating life such as burning hours for a lamp) under normal operating conditions. A commercial use is assumed for CFLs, but labor savings are not included.

(4) SPT is the number of years required to recoup the initial incremental investment in an energy-efficient measure through the resulting reduction in energy bills.

(5) Assuming price of 7.5¢/kWh for commercial sector electricity and a retail natural gas price of $7/MBtu (70¢/therm).

(6) For hot weather applications where low-E windows substantially reduce cooling loads, air conditioners in new buildings can be down-sized, saving more than the initial cost of the low-E window.

(7) Assuming marginal electricity comes from oil or gas at 11,600 BTU/kWh, thermally equivalent to 0.08 gallons of gasoline.

(8) Saturation is 100% of the market for all products excepts CFLs. It is unrealistic to assume that CFLs will replace infrequently used incandescents; thus, we have defined market saturation for CFLs as 50% of current energy used by incandescents.

(9) Net annual savings are in 1990 dollars, uncorrected for growth in building stock, changes in real energy costs, or discounted future values. See Ref. 17, Table 1. Note that we attribute energy saved by the product over its useful life to the year it gets sold.

(10) One 1000 MW baseload power plant supplying about 5 BkWh/year $= 57 \times 10^{12}$ Btu $= 0.1\times$ Alaskan Arctic National Wildlife Refuge (ANWR). One offshore oil platform $= 10,000$ bod. To convert "plants" burning natural gas to "platforms": 1 "plant" = 27, 000 bod = 2.7 "platforms." ANWR, at 0.3 Mbod, is equivalent to about 30 "platforms."

(11) 1 automobile (400 gallons/year) generates 1 tonne carbon per year. Thus electricity and gas savings can be converted to "autos offset" (1000 MW power plant is equivalent to 1 M autos).

(12) Descended from high-frequency ballasts (only DOE assistance was in testing).

Cost of Conserved Energy/ELectricty/Carbon

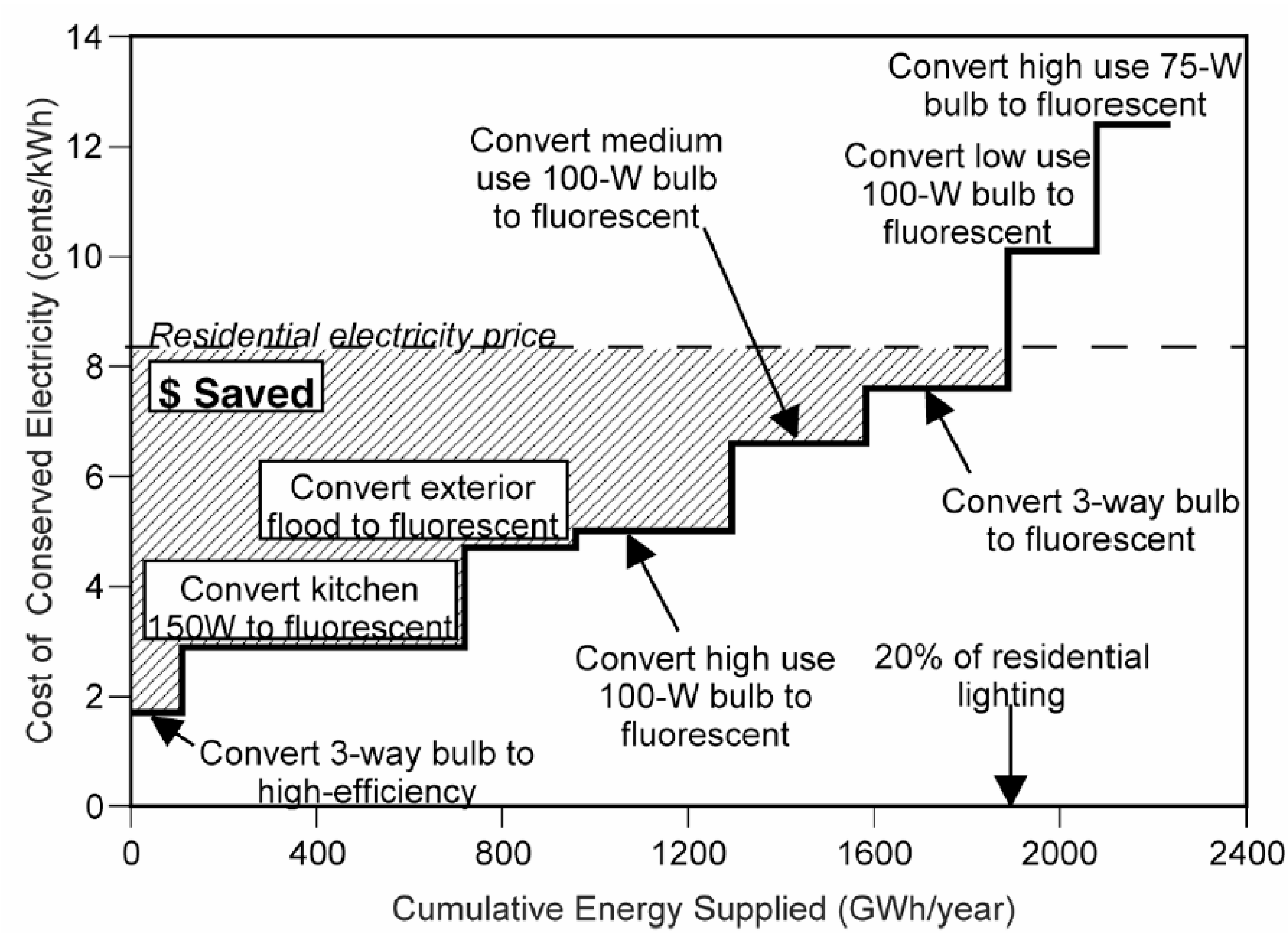
- Powerful Analytical Idea of Policy Makers
- Solves the inability to easily compare both the economics and the scale of conservation with new energy supplies
  - Energy Conservation (Negawatt) is a diffuse resource
  - Energy supplies tend to be large, lumpy, and expensive

Cost of Conserved Energy (CCE)

CCE – [Annualized Investment Cost] / [Annual Energy Savings

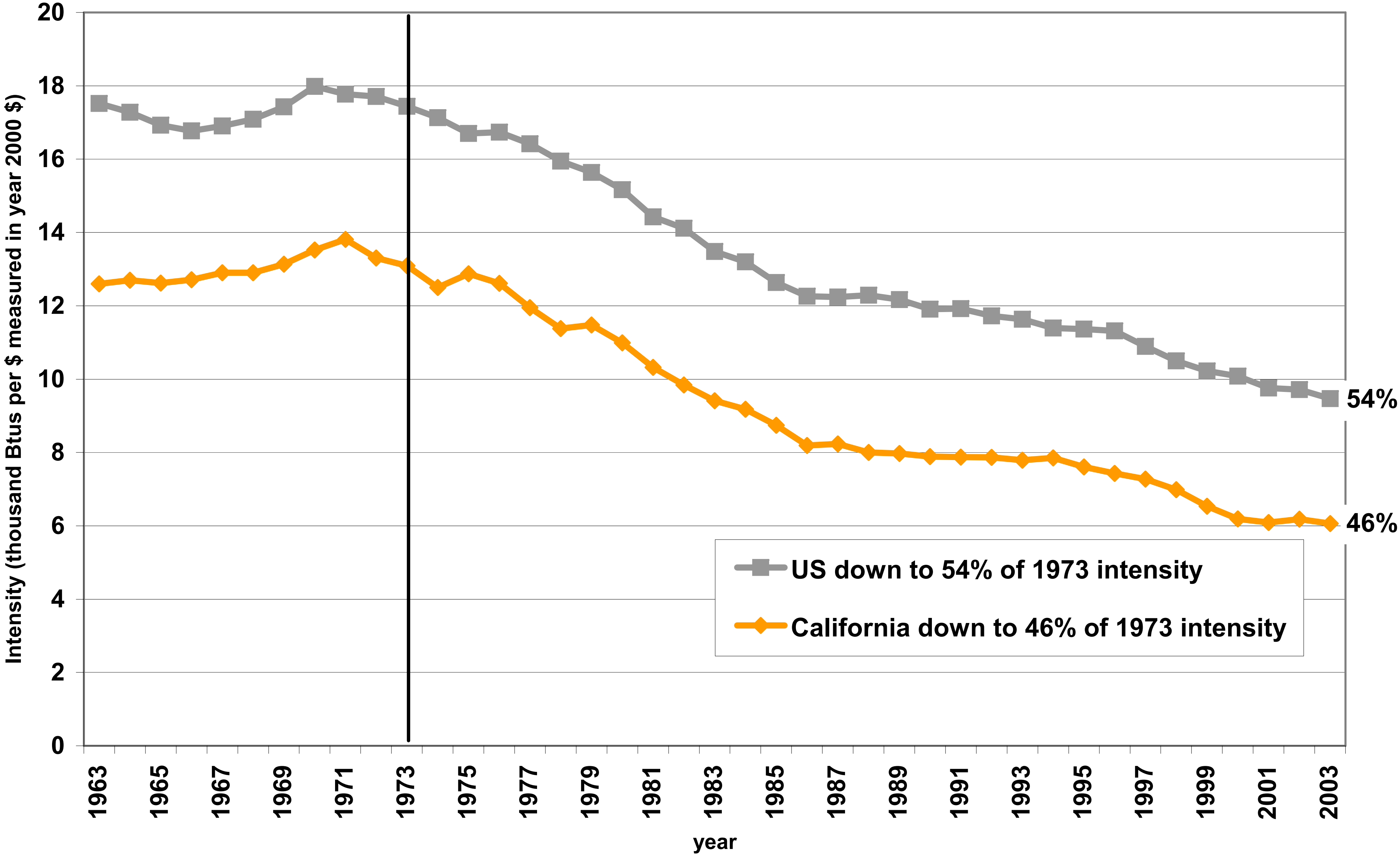
- The annualized cost corresponds to equal ("levelized") repayment, including interest, of the investment, with the payments extending over its useful life.
- The energy savings can be electricity (measured in kW) or gas (measured in MBtu), or even CO2 (MtC). For example, if the measure saves electricity, then the CCE will be in units of $/kWh.
- A measure is cost effective if its CCE is less than the price of the energy that it displaces. This permits easy comparison of the costs of supplying energy, such as from a new power plant, a new oil field, or even a wind farm.
- The cost of conserved energy is "portable"; that is, it does not depend on local prices of the displaced energy. By contrast, the price of displaced electricity may vary from state to state in India or country from country.

CCE Example

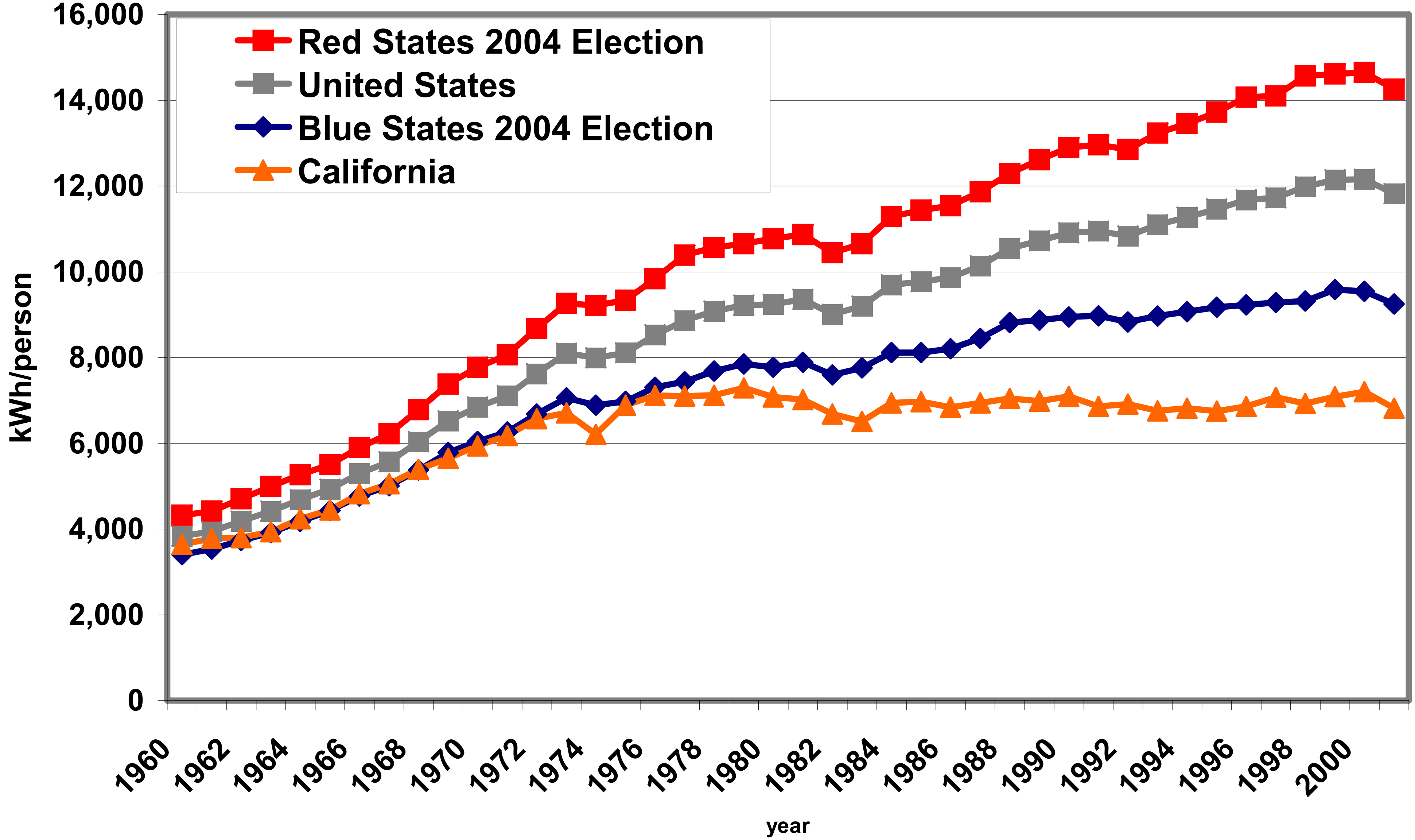


Convert high use 75-W bulb to fluorescent
Convert medium use 100-W bulb to fluorescent
Convert low use 100-W bulb to fluorescent
Residential electricity price
$ Saved
Convert exterior flood to fluorescent
Convert kitchen 150W to fluorescent
Convert 3-way bulb to fluorescent
Convert high use 100-W bulb to fluorescent
20% of residential lighting
Convert 3-way bulb to high-efficiency
Cost of Conserved Electricity (cents/kWh)
Cumulative Energy Supplied (GWh/year)
0
2
4
6
8
10
12
14
0
400
800
1200
1600
2000
2400

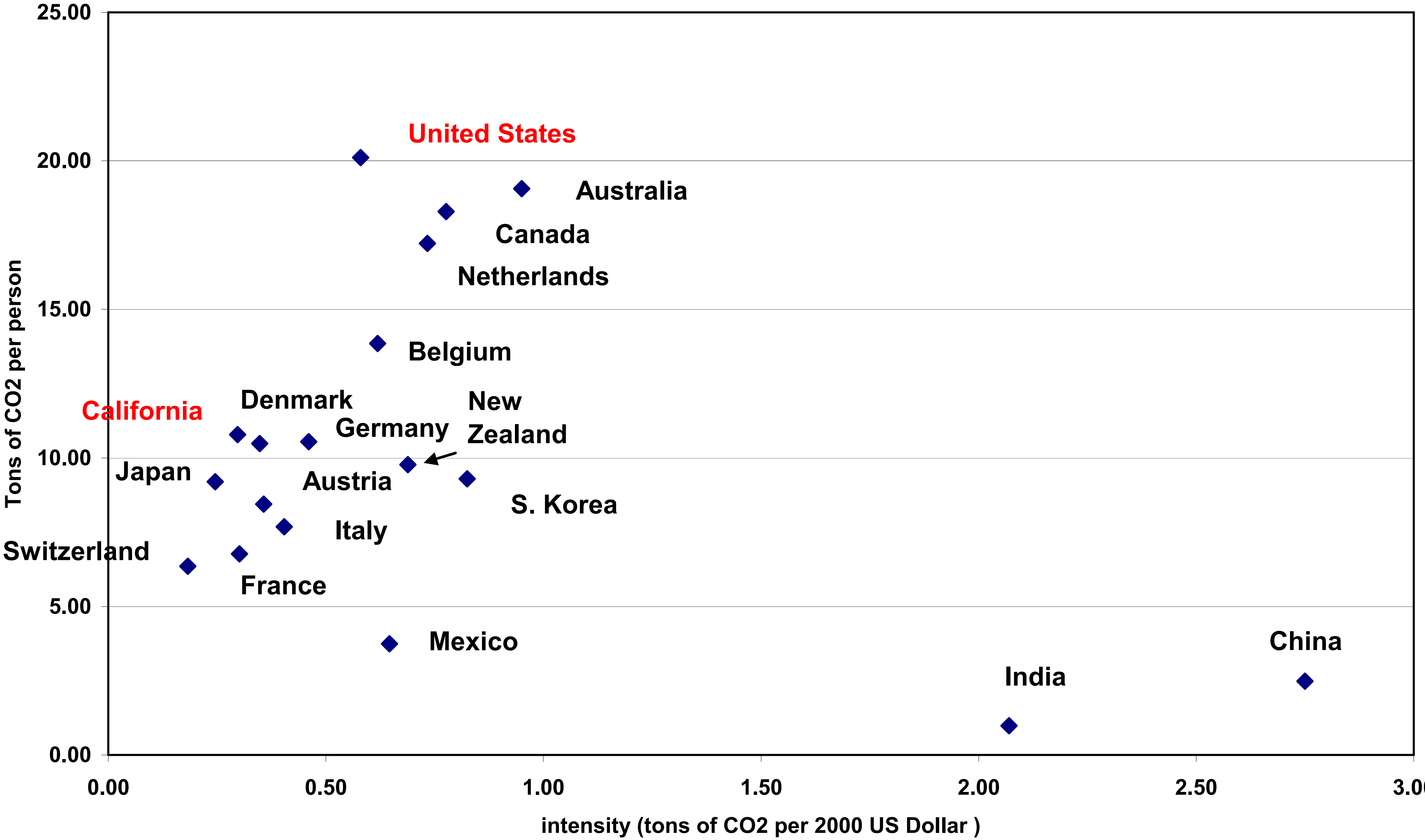
Energy Intensity – US and California



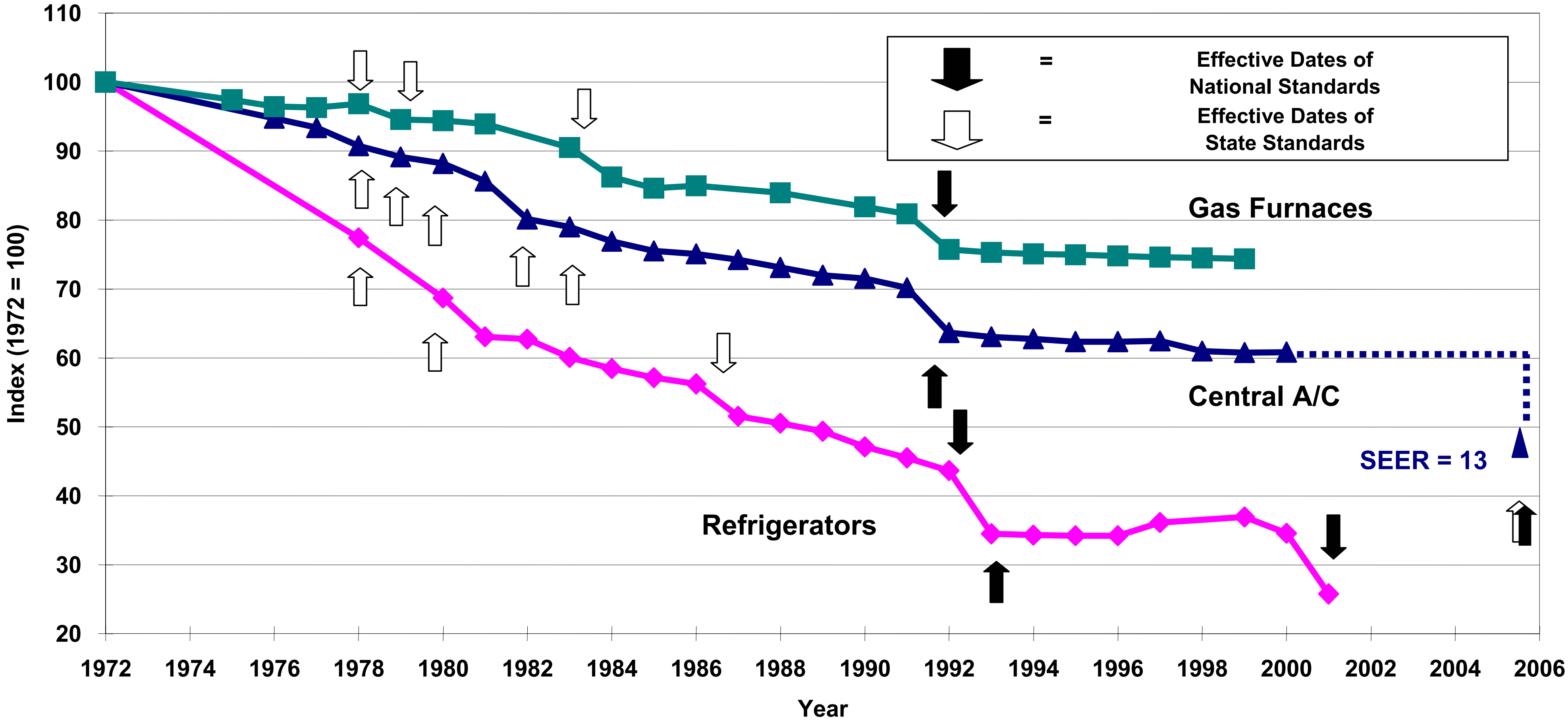
Per-Capital Electricity Consumption (kWh/person)



CO2 Intensity and Per Capita Emissions – 2001 (Fossil Fuel Only)



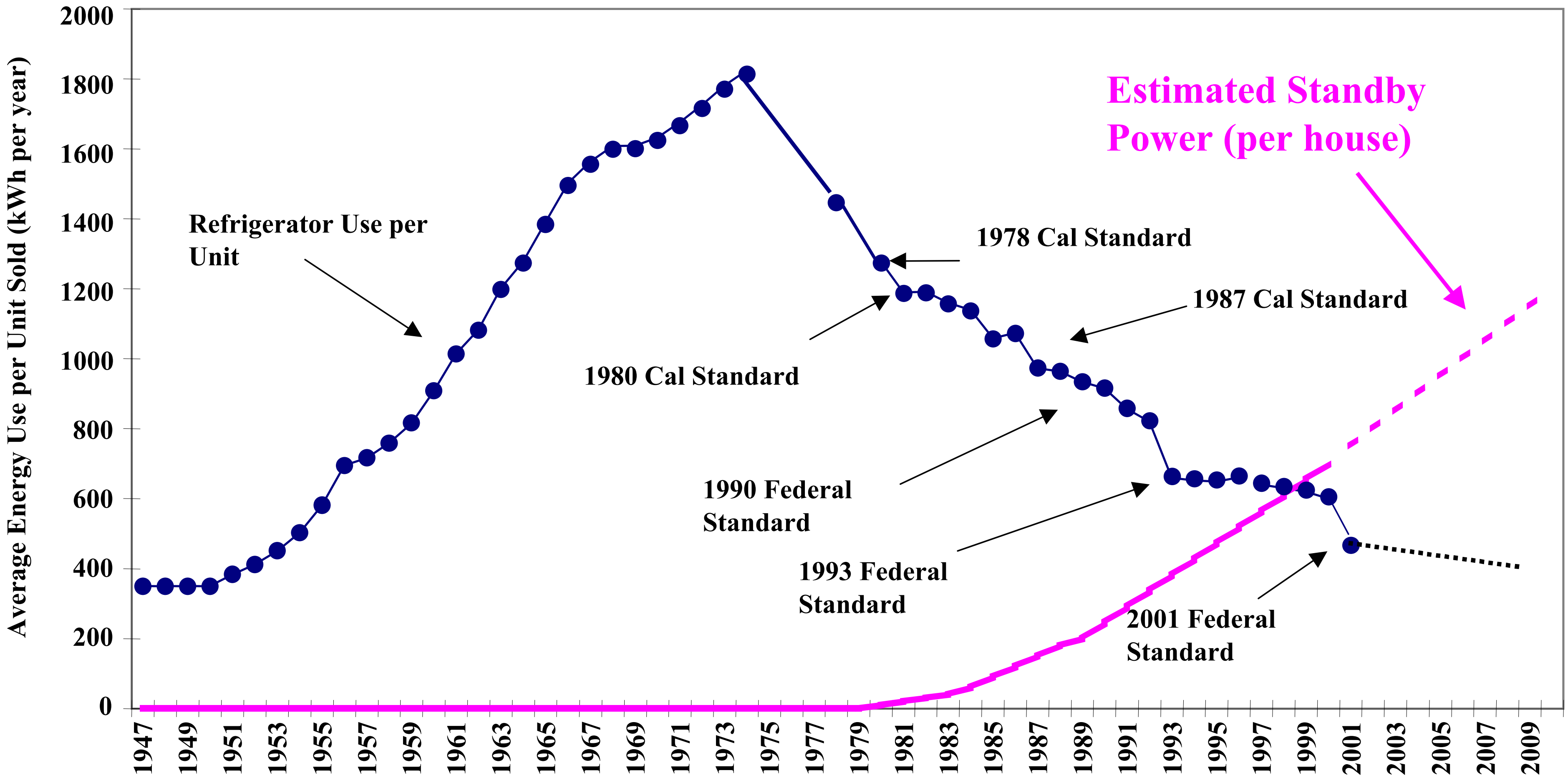
Impact of Standards on Efficiency of Three Appliances



Source: S. Nadel, ACEEE,

in ECEEE 2003 Summer Study, www.eceee.org

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



Estimated Power Saved Due to Air Conditioning Standards (1974 - 2002) (cont'd)

- Peak Power for United States Air Conditioning ~ 250 GW
- But standards cover only residential and rooftop units ~ 200 GW
- **Avoided GW: 67% of 200 GW = 135 GW**
- Comparisons:
  - California Peak Load ~ 50 GW
  - **United States Nuclear Plants net capability ~ 100 GW**
- Cooler roofs will save another 10% of 200 GW
  - Flat roofs, new or replacement, should be white
    - To be required in 2005 California Building Standards
  - Sloped roofs, new or replacement, can be colored but cool
  - Each strategy saves 10%, so 20 GW total
- Just switching a-c equipment located outside to white should save another 1%, or 2 GW

3 Gorges Dam vs. added Appliances in 2010

3 Gorges: 18 GW x 3,500 hours/year = 63 TWh at wholesale

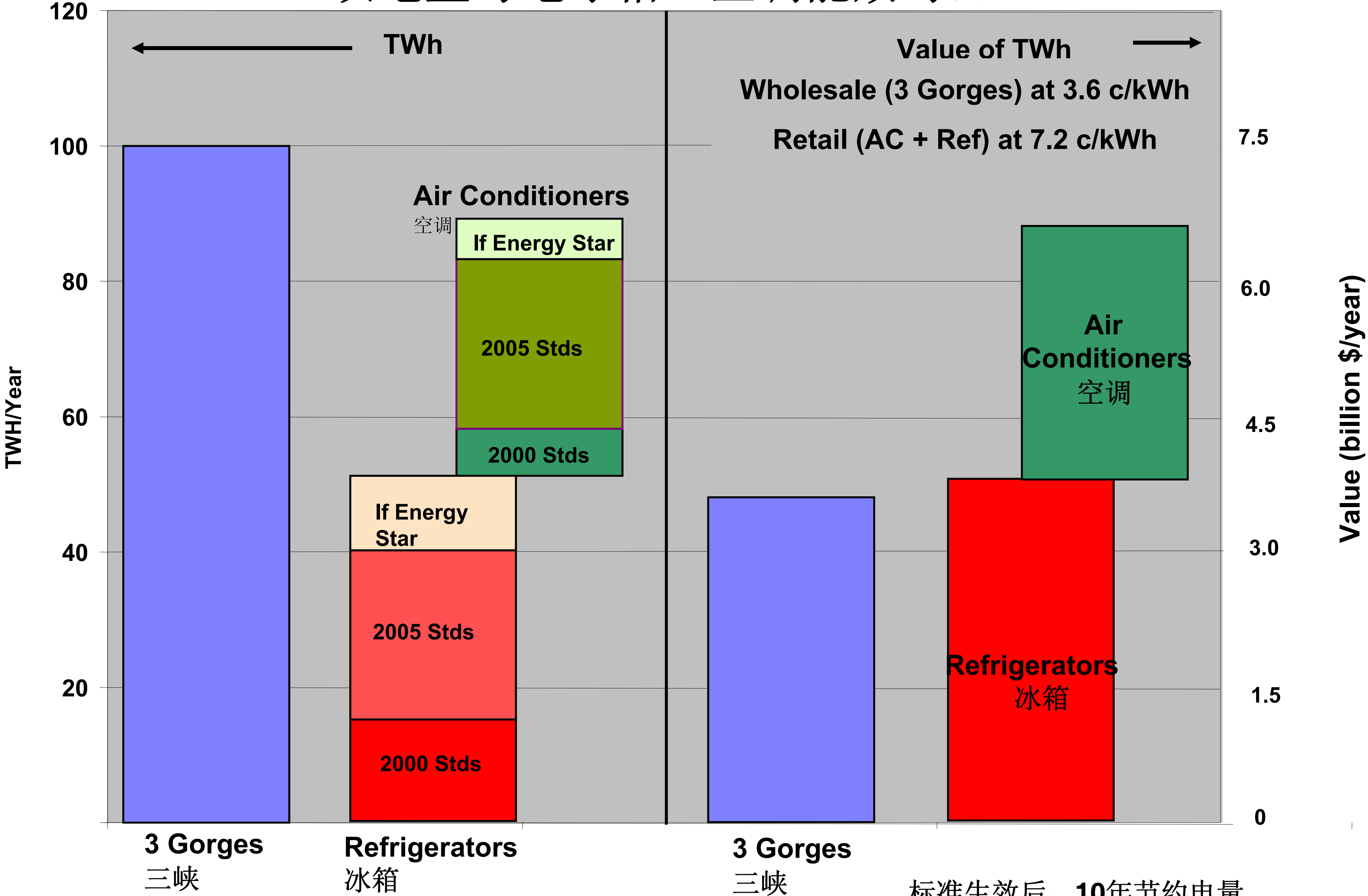
		Refrigerators	Air Conditioning	Total
Estimated Sales 2003 - 2010		125 Million	100 Million	
Today's Use				
per unit per year		440 kWh	360 kWh	
2003-2010 sales at this efficiency		55 TWh	36 TWh	91 TWh
Least Cost Optimum				
per unit per year		265 kWh	233 kWh	
2003-2010 sales at high efficiency		33 TWh	23 TWh	55 TWh
Percent Saved		**40%**	**35%**	
Savings from Least Cost Optimum		**22 TWh**	**13 TWh**	**35 TWh**

Conclusion: Optimum appliances could save 35 TWh/year, about one-half of 3 Gorges generation in 2010. Savings at retail at least twice as valuable as wholesale, so economically equivalent to the entire 3 Gorges project.

Source: David Fridley - LBNL

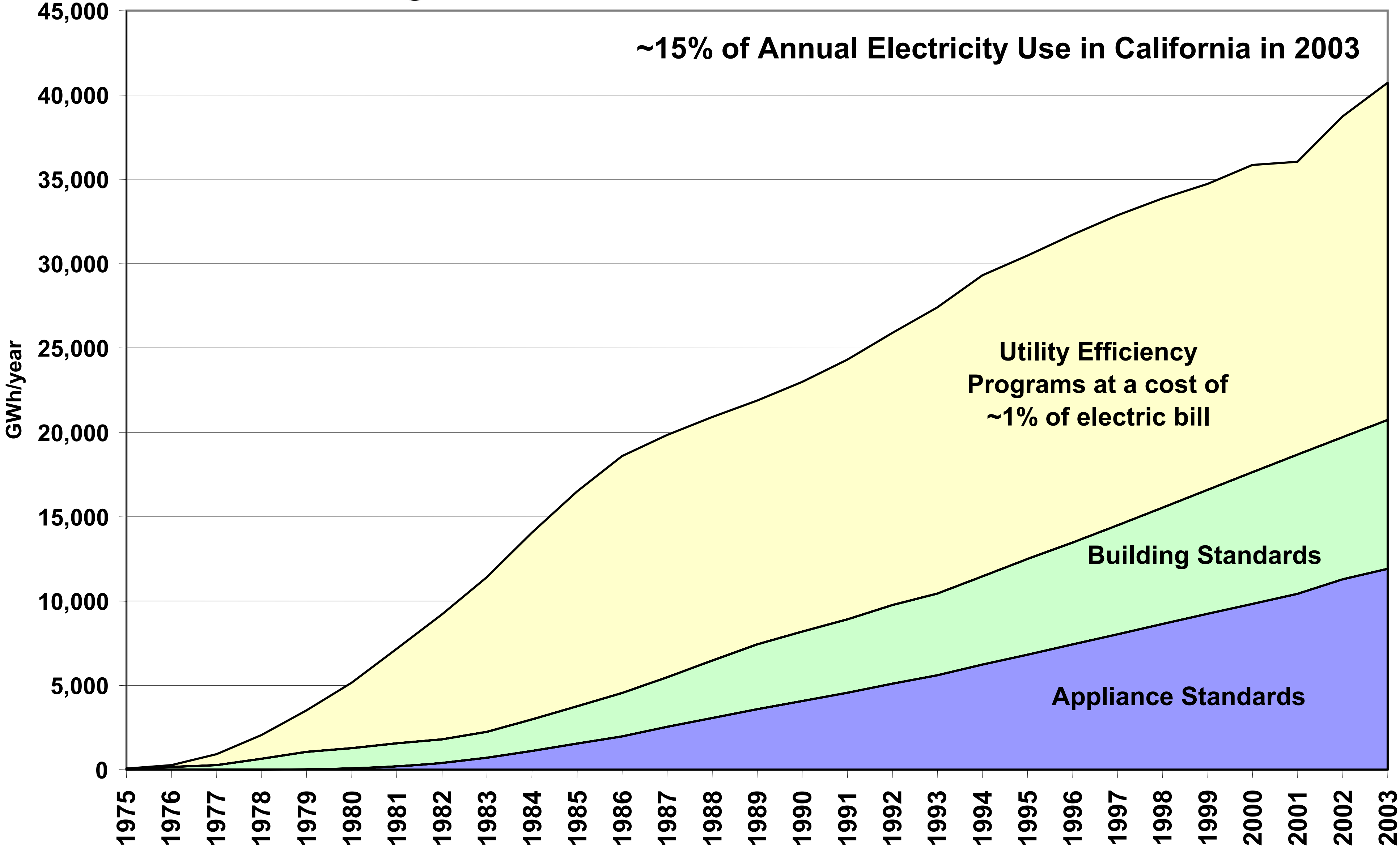
Comparison of 3 Gorges to Refrigerator and AC Efficiency Improvements

三峡电量与电冰箱、空调能效对比

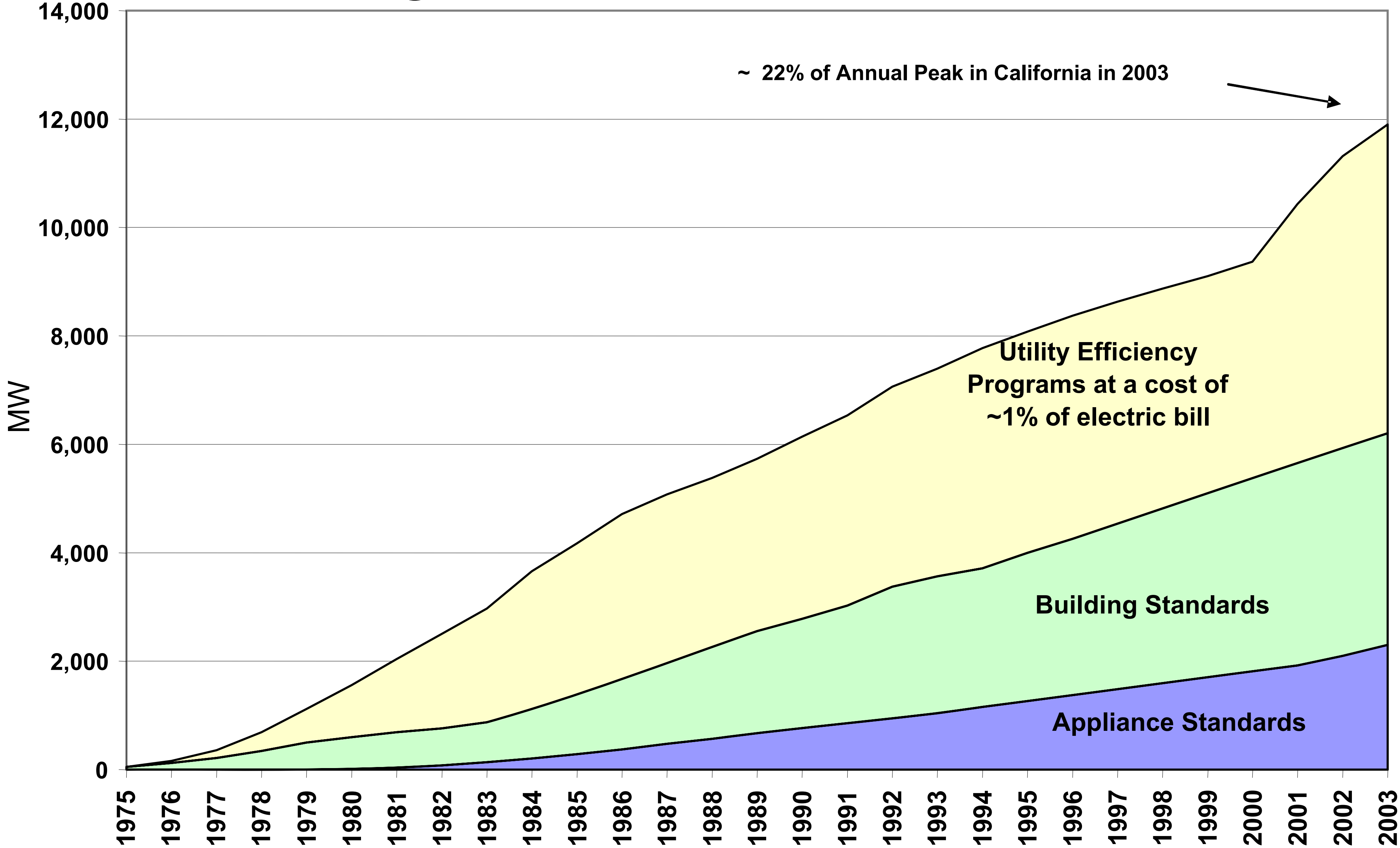


Savings calculated 10 years after standard takes effect. Calculations provided by David Fridley, LBNL

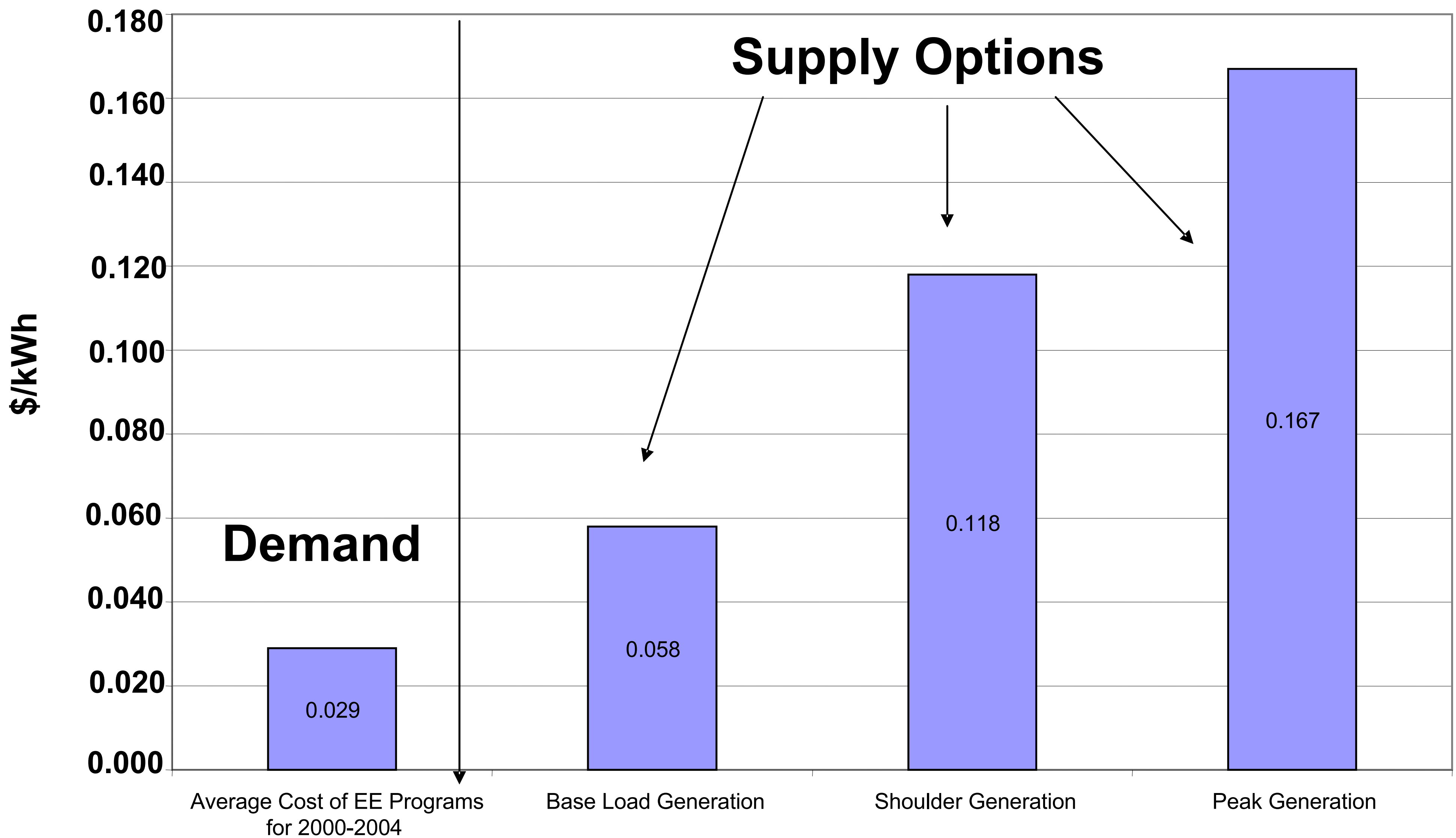
Annual Energy Savings from Efficiency Programs and Standards



Annual Peak Savings from Efficiency Programs and Standards

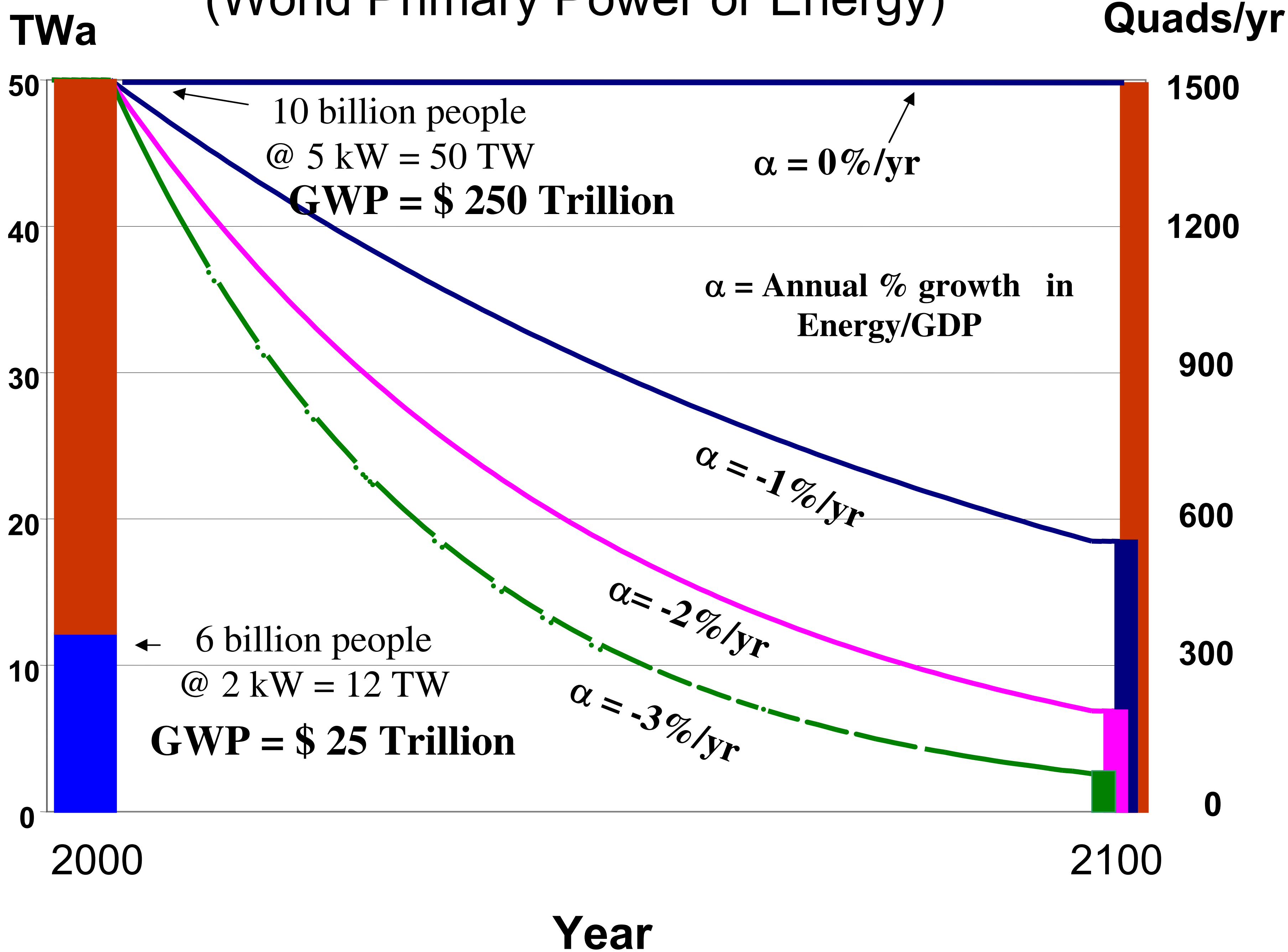


Comparison of EE Program Costs to Supply Generation Costs



The "Conservation Bomb"

(World Primary Power or Energy)



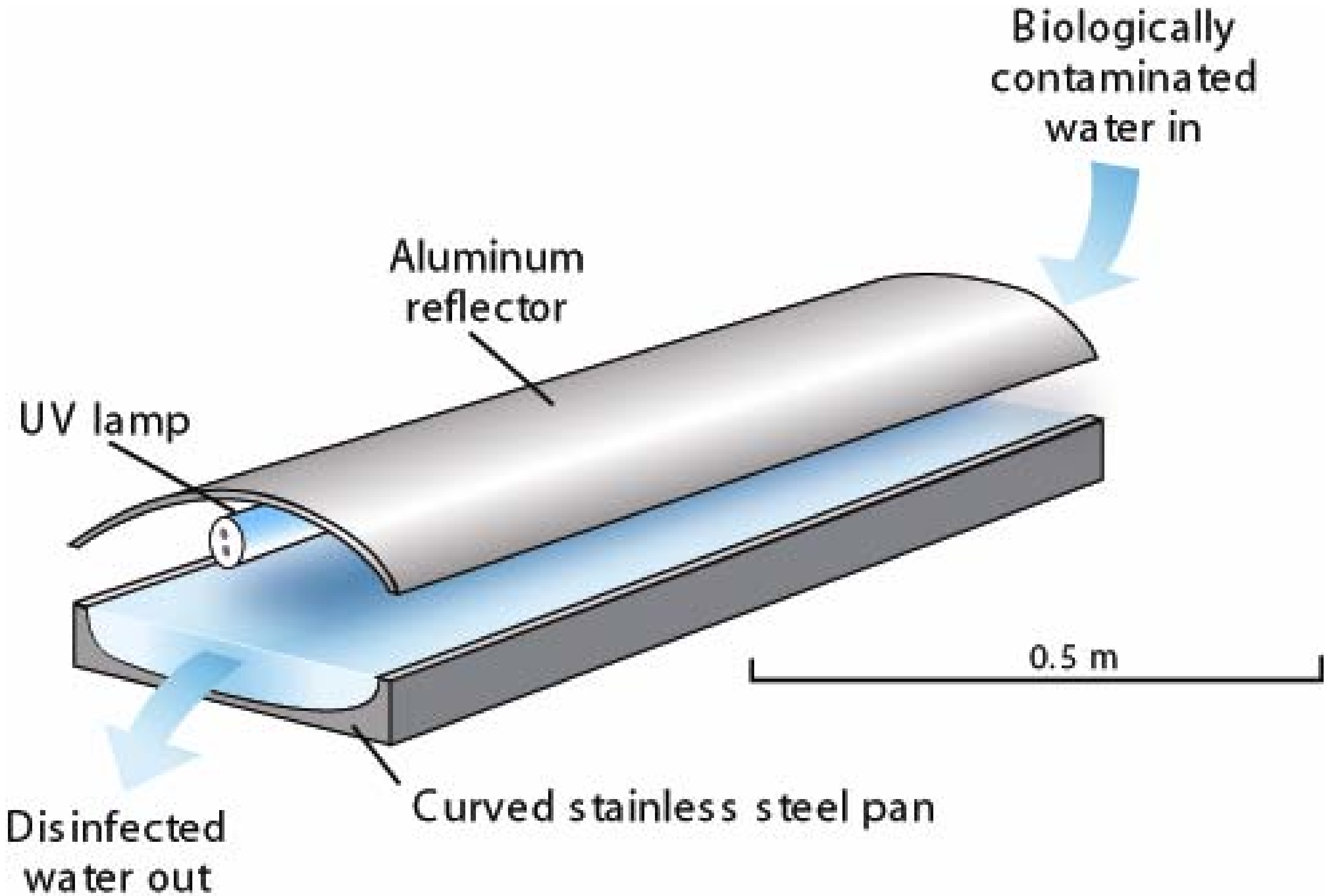
LEDs Powered with Photovoltaics

- Evan Mills at LBNL points out the following: If 1 billion people could replace kerosene lamps with LEDs, emissions would drop by the equivalent of 1 million barrels of petroleum per day
- http://eetd.lbl.gov/emills/PUBS/Fuel_Based_Lighting.html

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 **4 tons of CO2 per day**
- Meet / exceed WHO and US EPA criteria
- Energy efficient: 60 watts disinfects 1 ton / hour
- Low cost: 4 cents disinfects a ton of water
- Reliable, Mature components
- Can treat un-pressurized water
- Rapid throughput: 12 seconds
- Low maintenance: once every three months
- http://www.waterhealth.com/

UV Water Purification



The hamburger standard

	Big Mac price in dollars*	Implied PPP† of the dollar	Under (-)/ over (+) valuation against the dollar, %
United States‡	2.90	-	-
Argentina	1.48	1.50	-49
Australia	2.27	1.12	-22
Brazil	1.70	1.86	-41
Britain	3.37	1.54§	+16
Canada	2.33	1.10	-20
Chile	2.18	483	-25
China	1.26	3.59	-57
Czech Rep.	2.13	19.5	-27
Denmark	4.46	9.57	+54
Egypt	1.62	3.45	-44
Euro area	3.28**	1.06††	+13
Hong Kong	1.54	4.14	-47
Hungary	2.52	183	-13
Indonesia	1.77	5,552	-39
Japan	2.33	90.3	-20
Malaysia	1.33	1.74	-54
Mexico	2.08	8.28	-28
New Zealand	2.65	1.50	-8
Peru	2.57	3.10	-11
Philippines	1.23	23.8	-57
Poland	1.63	2.17	-44
Russia	1.45	14.5	-50
Singapore	1.92	1.14	-34
South Africa	1.86	4.28	-36
South Korea	2.72	1,103	-6
Sweden	3.94	10.3	+36
Switzerland	4.90	2.17	+69
Taiwan	2.24	25.9	-23
Thailand	1.45	20.3	-50
Turkey	2.58	1,362,069	-11
Venezuela	1.48	1,517	-49

MORE COUNTRIES Data for the countries below are not provided in printed editions of *The Economist*

	Big Mac price in dollars*	Implied PPP† of the dollar	Under (-)/ over (+) valuation against the dollar, %
Aruba	2.29	1.41	-21
Belarus	1.37	1021	-53
Bulgaria	1.85	1.03	-36
Colombia	2.35	2241	-19
Costa Rica	2.61	390	-10
Croatia	2.42	5.14	-17
Dom. Rep.	1.32	20.7	-54
Estonia	2.27	10.2	-22
Fiji	2.35	1.47	-19
Georgia	1.90	1.26	-34
Guatemala	2.01	5.52	-31
Honduras	1.98	12.4	-32
Iceland	6.01	151	107
Jamaica	1.88	39.0	-35
Jordan	3.65	0.89	26
Kuwait	7.33	0.74	153
Latvia	2.00	0.38	-31
Lebanon	2.84	1483	-2
Lithuania	2.26	2.24	-22
Macau	1.40	3.86	-52
Macedonia	1.84	32.8	-36
Moldova	1.93	7.93	-33
Morocco	0.26	0.82	-91
Nicaragua	2.19	11.9	-25
Norway	5.18	12.2	79
Pakistan	1.90	37.9	-34
Qatar	0.68	0.85	-77
Saudi Arabia	0.64	0.83	-78
Slovakia	1.98	22.8	-32
Slovenia	2.42	166	-17
Sri Lanka	1.41	48.3	-51
Ukraine	1.36	2.50	-53
UAE	0.67	0.84	-77
Uruguay	1.00	10.3	-65

*At current exchange rates †Purchasing-power parity ‡Average of New York, Chicago, San Francisco and Atlanta §Dollars per pound **Weighted average of member countries ††Dollars per euro

Sources: McDonald's; *The Economist*

Thank You!

- Slide Credits – Dr. Arthur Rosenfeld, Fermi Award Winner, California Energy Commissioner

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