Improving Energy Efficiency 2-3%/year to save money and avoid Global Warming.

Rohsenow Symposium, MIT, 16 May 2003

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

End notes follow last figure

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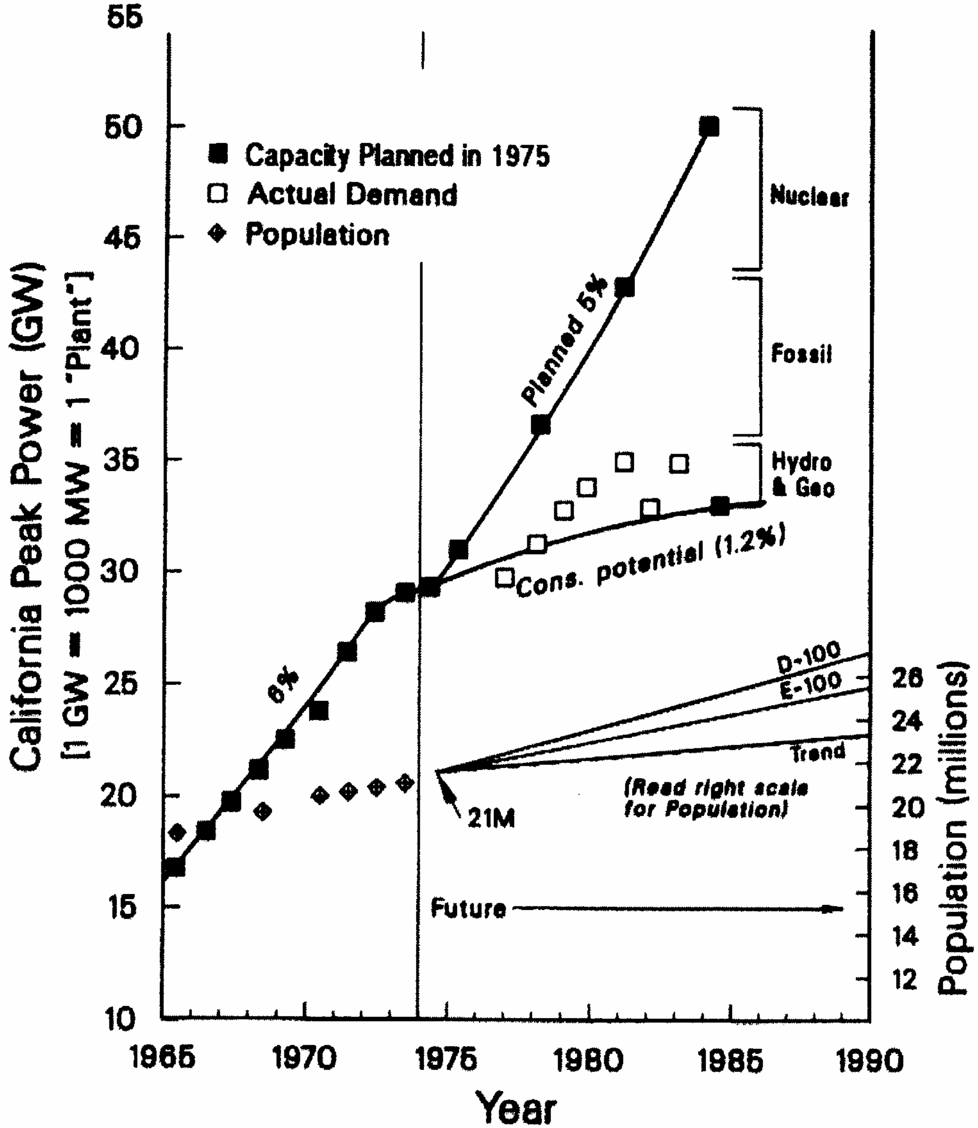
California Peak Power Demand:Planned in 1974, and Actual to 1990



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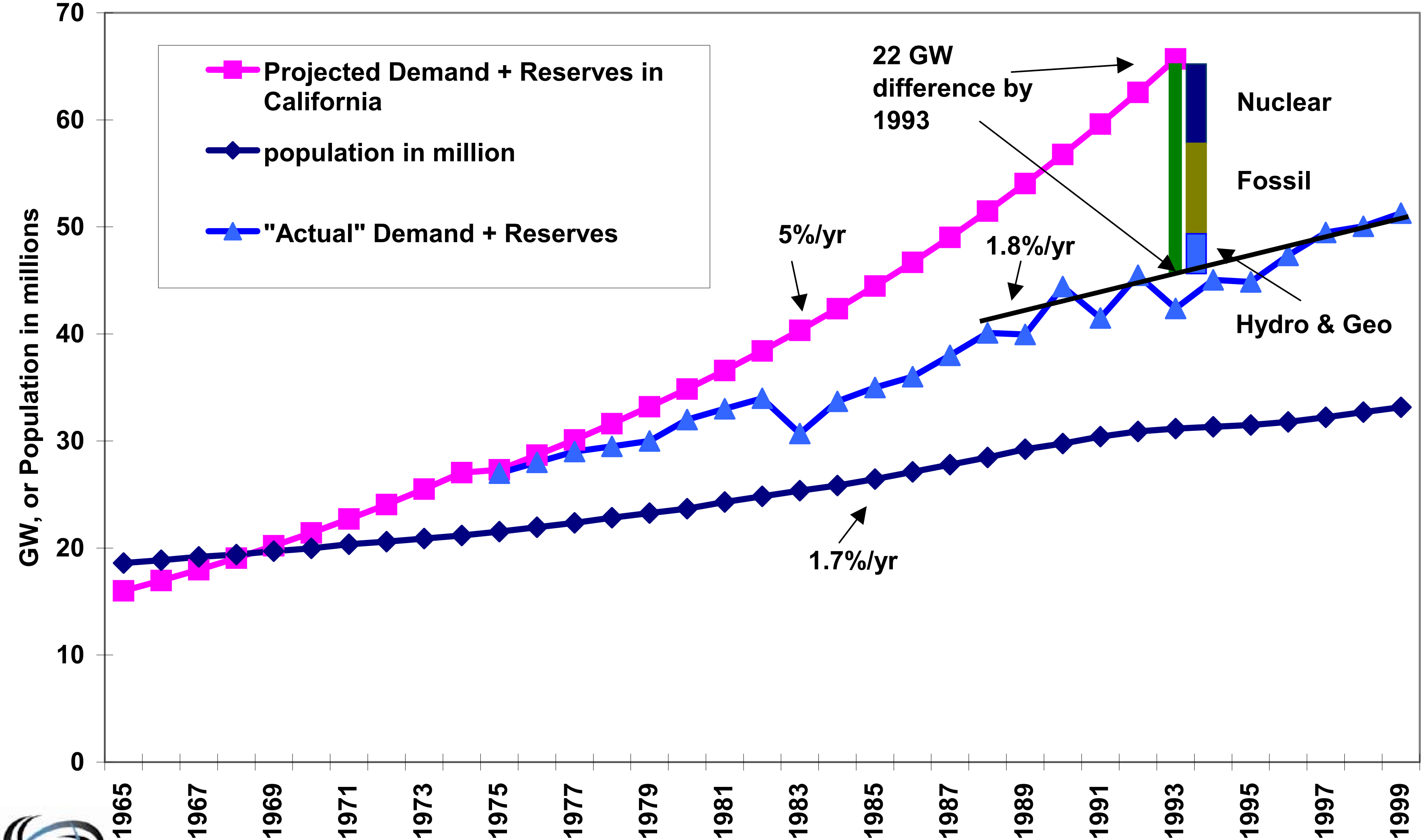
Arthur Rosenfeld, Figure 2

California Peak Power Demand: Planned in 1974 Compared to Actual



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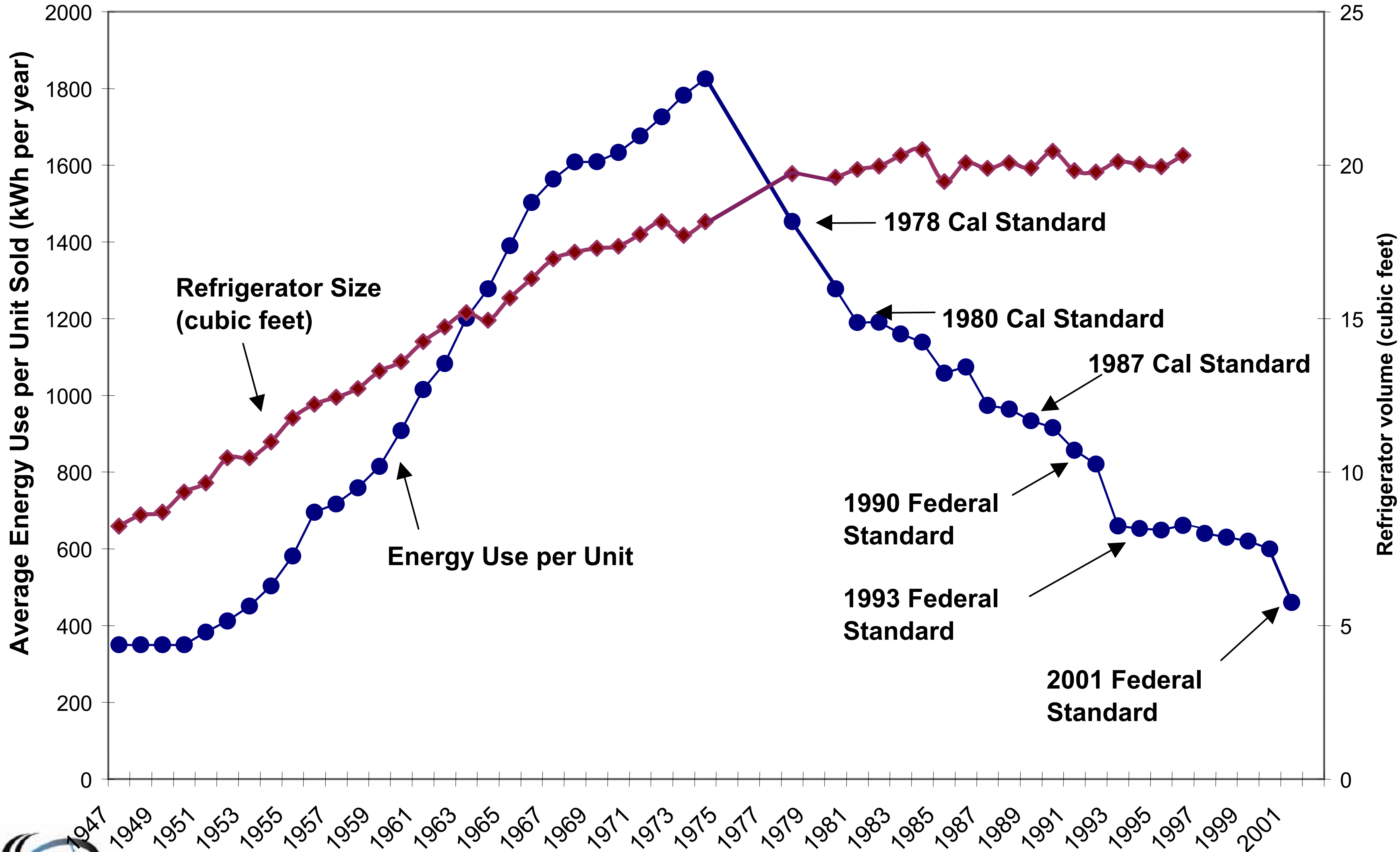
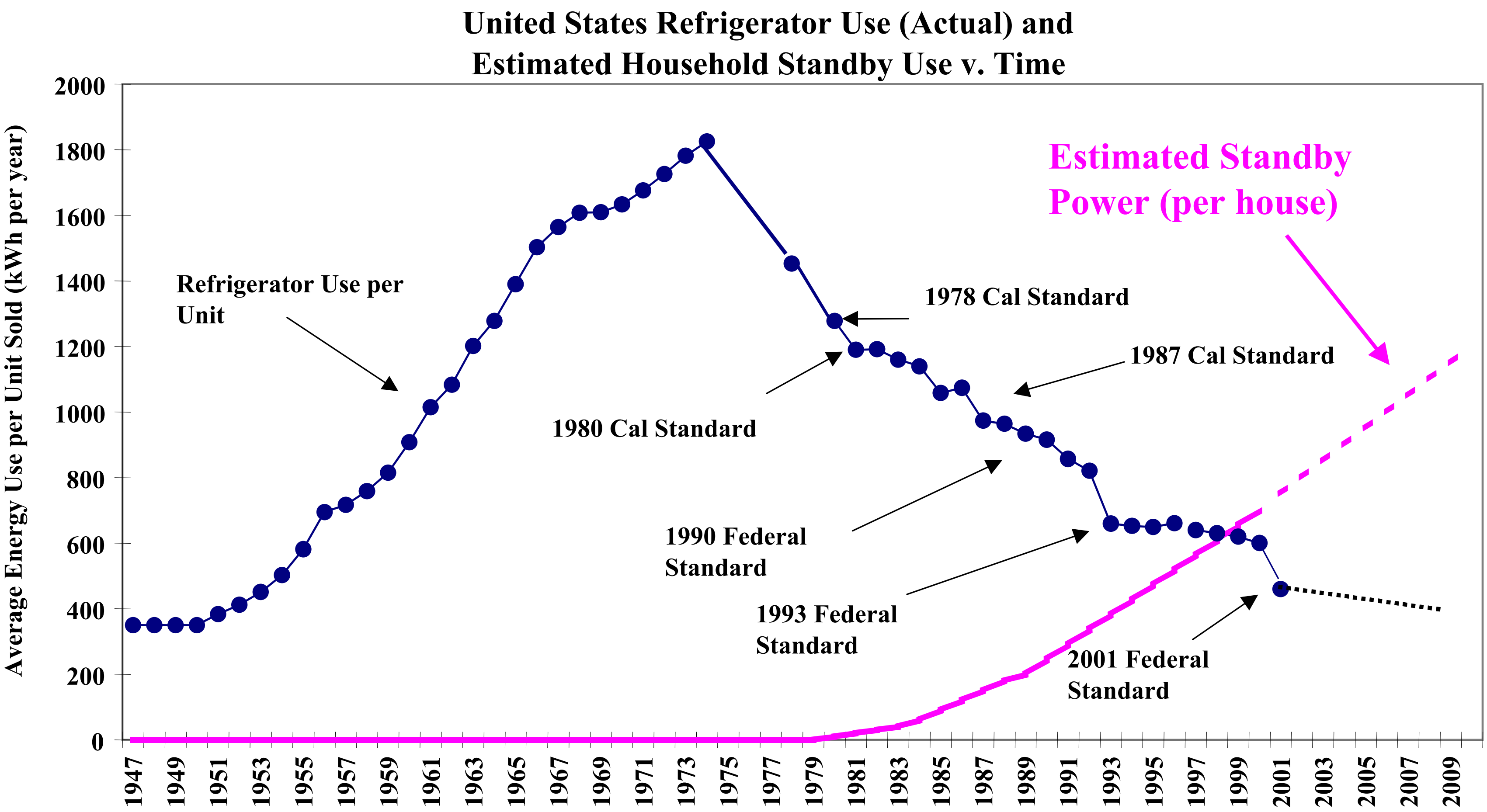
Arthur Rosenfeld, Figure 3

United States Refrigerator Use v. Time





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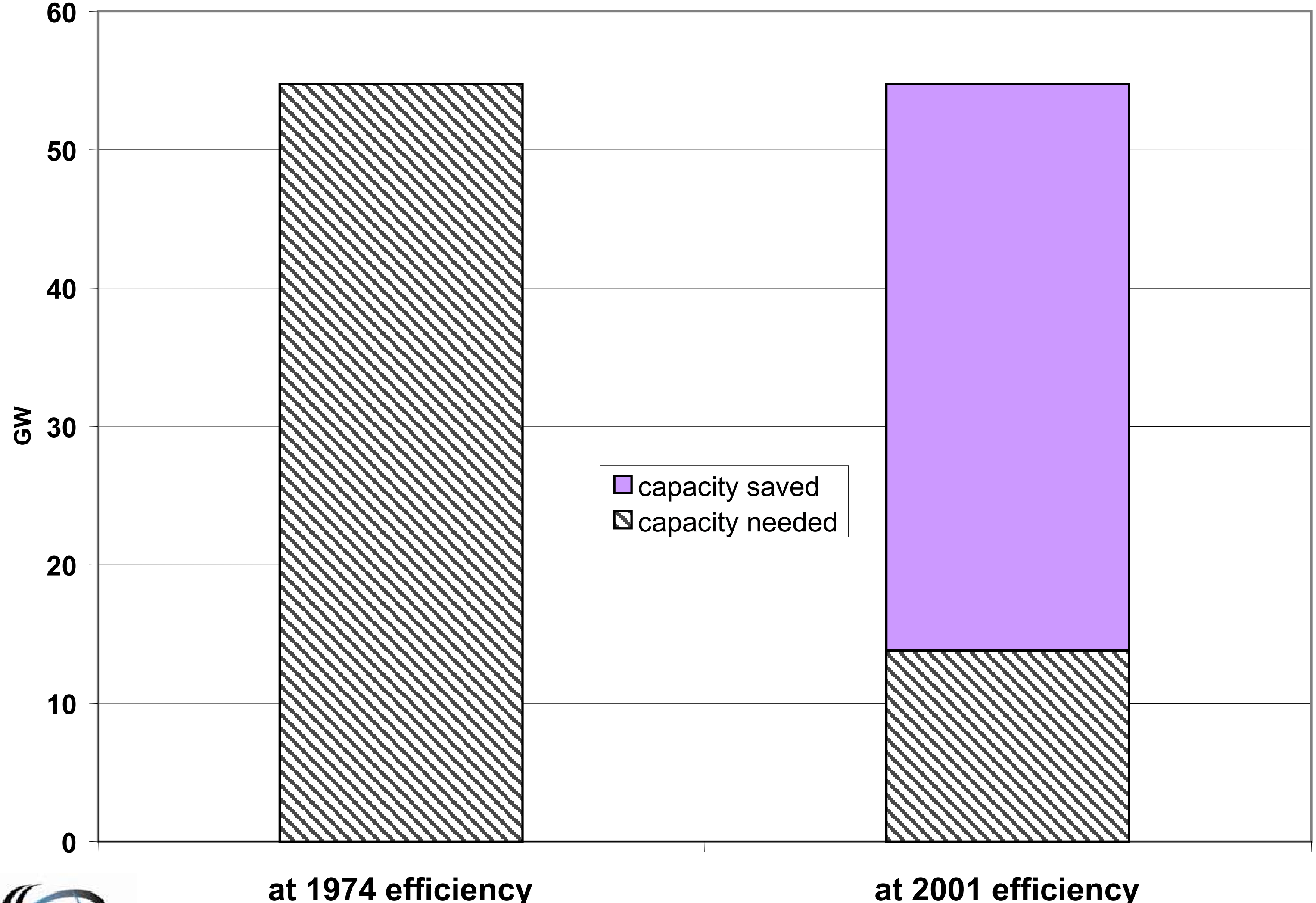
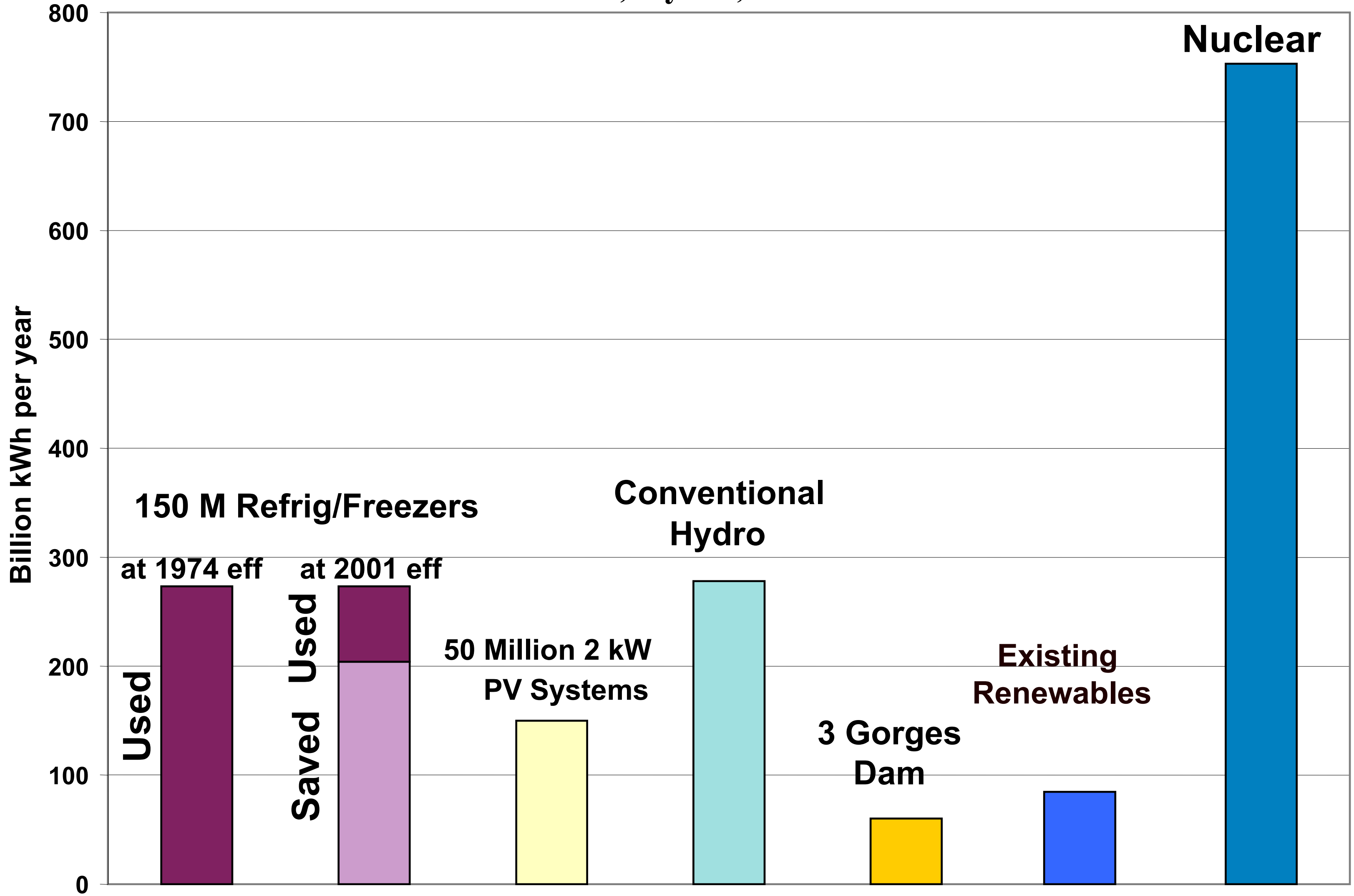
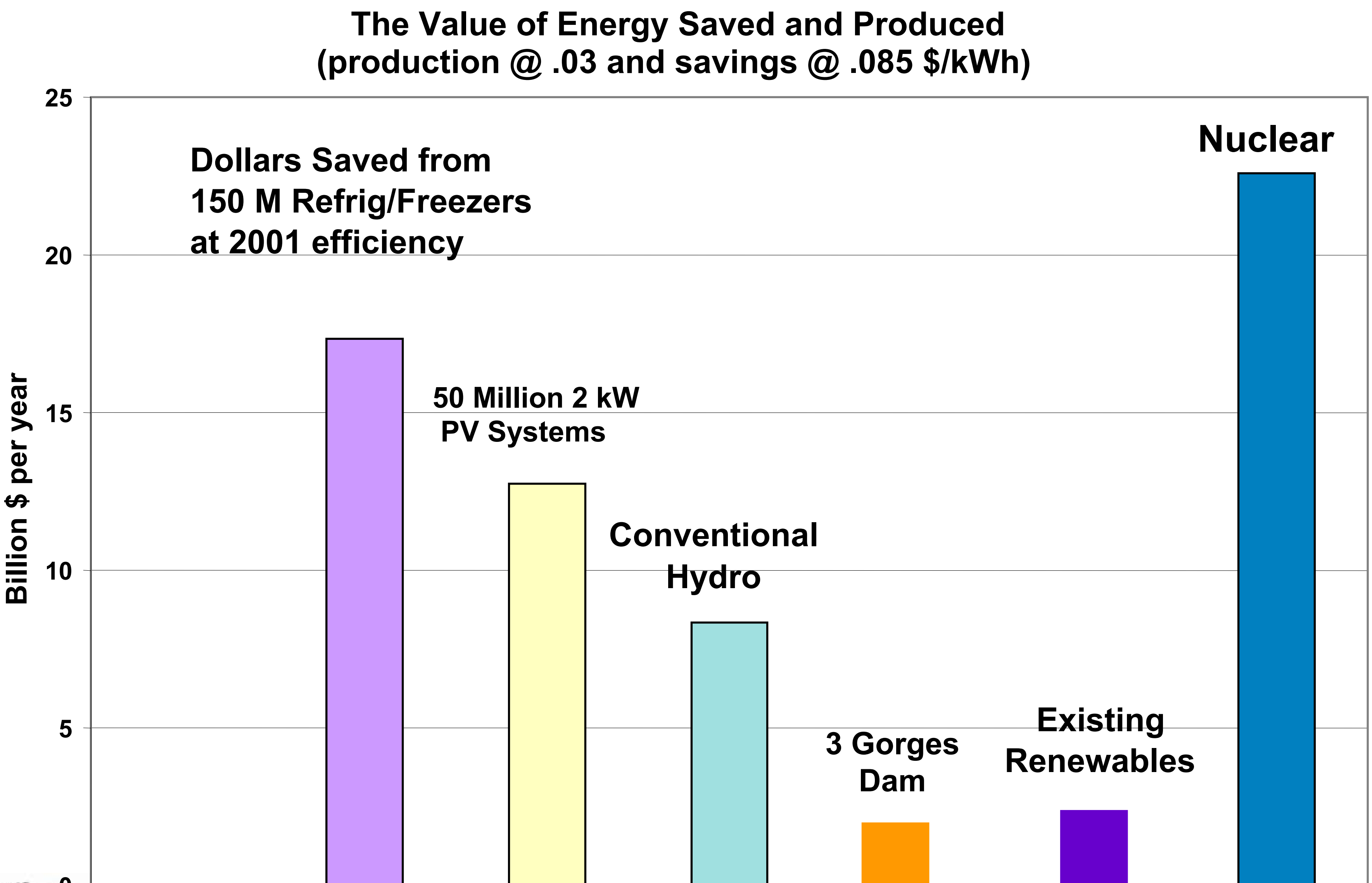
Arthur Rosenfeld, Figure 5

Electricity Generating Capacity for 150 Million Refrigerators + Freezers in the US



Electricity Use of Refrigerators and Freezers in the US compared to Generation from Nuclear, Hydro, Renewables and ANWR




The Value of Energy Saved and Produced
(production @ .03 and savings @ .085 $/kWh)
25
20
15
10
5
0
Billion $ per year
Dollars Saved from
150 M Refrig/Freezers
at 2001 efficiency
50 Million 2 kW
PV Systems
Conventional
Hydro
3 Gorges
Dam
Existing
Renewables
Nuclear

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

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

	SEER	COP	EER
1975 Average	NONE	2	7
1992 Standard	10	2.5	9
2006 Standard	12	3.2	11
SEER= Seasonal Energy Efficiency Rating			
COP = Coefficienct of Performance			
EER = Energy Efficiency Rating, 3.415 x COP			

So, Standards have avoided (9/7 -1) or 28% of peak

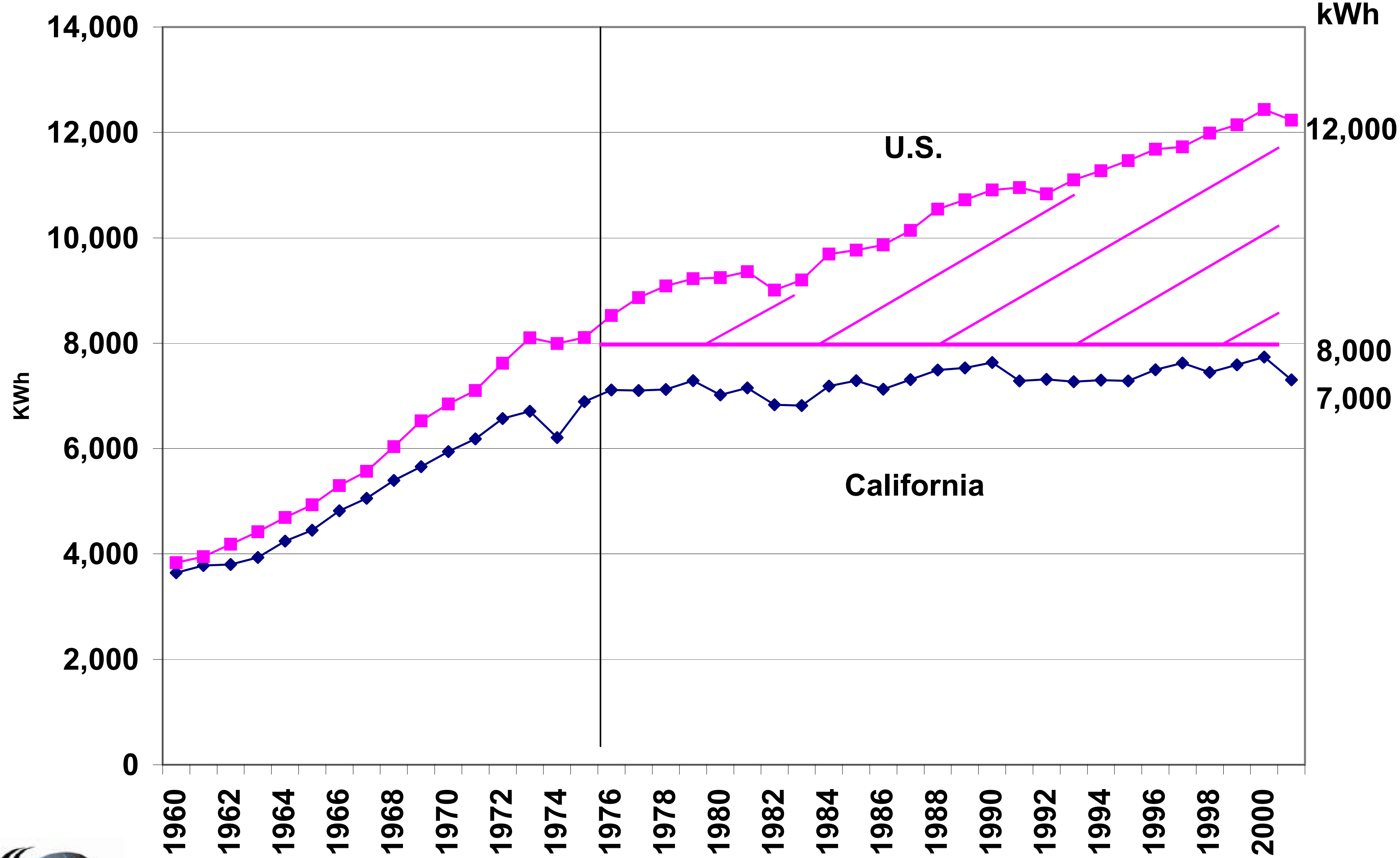
and the new 2006 will avoid (11/9 - 1) or 22% of peak GW

For a Grand Total Savings of 50%

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: 50% of 200 GW = 100 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

Total Electricity Use, per capita, 1960 - 2001



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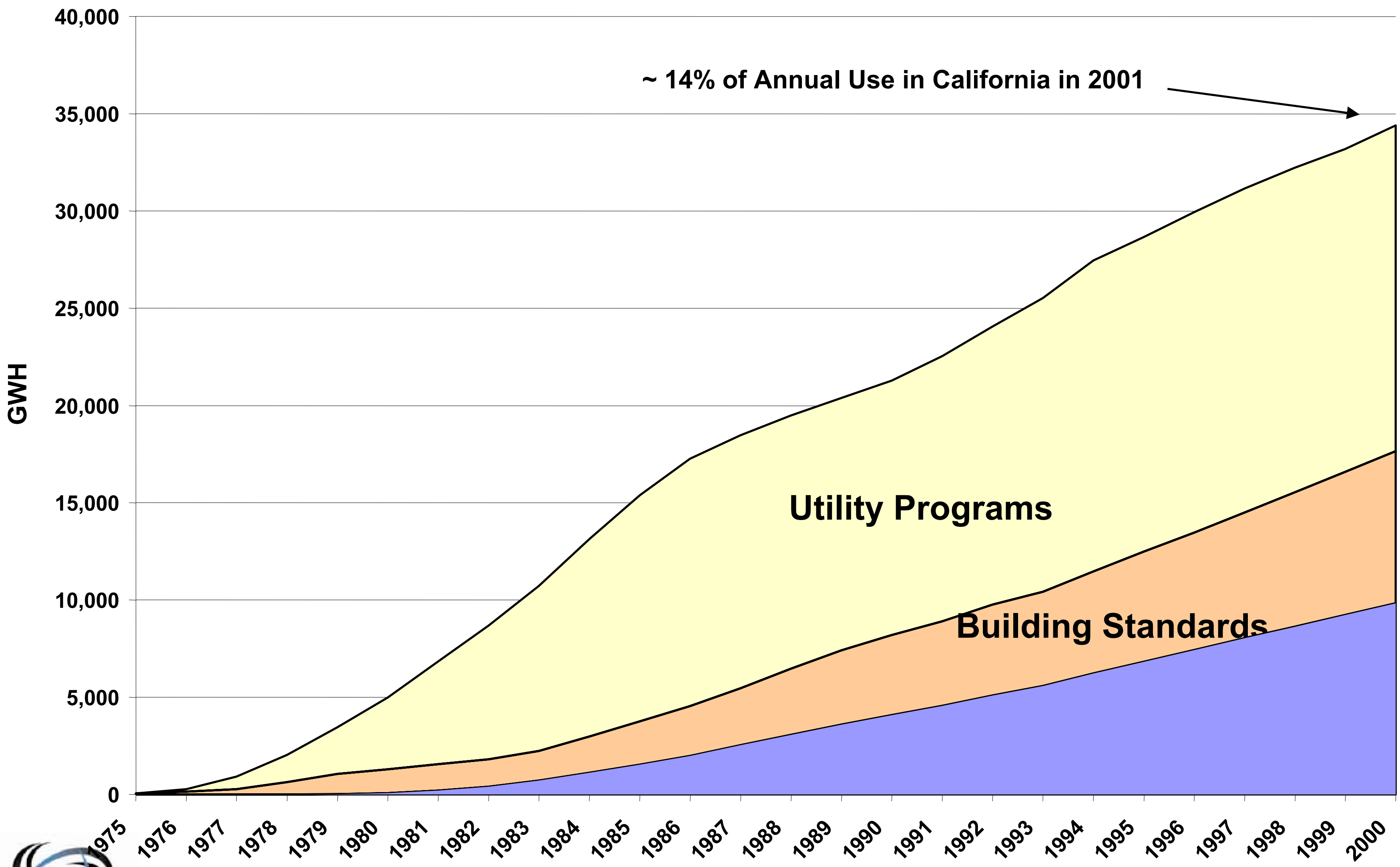
Arthur Rosenfeld, Figure 12

GWH Impacts from Programs Begun Prior to 2001



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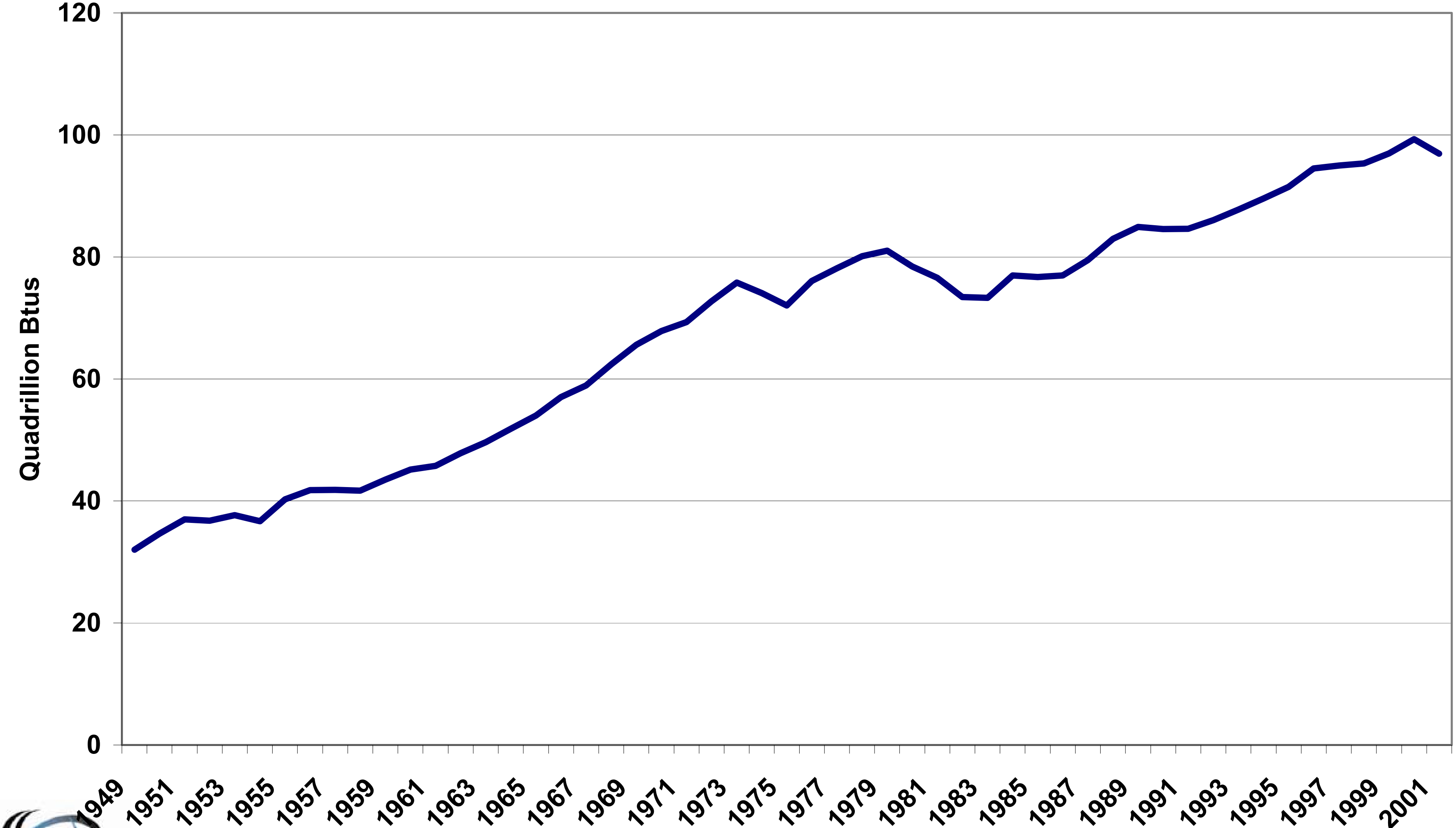
Source: Mike Messenger, CEC Staff, April 2003

Arthur Rosenfeld, Figure 13

United States Energy Consumption 1949 to 2001

Source: Table 1.5 Annual Energy Review; data for 2001 is preliminary



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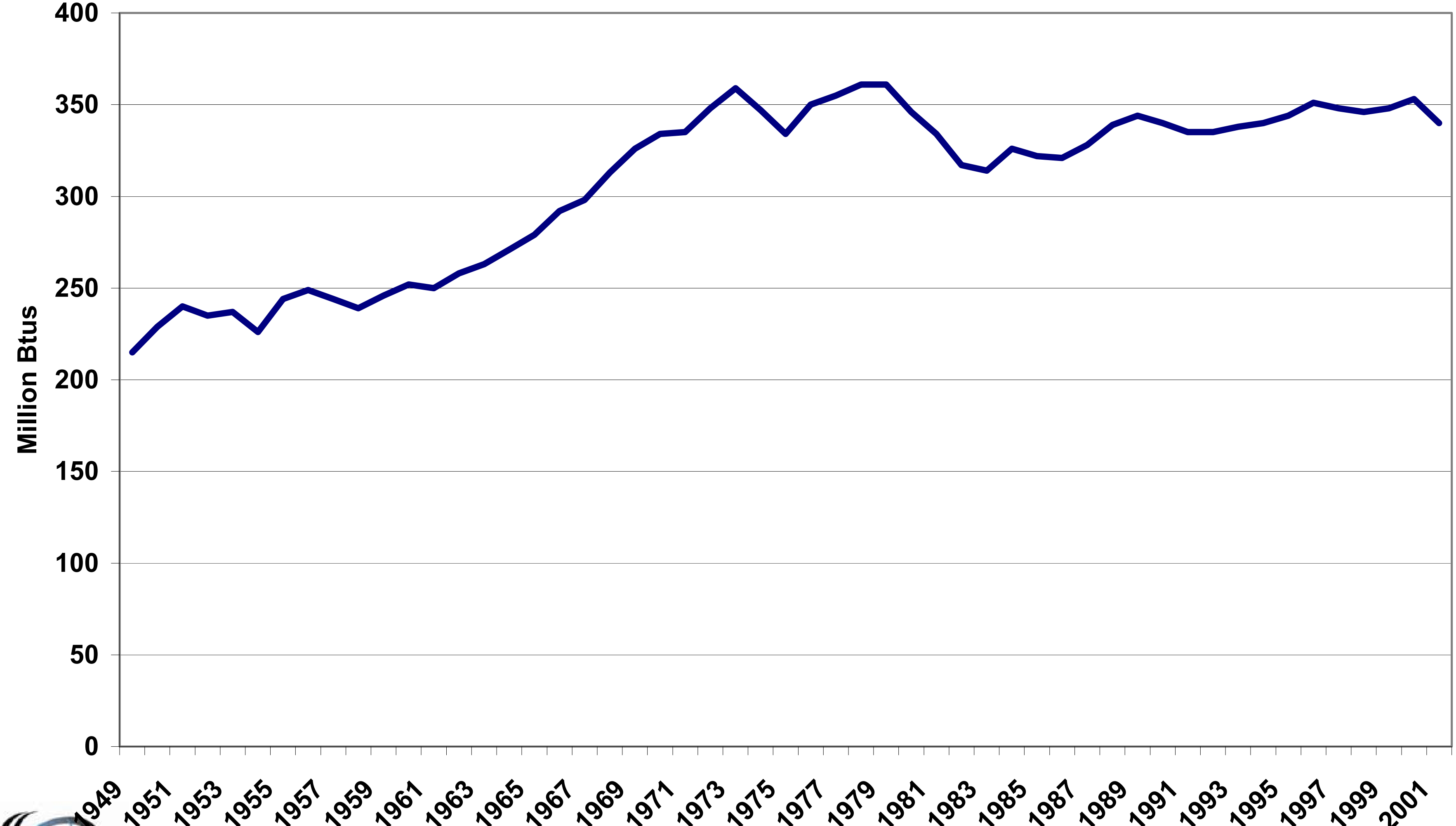
Arthur Rosenfeld, Figure 14

Energy Consumption Per Person 1949 to 2001

Source: Table 1.5 Annual Energy Review; data for 2001 is preliminary



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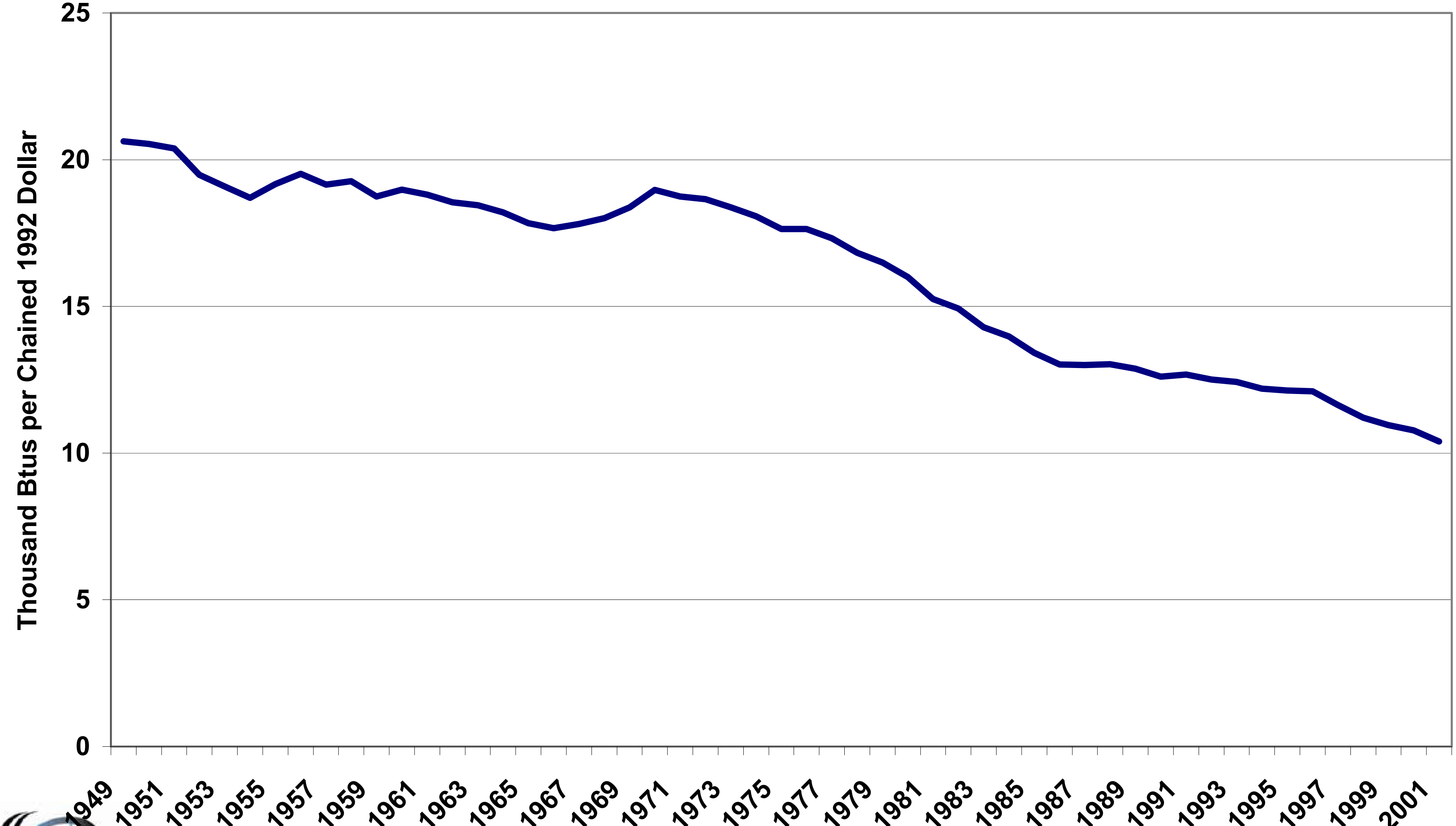
Arthur Rosenfeld, Figure 15

Energy Consumption Per $ of Gross Domestic Product 1949-2001

Source: Table 1.5 Annual Energy Review; data for 2001 is preliminary



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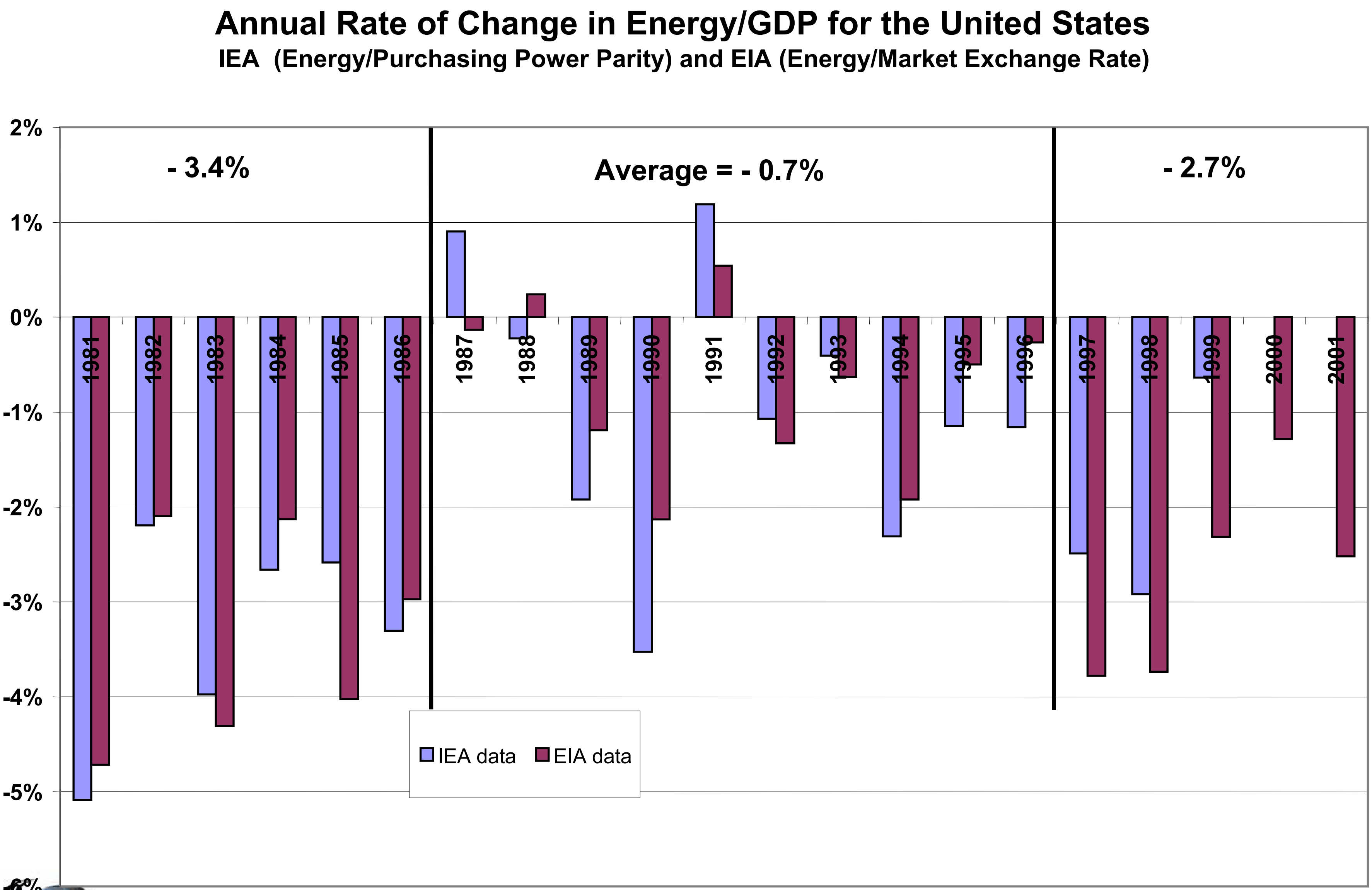
Arthur Rosenfeld, Figure 16



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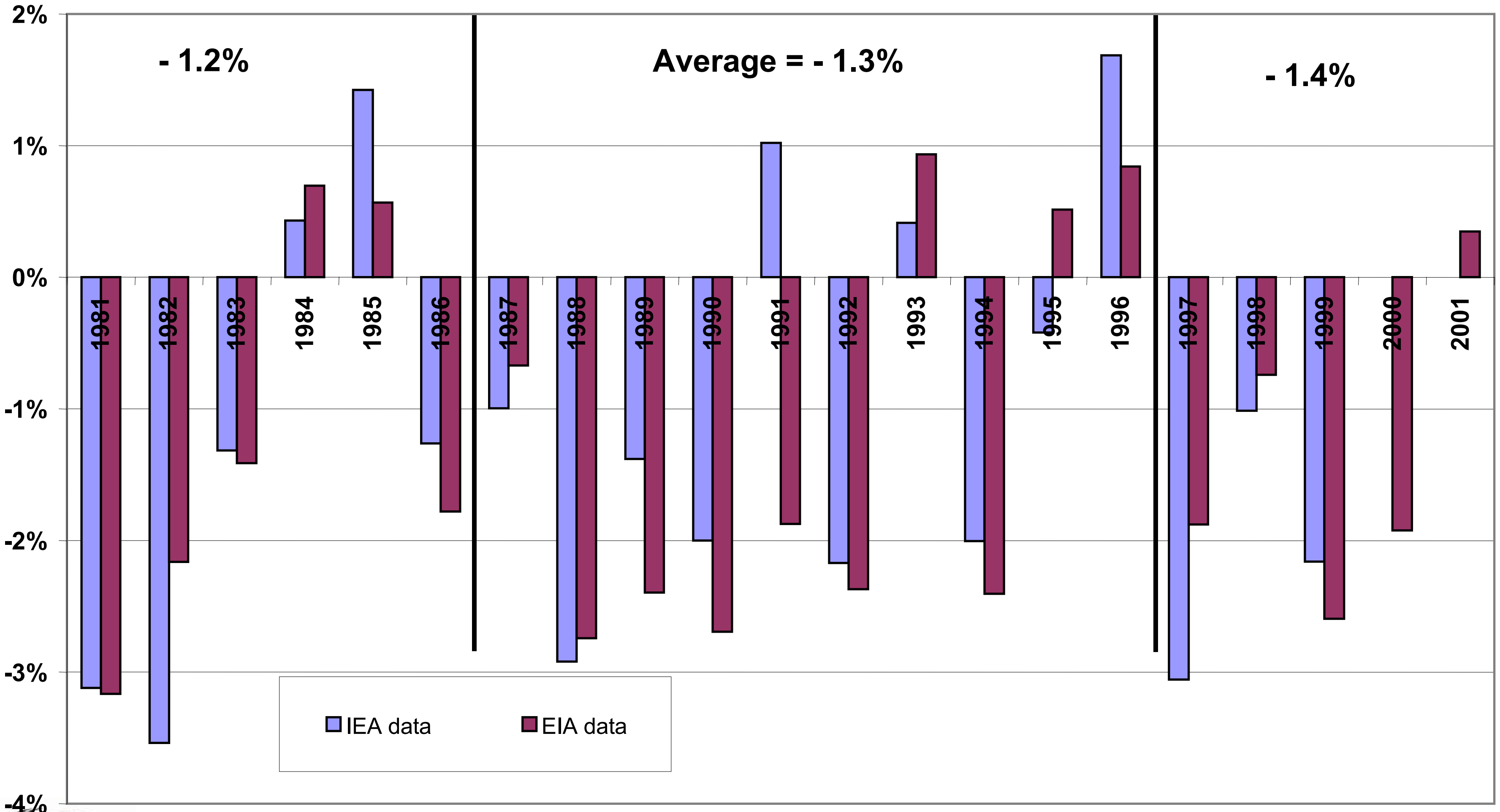
Arthur Rosenfeld, Figure 17

Annual Rate of Change in Energy/GDP for Europe

IEA (Energy/Purchasing Power Parity) for European Union and Western Europe EIA (Energy/Market Exchange Rate)



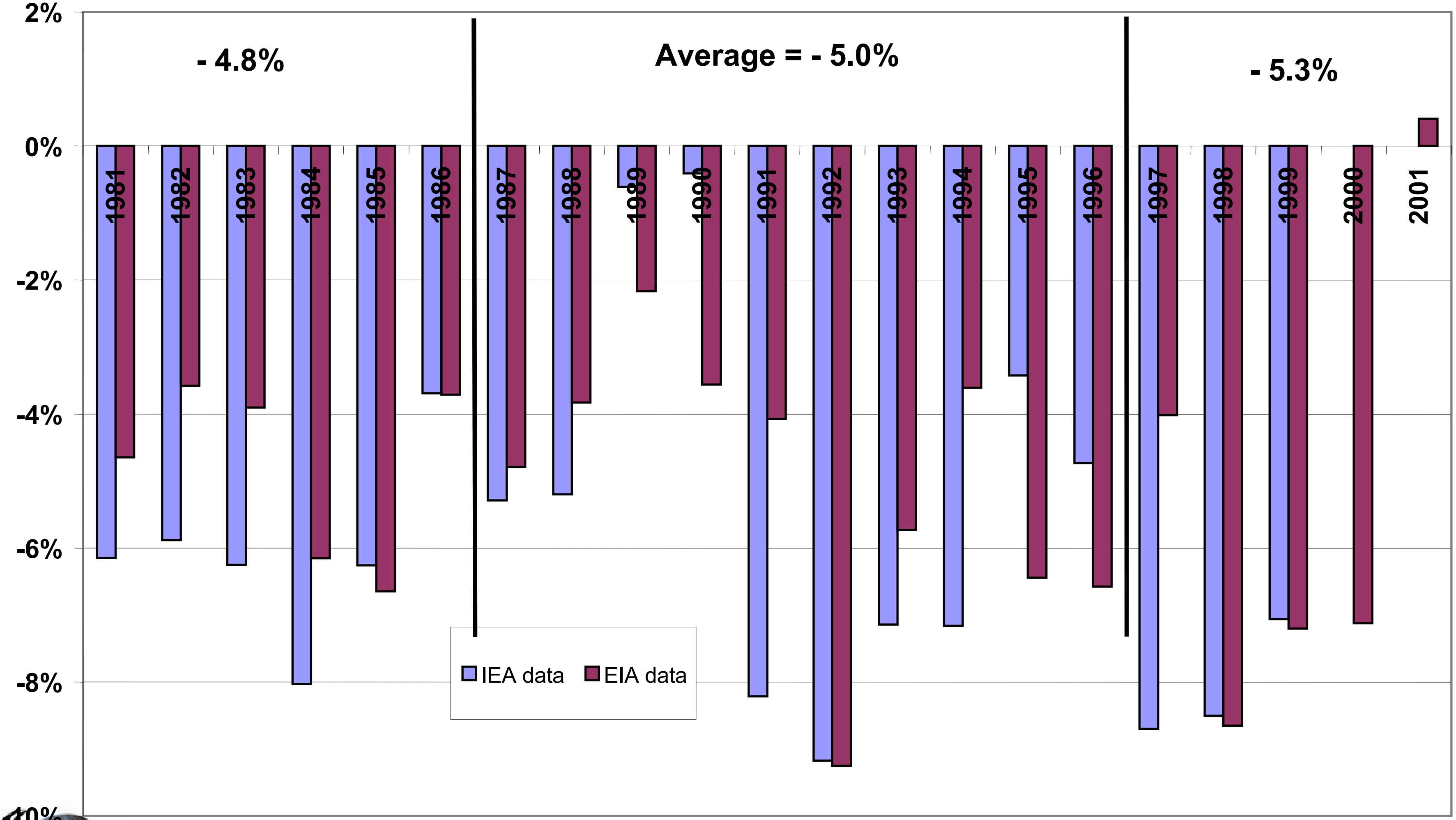
Efficiency

Energy for the Future

Arthur Rosenfeld, Figure 18

Annual Rate of Change in Energy/GDP for China

IEA (Energy/Purchasing Power Parity) and EIA (Energy/Market Exchange Rate)



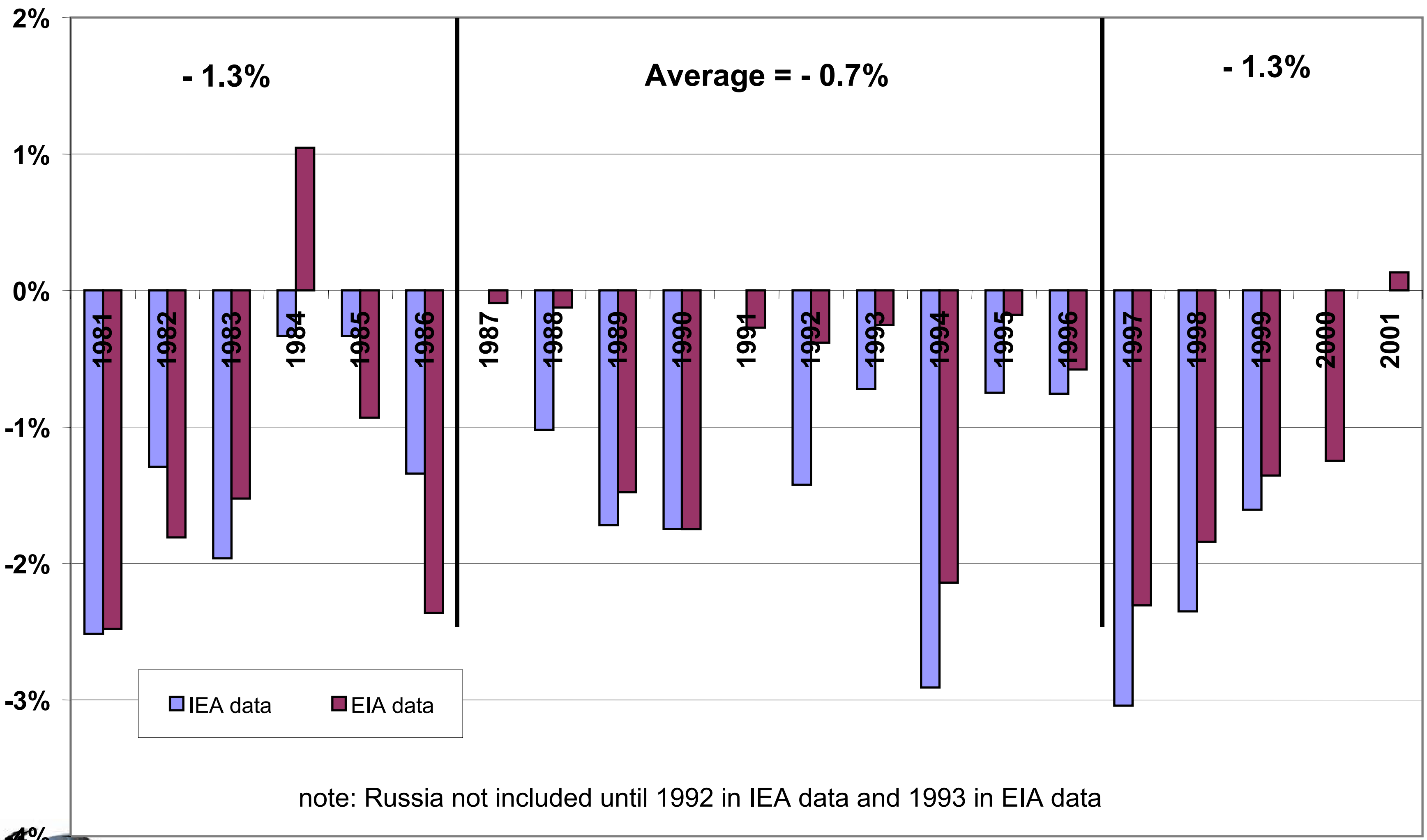
Efficiency

Energy for the Future

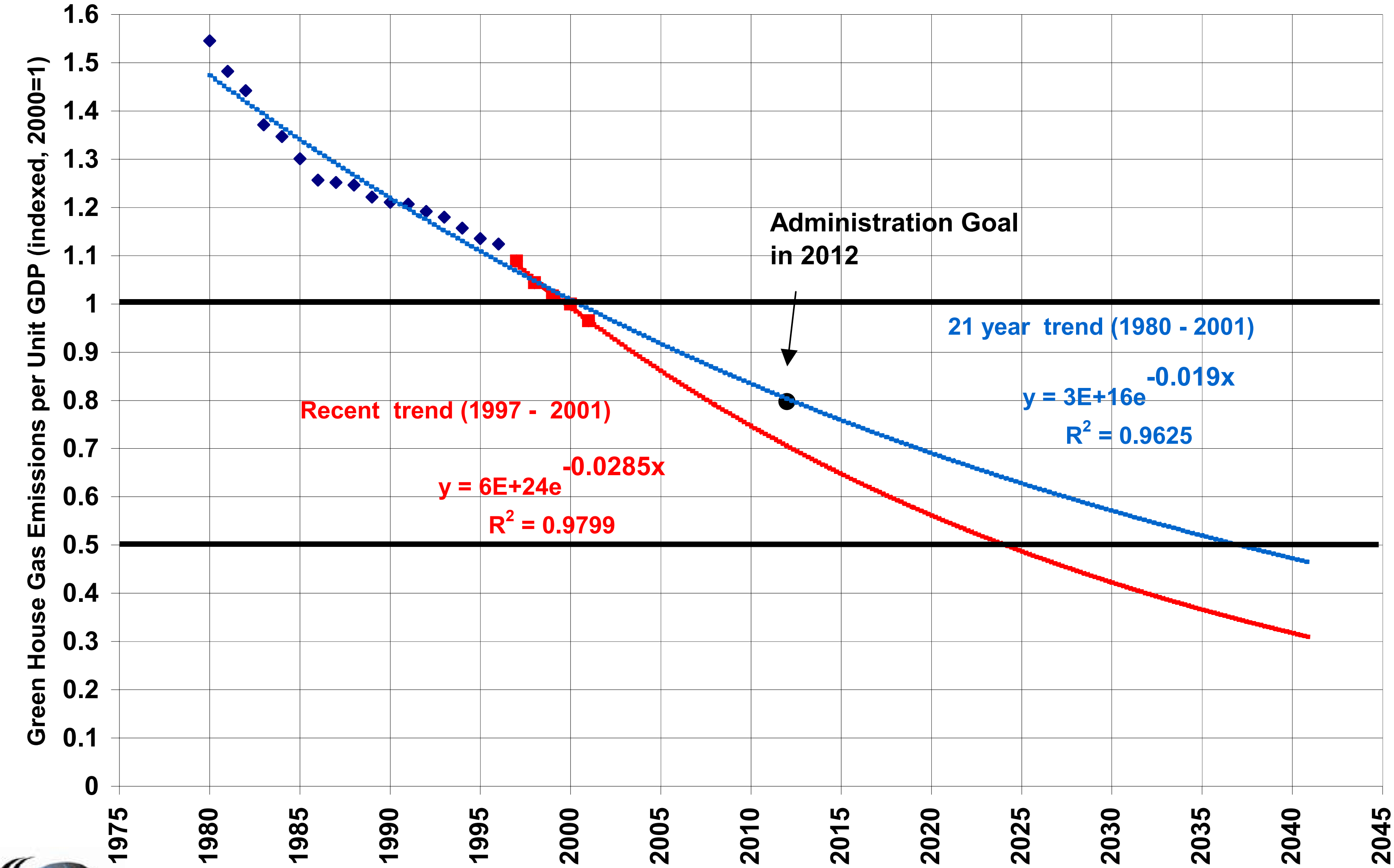
Arthur Rosenfeld, Figure 19

Annual Rate of Change in Energy/GDP for the World

IEA (Energy/Purchasing Power Parity) and EIA (Energy/Market Exchange Rate)



Green House Gas Intensity (GHG/GDP indexed, 2000=1)



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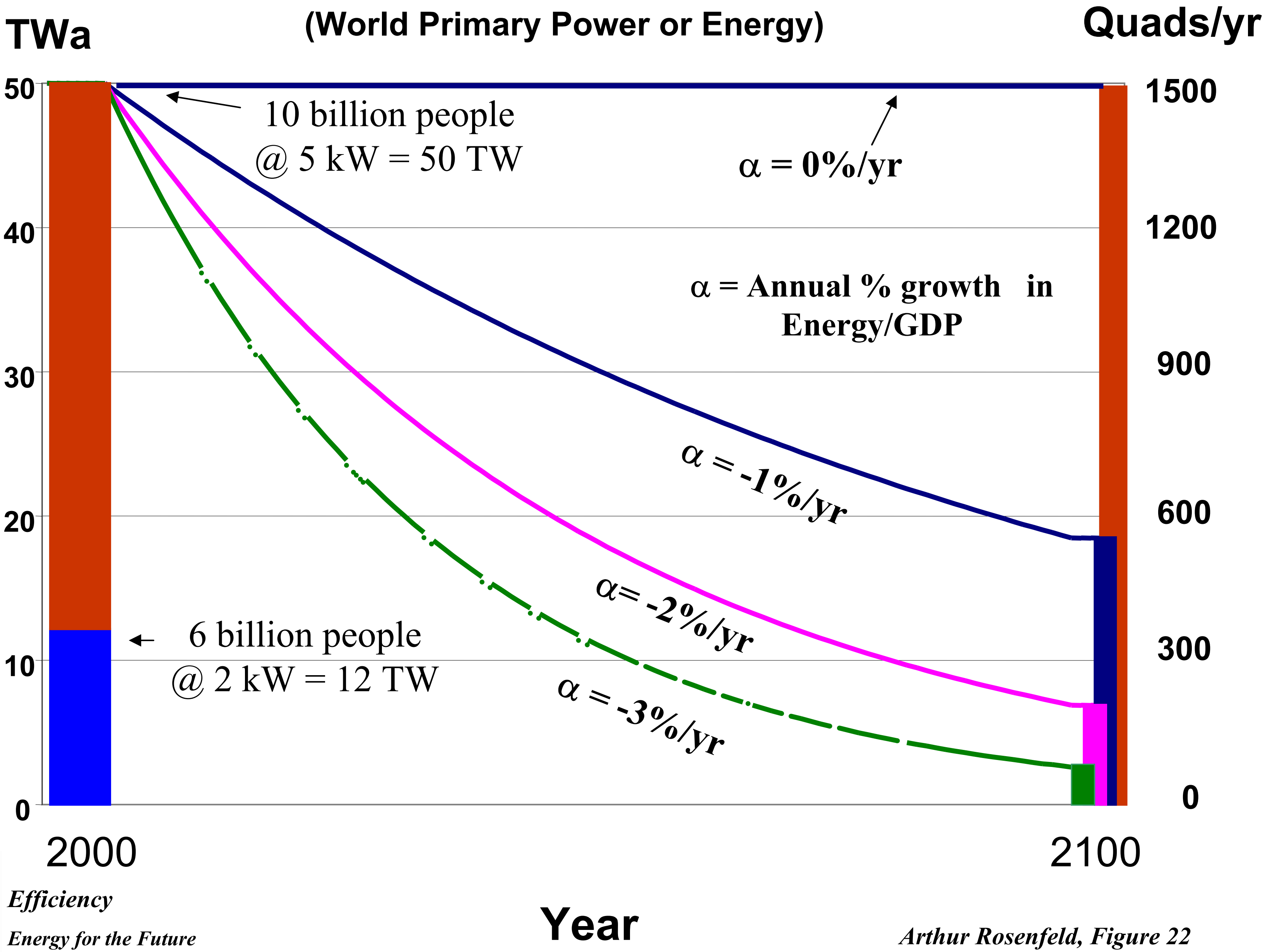
Energy for the Future

Arthur Rosenfeld, Figure 21

The "Conservation Bomb"



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Energy for the Future

Arthur Rosenfeld, Figure 22


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Energy Policy should plan to drop Energy Intensity (E/GDP) 2-3%/year; we're doing that now in the West and in China, and if we keep it up we can prevent serious global warming.

Figure 1 – Title and presenter page

Figure 2. This figure dates back to 1975. *(Source: Annual Review of Energy and the Environment, Volume 24, 1999, page 41)*. Before the OPEC embargo, Calif. Power demand was growing 6%/year, and population was growing at 1.5%/year, so per capita power was growing about 4.5%/year. Now, per capita, it is flat, so we've shaved > 4%/year, always with a simple payback time (SPT) < 5 years. In energy policy, many developing countries today are where the West was in 1974, so they can achieve similar remarkable savings.

Figure 3. Provides updates to Figure 2. Actual demand growth over the last twelve years has been at a rate of 1.8% per year. California's population has risen at 1.7% per year. The bar labelled Nuclear, Fossil, Hydro&Geo shows nuclear and fossil plants planned in 1975 but later cancelled.

Figure 4. The most effective path toward energy efficiency has been standards for autos, buildings, appliances, equipment, etc. Figure 4 shows the remarkable gains in refrigerators. The red smoothly rising line is the increase in size, and the unit energy use is not corrected for this, nor the fact that we've dropped CFC's. Since 1975, refrigeration labels and standards have improved efficiency 5%/year for 25 straight years. We have now saved 40 GW of power plants, just due from refrigerators.

Figure 5. Shows the estimated growth of "standby" power, compared to refrigerators. Standby power is still unregulated, and is already 5-10% of world residential kWh use.
This shows the need for vigilance and an aggressive standards program

Figure 6 shows the savings from improved US refrigerators and freezers (40 GW)

Figure 7 is the same gain, expressed in TWh/year, compared with all US hydro, the Three Gorges dam, existing renewables, and nuclear power.

Figure 8 is Figure 7, re-expressed in dollars, noting that refrigerators save retail electric cost, whereas a kWh of supply is worth only its wholesale price, and in the United States the retail/wholesale ratio is nearly three to one. So, expressed in dollars, refrigerator bill savings, at the meter, will soon surpass the value of nuclear power, at the bus bar.

Figure 9 is based on the analysis that if Chinese refrigerators and air conditioning were as efficient as those in the US, they would use 40% less kWh, and a/c would use 35% less. At today's rate of Chinese sales, demand from these two appliances will grow to 1.5 times the output of the Three Gorges dam in the decade it will take to fill the dam. If China tightened appliance standards, it could save half the output of the dam. This policy message applies to most developing countries.

Figure 10. Air Conditioning Standards have significantly improved the performance of residential and package commercial ("rooftop") units. To date, we estimate that moving from energy efficiency ratings (EER) of 7 to 9 have saved 28% of the United States peak load and the new 2006 standards (EER = 11) will save an additional 22%.

Figure 11 continues the discussion of estimated power savings due to air conditioning. By moving from EER 7 to 11, we will avoid the need for 100 GW of peak generating capability. This is about twice the California peak load and about equal to the nuclear capacity in the United States. In addition, cool roofs can save an additional 20 GW.

Figure 12 compares kWh/capita for California, constant for 27 years, with the US, which during the same time grew 50%, i.e. 2%/year.

Figure 13 shows an estimate of the causes of this 2%/year gain. Each year, the cost of conservation programs, public interest R&D, and standards adds ~1% to electric bills, but cuts 1/2% off the bill. So an investment of $1 in say 1990 saves $.50 per year for 10 to 20 years. Although not depicted on this slide, other policies also have led to electricity savings in California. For example, California standards allow electric water heating in homes only when it is cost effective: which is seldom the case. This has resulted in only limited electricity use for this purpose in California. Per Capita use is just 200 kWh in California for electric hot water heating while in Florida the use is about 1,200 kWh per person.

Figures 14, 15, and 16 show US primary energy (not electricity) use from 1949 to present, for the United States, per capita, and per $ of real GDP. Note the downward kink in E/GDP (see Figure 16) starting in 1997

Figures 17 through 20 illustrate annual rates of change in energy intensity data provided by the United States Energy Information Agency and the International Energy Agency. Figures are provided for the United States, Western Europe, China and the entire World. Recent changes (from 1997 onward) look to me (and to Joe Romm) to be making a permanent change in the rate of decrease of our energy intensity (E/GDP). The vertical lines divide the time period (1981 to 2001) into three eras. Era 1 covers the latter years of high OPEC oil prices. Era 2 starts soon after the collapse of OPEC and the consequent stagnation of CAFE (Corporate Automobile Fuel Economy) standards. Era 3 begins with the significant impact of information technologies on business and the economy. The numbers written above each era reflect the average rate of change in E/GDP (EIA data) for that era. Compare for example, in Figure 17 the United States trend in Era 2 of only – 0.7% per year to the more sudden – 2.7% per year in Era 3. Figure 18 shows a nearly constant improvement in E/GDP, averaging – 1.3% over the entire time period.
Also of note, see Figure 19, are the efficiency gains made by China. Over the last twenty years China has averaged - 5% per year in E/GDP.

Figure 21 shows GHG (GreenHouse Gas) intensity (i.e. per GDP) for the last 26 years. The Blue 21-year fit, which is also the Bush Admin. Target, drops 1.9%/year, BUT the red 5-year fit drops 2.85%/year, and gets us down to 50% 10 years earlier. I think the Administration goal should at least try to keep up the 5-year trend.

Figure 22 illustrates the 100 year importance of maintaining the 2-3%/year drop in energy intensity, compared to 1%, and is stimulated by Hoffert *(Martin Hoffert (NYU) et al., Nature 395, 29 Oct. 1998, p. 881; www.nature.com)*, whose 1998 paper in Nature says that 1%/year is as good as we can hope for. Hoffert et al. then call for a Manhattan-scale project for getting off fossil fuel. My cheaper and faster approach is to invest more heavily in negawatts. In Figure 22, the vertical scale is world energy use, in TWa ("a" for average) on the left, or Quads/yr on the right. The blue bar (12 TWa) at 2000 represents today's energy use. Now I chose a goal for 2100, mainly for the developing world outside of US, Europe, and Japan. Population is leveling off, thankfully, so 10 billion people in 2100 seems generous. Let's plan to give everybody the standard of living, and the energy use/capita, of W. Europe today (i.e. 5 kWa, compared with 2 kWa worldwide). Then world TWa would be 10B x 5 kWa = 50 TWa, or about 4 times today. We plot this as the red bar at 2000, since it's just 10 B x **today's** technology). But we have 100 years before we are there. So we introduce Alpha as the rate of growth of energy intensity. If Hoffert's right and alpha = -1%/year, then we'll drop from 50 to 18 TW (i.e. drop to only 1.5 x today). But if we can keep up even 2%/year, then in 100 years we'll be down to ***half*** of today, and with alpha = -3% ---- no GHG problem.

Of course, even with alpha = -2%, the energy trajectory during this century will still grow before it levels off. And the West may have become very energy intensive; but we're so rich we really can develop wind and other promising renewables. But I hope I've shown the importance of keeping our eye on the greenest energy of all --- negawatts through vigilant efficiency improvement.

Figure 23 shows direct lights, visible from an airplane above Los Angeles. During the 2000-2001 California electricity crisis, the CEC was given the power to regulate out-door lighting, and thus reduce CA kWh usage by 1-2%. Thus modern street lights, instead of drawing say 150 watts with half the light going upwards, will need only 75watt if a reflector directs all the light downward. So seen from the air at night, California cities should gradually disappear. This slide illustrates how we can add new scope to our energy efficiency standards and policies.

Figure 24 shows how Bermuda homes avoid air conditioning with white roofs. The California 2005 new building standards will give credit for cool roofs. Eventually this will save several percent of our peak power demand. This is another example of adding new scope to our efficiency portfolio.

If we keep addressing new areas (like outdoor lighting or cool roofs) each year, and improving vehicles, buildings, equipment, and industrial and agricultural processes, we should be able to keep alpha at –2% to –3% per year, thus saving money and capping global warming.