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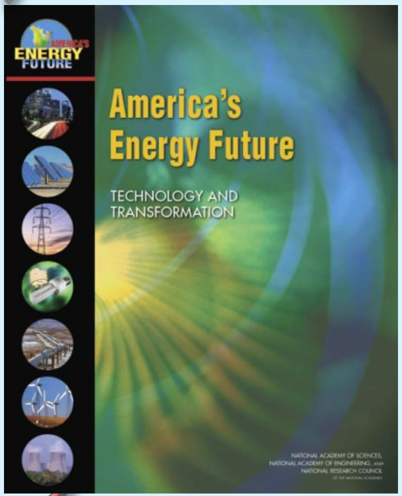
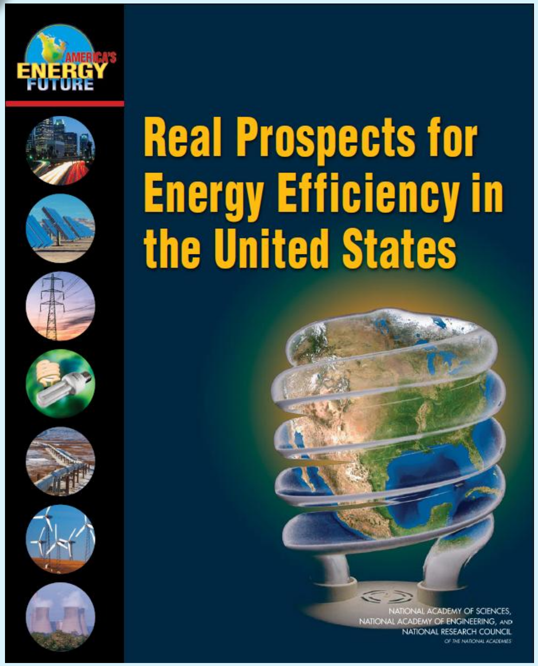
America's Energy Future: Technology Opportunities, Risks, and Tradeoffs

http://www.nationalacademies.org/energy

July 29, 2009



Scheduled Release December 9, 2009



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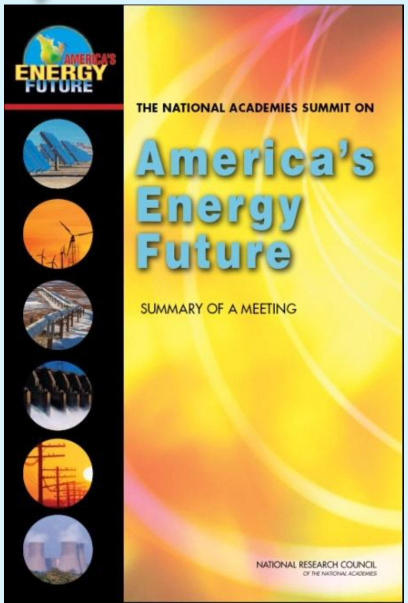

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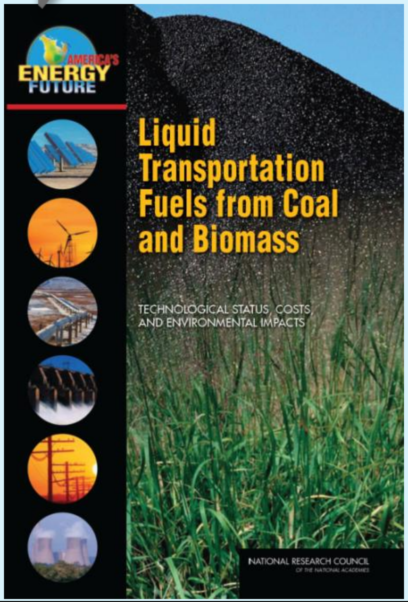

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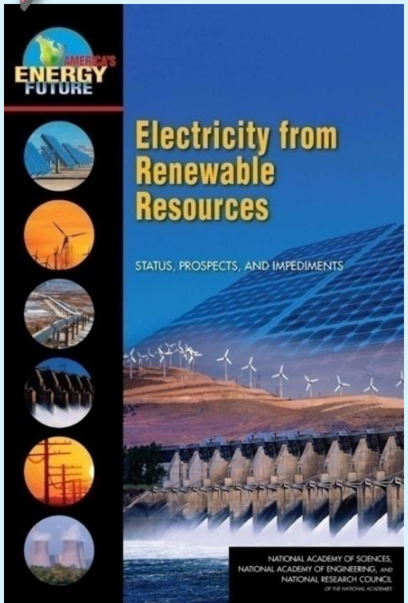

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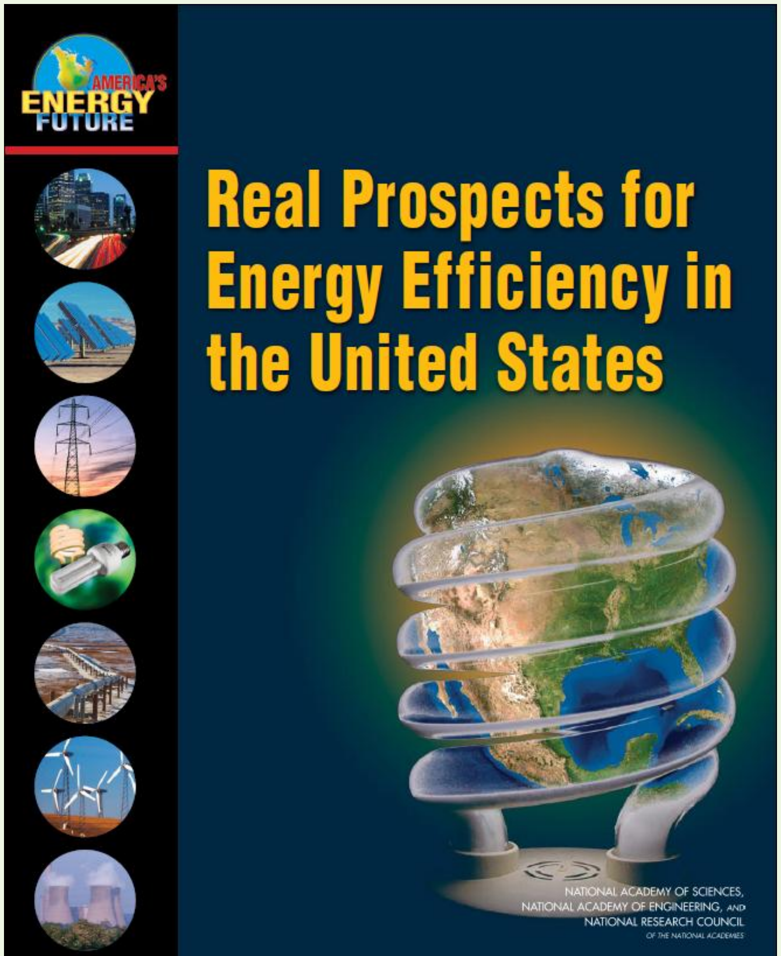

December 2009

National Research Council
America's Energy Future Panel
on Energy Efficiency Technologies

Lester Lave, Chair
Maxine Savitz, Vice-Chair

Public release:
December 9, 2009

U.S. Energy Efficiency Potential
(Quadrillions of Btus [quads])

- U.S. energy use (2008): 101 quads
- EIA projected U.S. energy use (2030): 118 quads
- Energy efficiency savings potential: 35 quads saved
- Net U.S. 2030 energy use: 83 quads

- 35 quads/yr savings potential by 2030, saving money & energy

AMERICA'S ENERGY FUTURE

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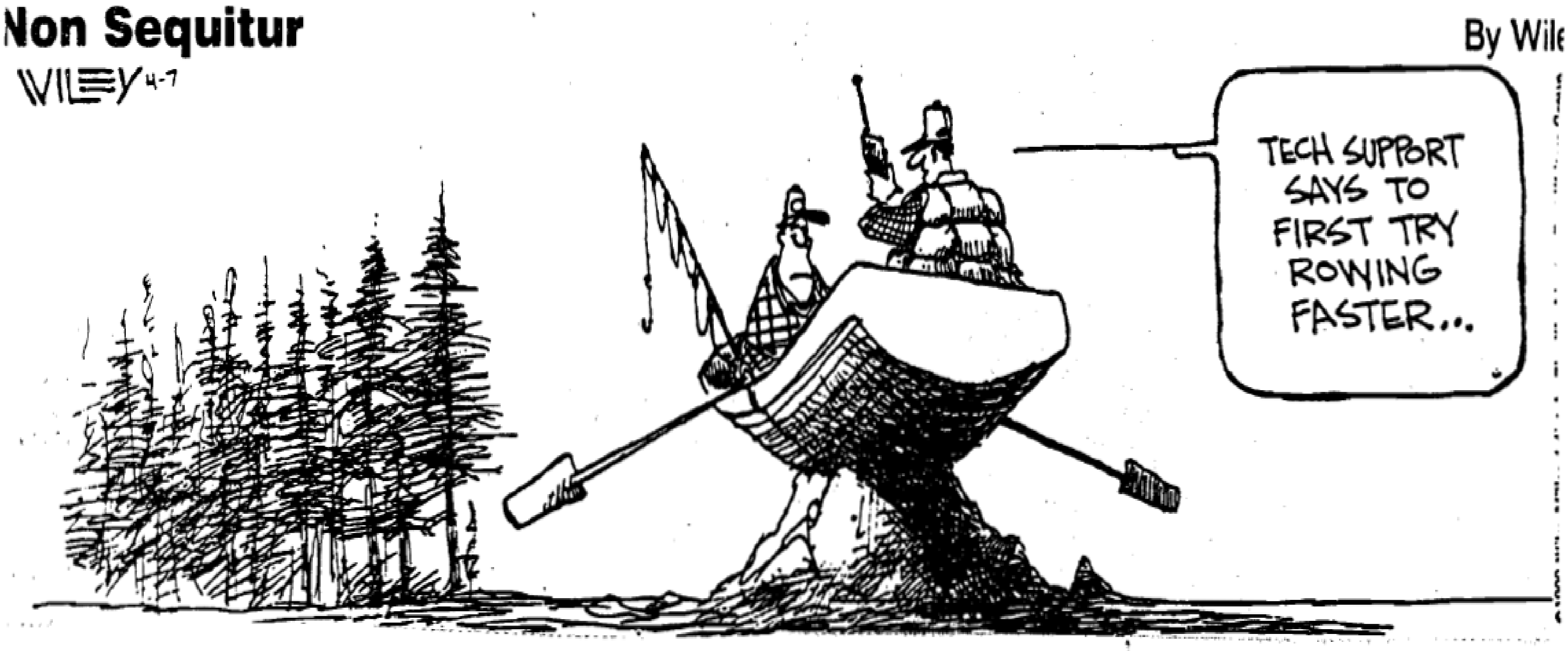
Current US Energy Policy



Tech support says to try rowing faster…

We are trying to solve the wrong problem!

Is the goal finding & using more energy?

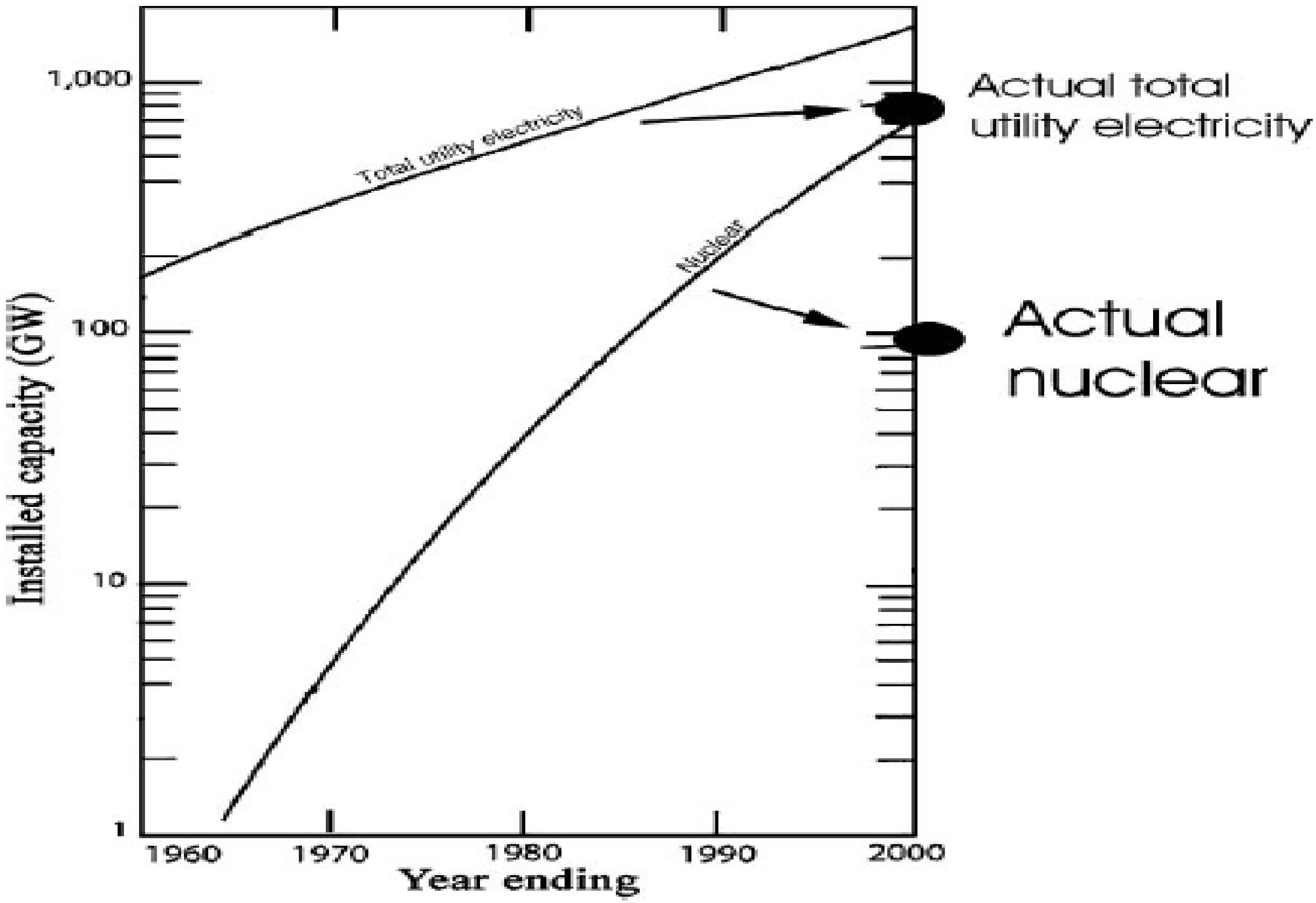
Is Energy Important?

http://needtoknow.nas.edu/?utm_medium=etmail&utm_source=National Academies Press&utm_cam

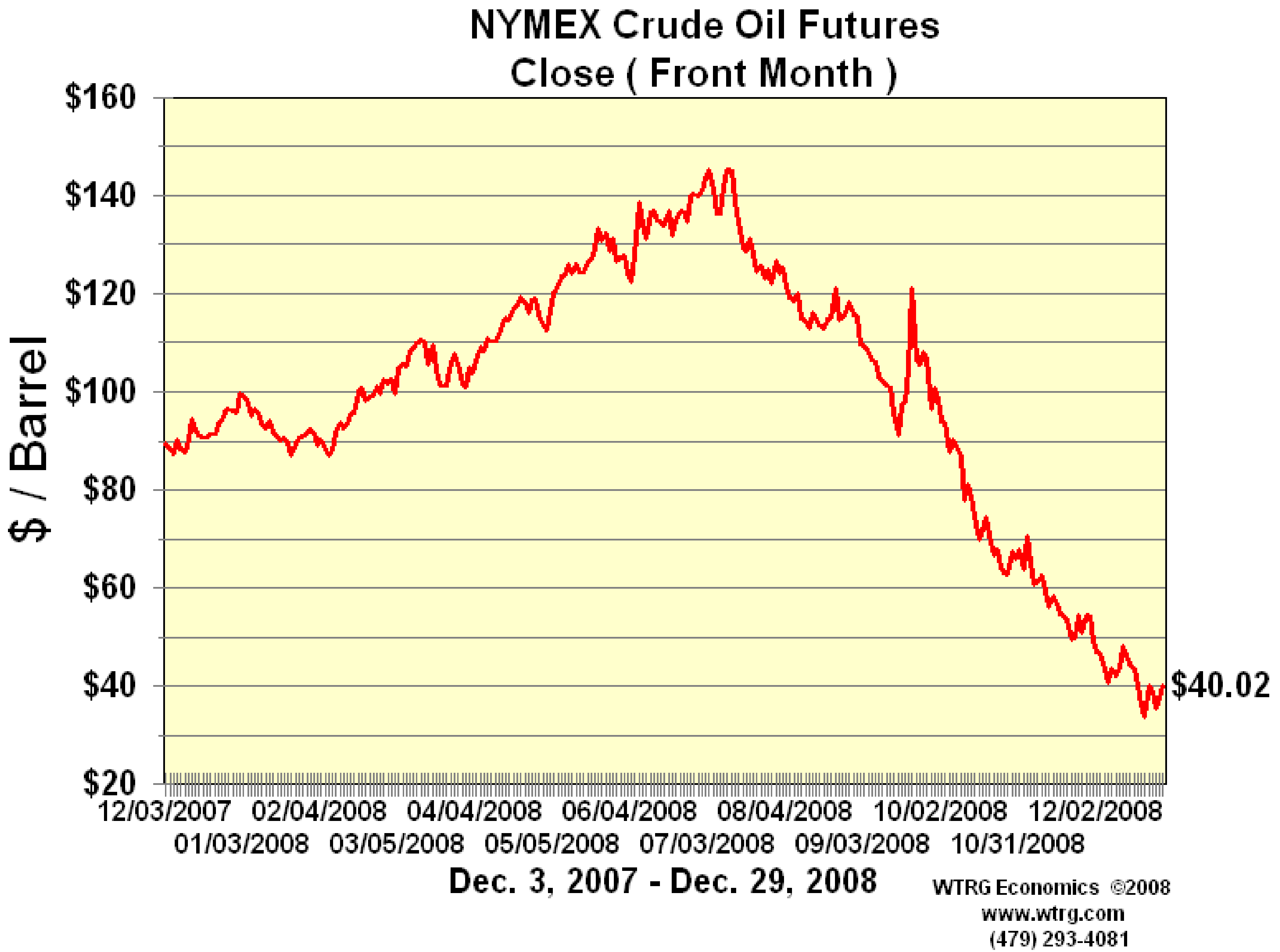
- The average American uses 350 giga-joules of energy per year
- Equivalent to having 45 horses/working hour
- Or 450 workers per working hour
- A rich man could afford a slave or a horse
- An American has the equivalent of 450 slaves or 45 horses
- Energy makes modern civilization possible

How Much Energy Will We Need? Don’t Believe Forecasts

- What can we say about the world of 2106? 2056? 2011?
- What did the smartest people in 1906 predict for 2006? Medicine? Homes? Offices? Space travel? Air travel?
- Their forecasts were wild fantasies: Health care, computers, jet travel, electricity, TV, space travel, synthetic fabrics, high incomes, food quality, entertainment
- When are markets best



igure 3   An Atomic Energy Commission forecast from 1962, designed to sh


NYMEX Crude Oil Futures
Close (Front Month)
$ / Barrel
$160
$140
$120
$100
$80
$60
$40
$20
$40.02
12/03/2007
02/04/2008
04/04/2008
06/04/2008
08/04/2008
10/02/2008
12/02/2008
01/03/2008
03/05/2008
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Dec. 3, 2007 - Dec. 29, 2008
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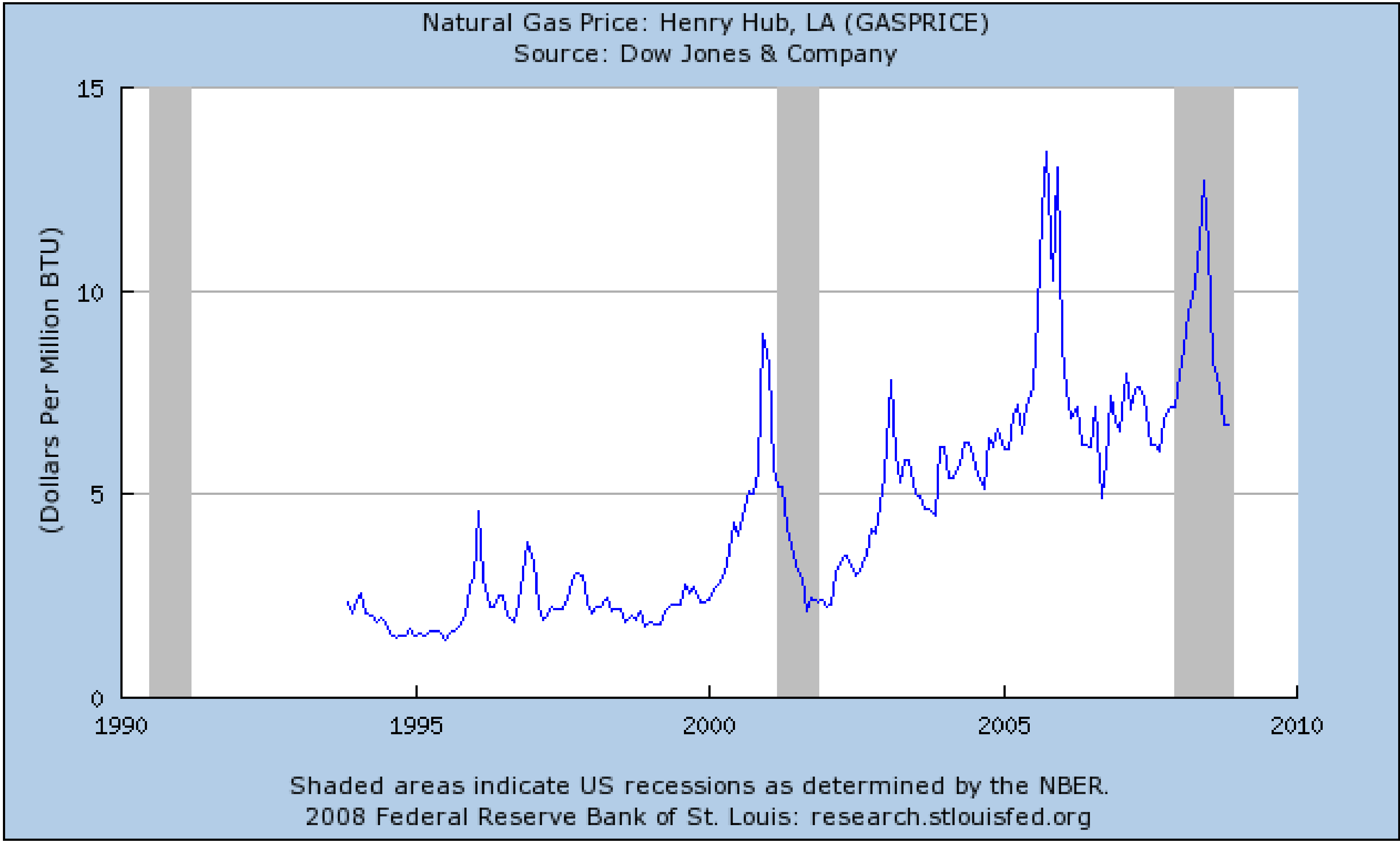
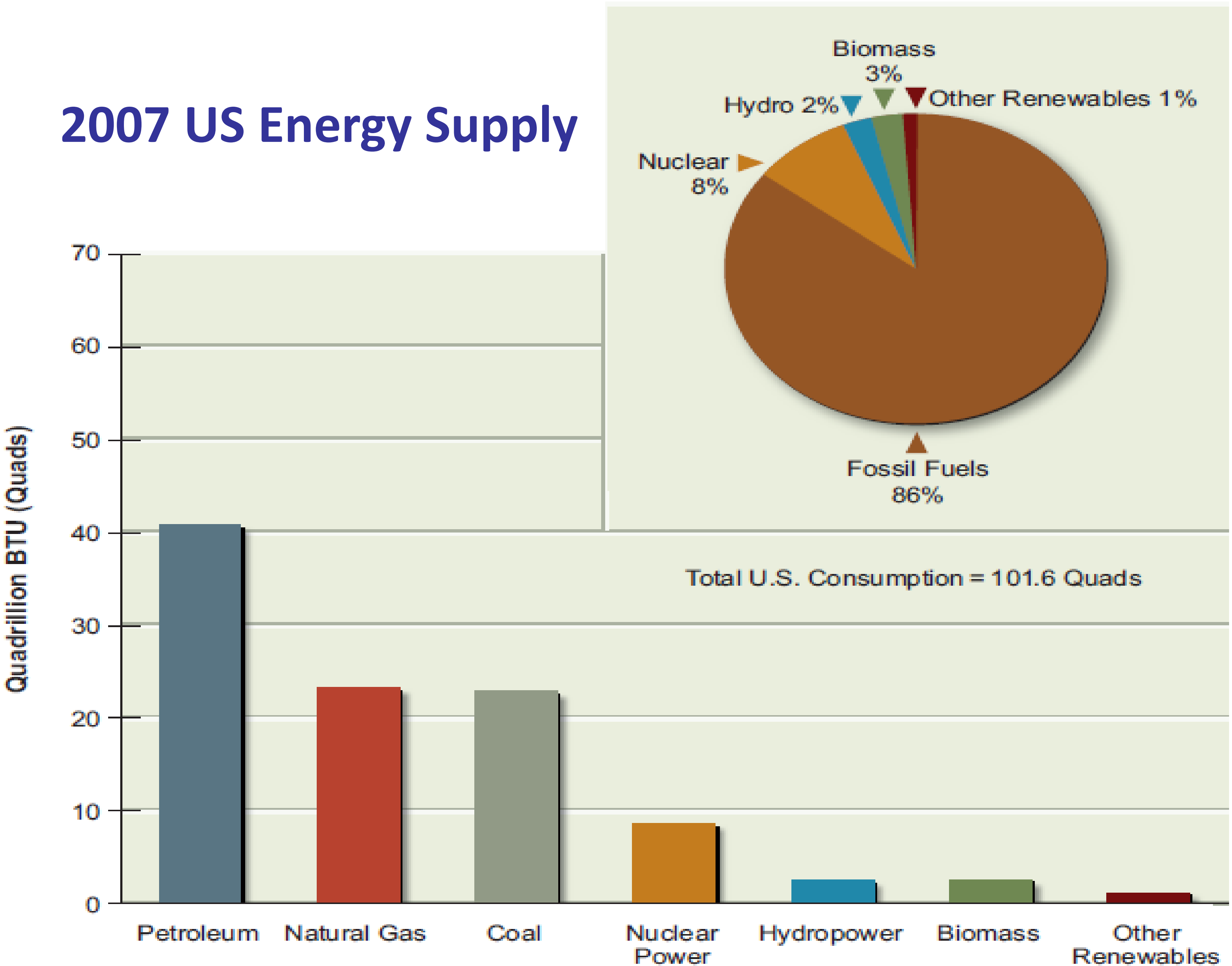


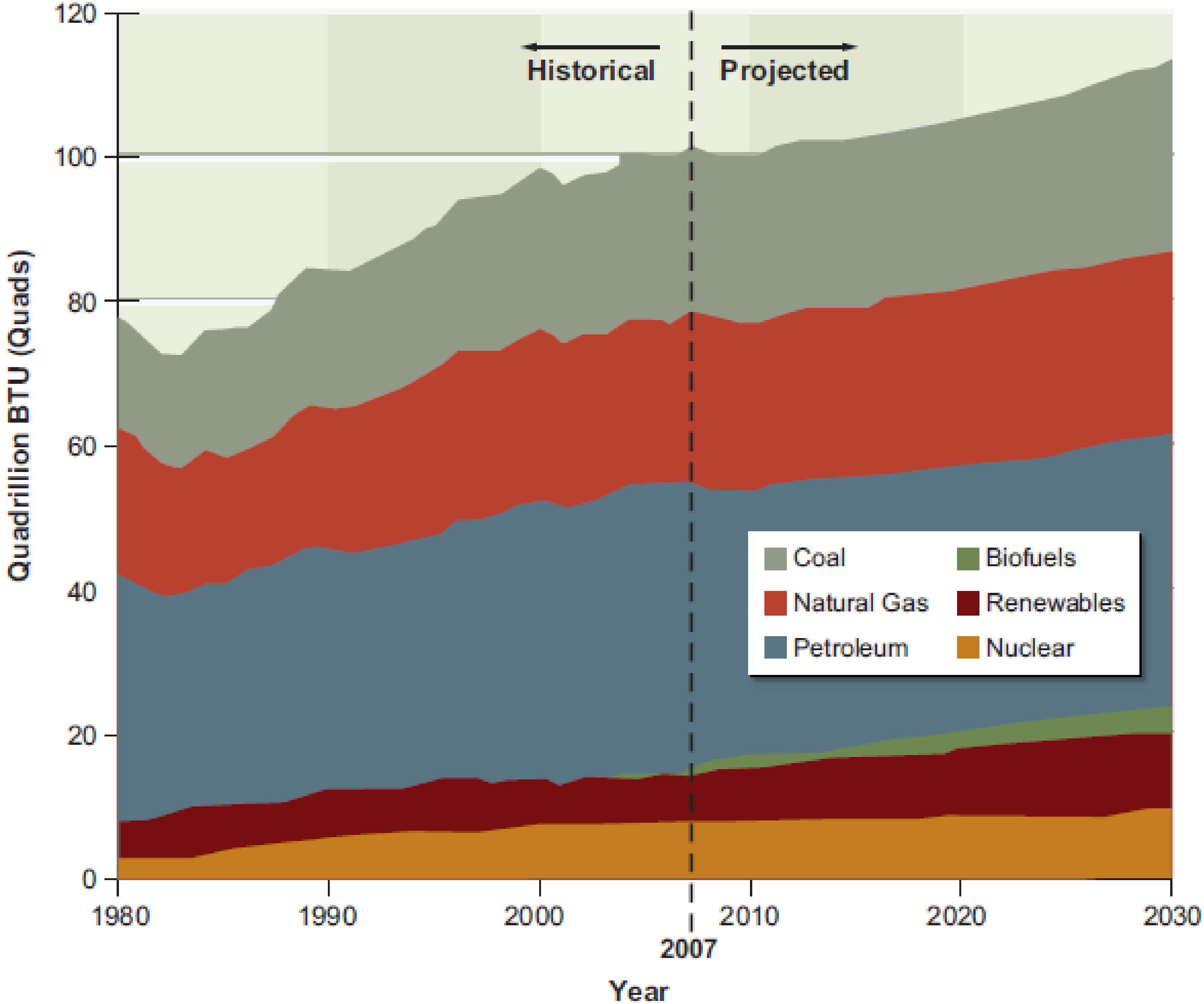
Natural Gas Price: Henry Hub, LA (GASPRICE)
Source: Dow Jones & Company
(Dollars Per Million BTU)
15
10
5
0
1990
1995
2000
2005
2010
Shaded areas indicate US recessions as determined by the NBER.
2008 Federal Reserve Bank of St. Louis: research.stlouisfed.org

Supplying more Energy

- US energy use increased from about 10 to more than 100 quadrillion BTUs per year from 1900 to 2000
- Can we get 1,000 quads/yr by 2100 from petroleum, natural gas, and coal (86% of current energy supply)?
- 1,000 quads/yr from wind, solar, nuclear?
- Every new well, mine, generator, wind turbine, & PV array has opponents!

2007 US Energy Supply





Historical
Projected
Quadrillion BTU (Quads)
120
100
80
60
40
20
0
1980
1990
2000
2007
2010
2020
2030
Year
Coal
Natural Gas
Petroleum
Biofuels
Renewables
Nuclear

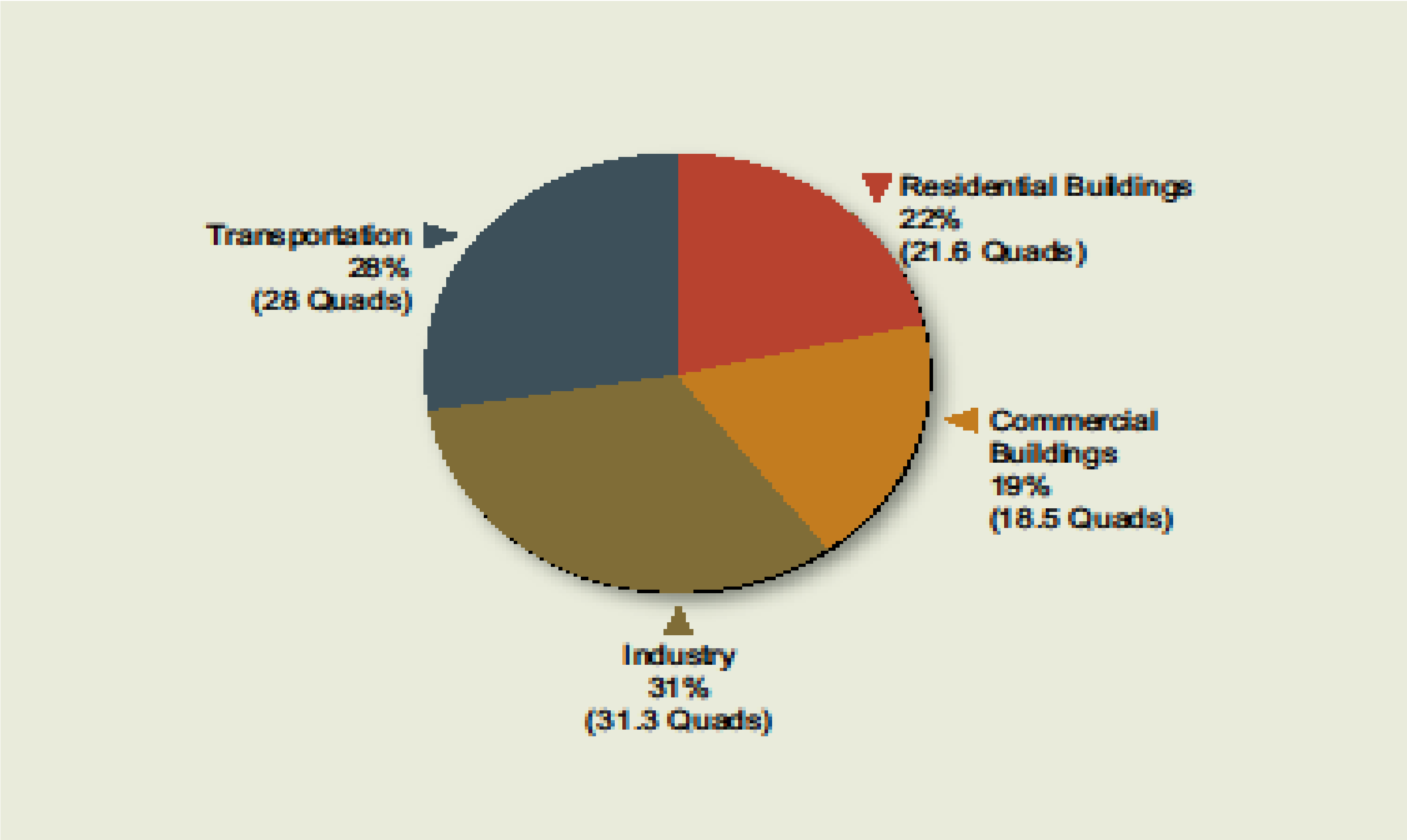
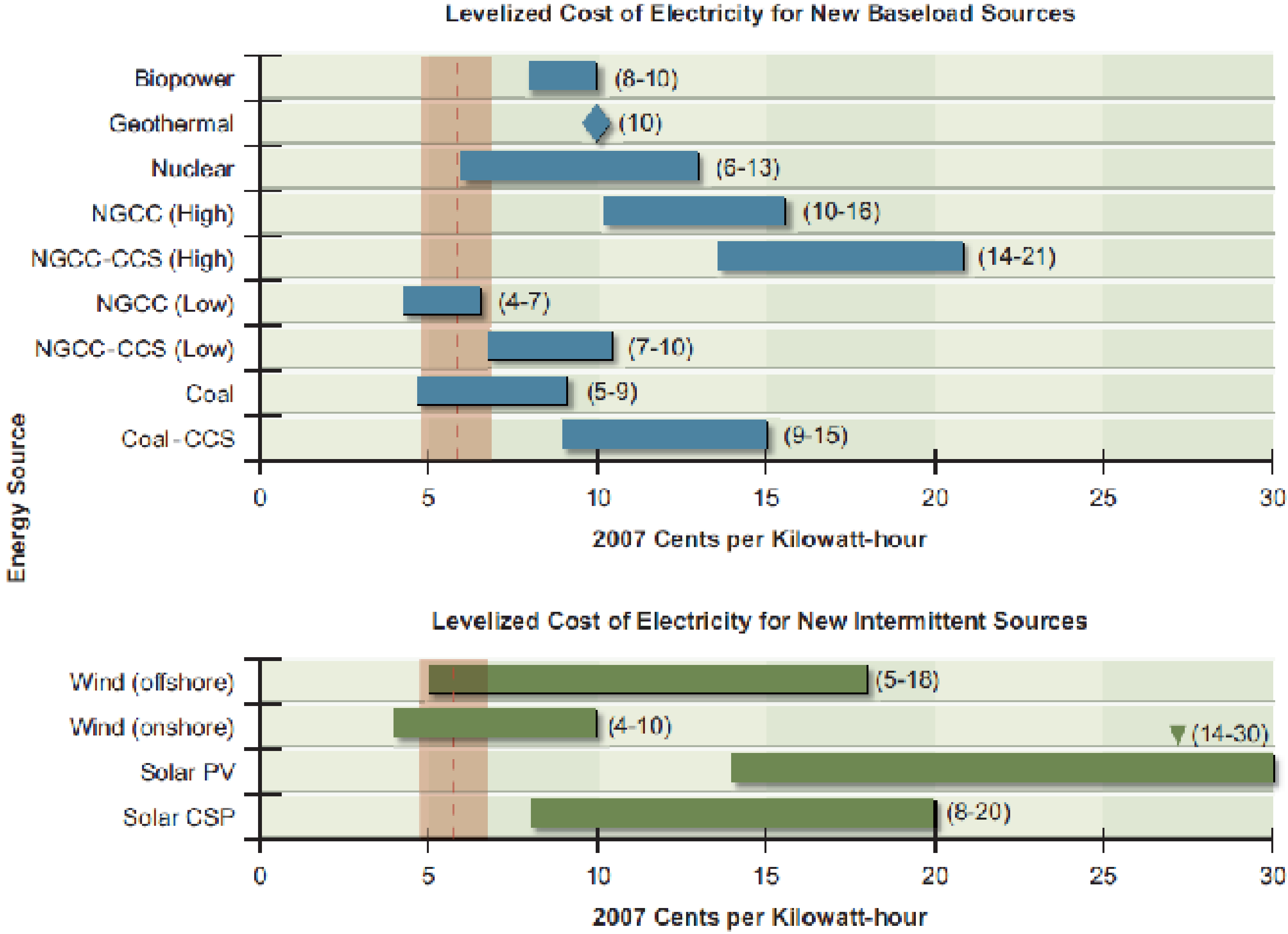


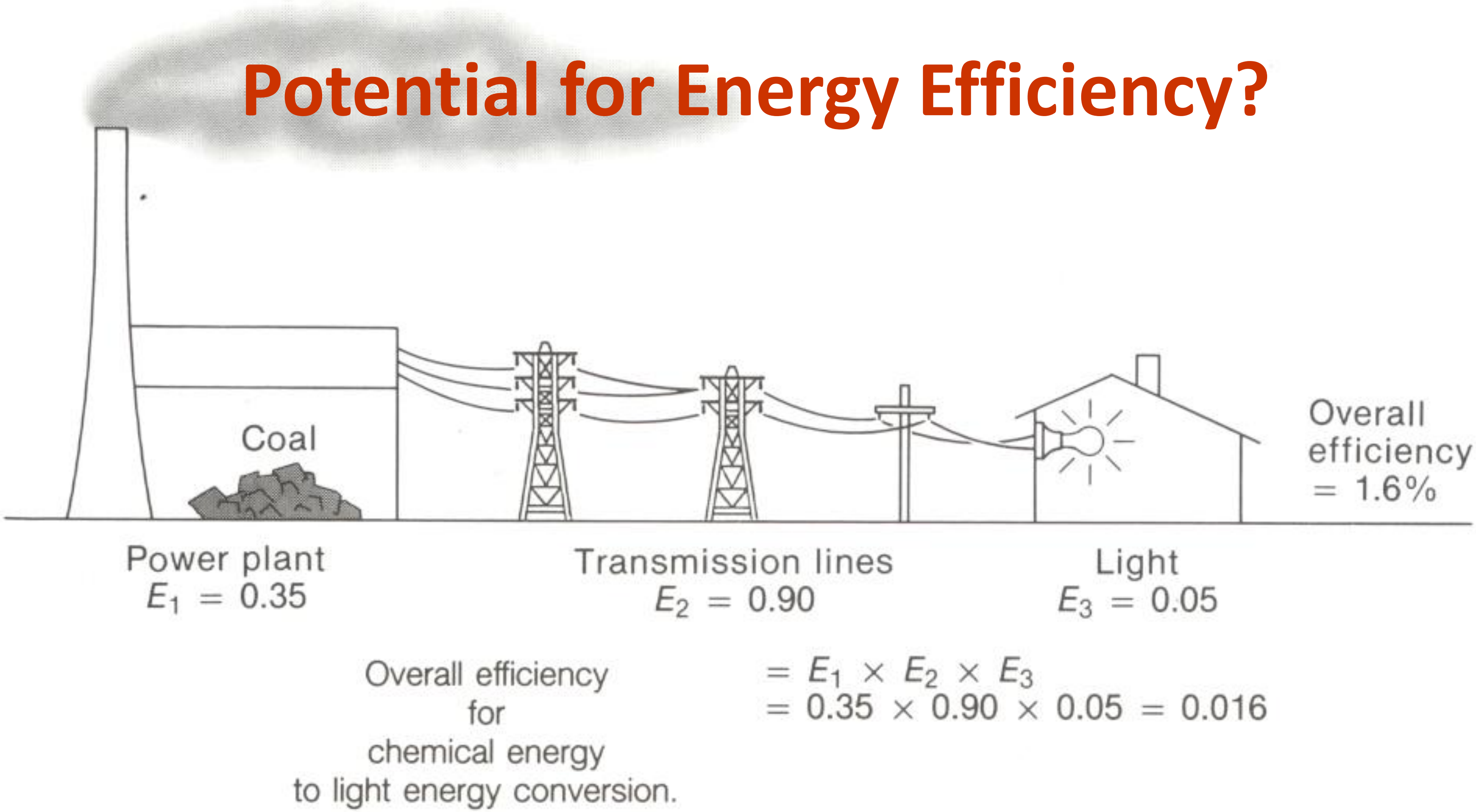
FIGURE S.2 *Total energy consumption in the United States in 2008, by sector and fuel. Shown are electricity consumption, with the losses in generation, transmission and distribution allocated to the end-use sectors, and the fuels used on-site in each sector. Electricity is generated off-site using fossil, renewable, and nuclear energy sources. Source: EIA 2009a, as updated by EIA, 2009c.*

ally achievable savings as a function of the cost of saved energy show consistent

Levelized Cost of Electricity Generation



Potential for Energy Efficiency?



Replace incandescent lamps with CFL: 6.4%

Replace CFL with LED (2013): 12.5%

Conclusion: Tremendous potential for efficiency

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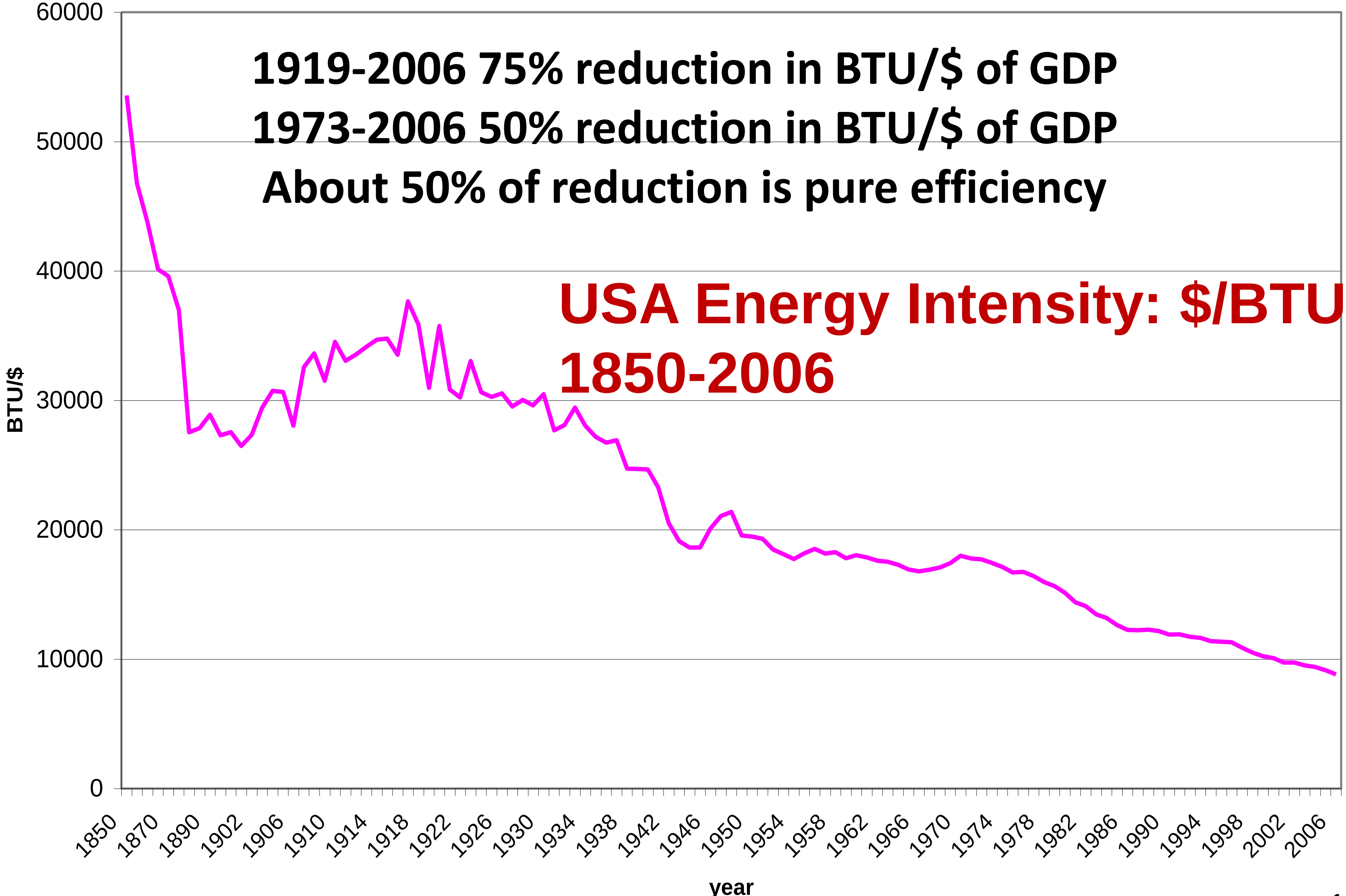
Energy intensity (BTU/$) 1850-2006

USA



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2005 Energy Use

	BTU/person (millions of BTU)	BTU/$ of GDP
USA	340	9,113
Japan	177	4,519
Denmark	153	4,845
France	182	7,994
Germany	176	7,396

About half of the US-Denmark difference is efficiency & half is lifestyle (the bundle of goods & services)

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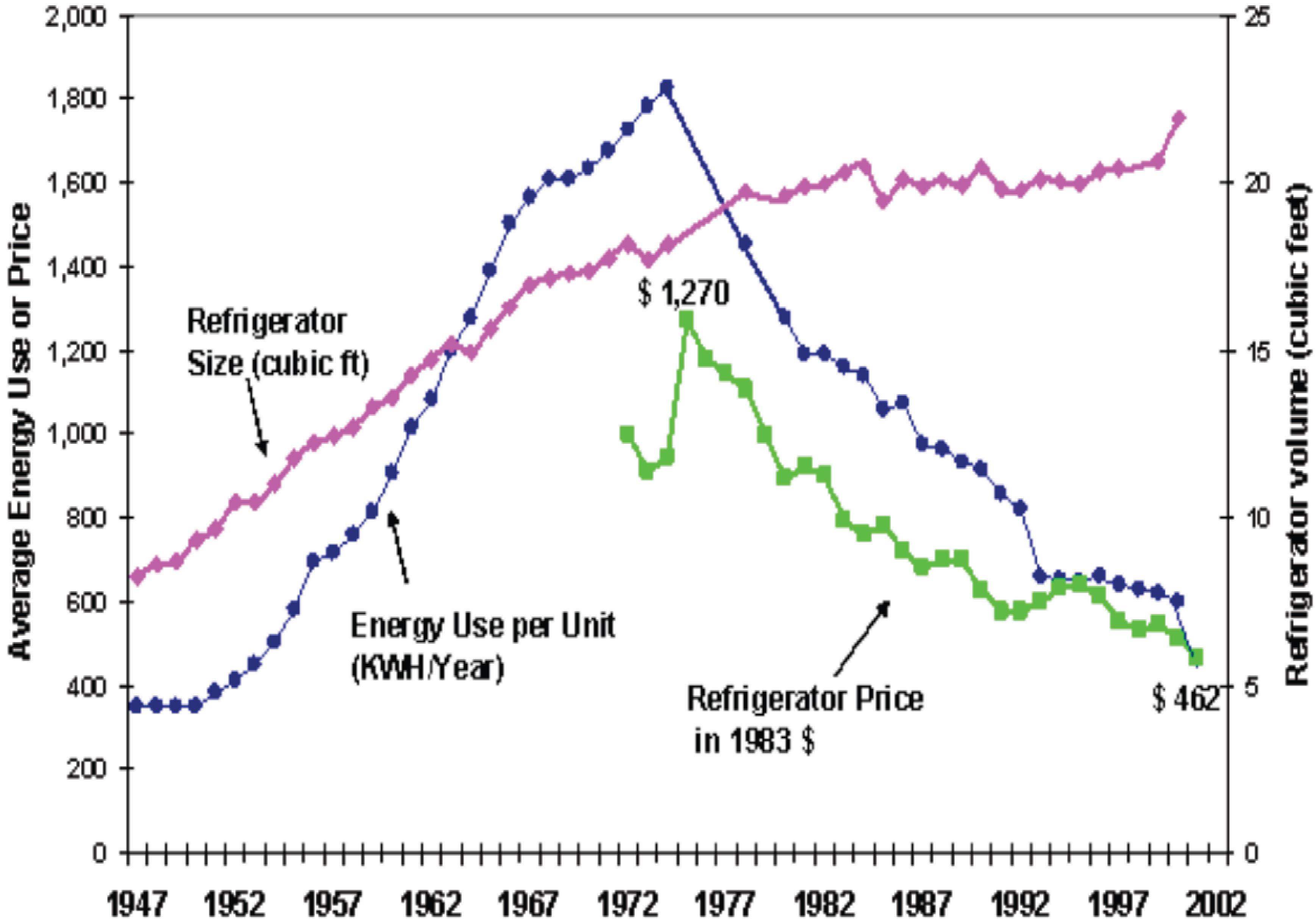
Average Energy Use or Price
Refrigerator volume (cubic feet)
2,000
1,800
1,600
1,400
1,200
1,000
800
600
400
200
0
25
20
15
10
5
0
Refrigerator Size (cubic ft)
Energy Use per Unit (KWH/Year)
$ 1,270
Refrigerator Price in 1983 $
$ 462
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002

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Formidable Barriers to Energy Efficiency

- Pricing doesn’t reflect scarcity & externalities
- Lack of knowledge/information
- Landlord-tenant, builder-buyer
- Enough demand to lower production costs
- Imperfect installation
- Enacting & enforcing legislation & regulations
- Access to credit
- Poor second-hand market

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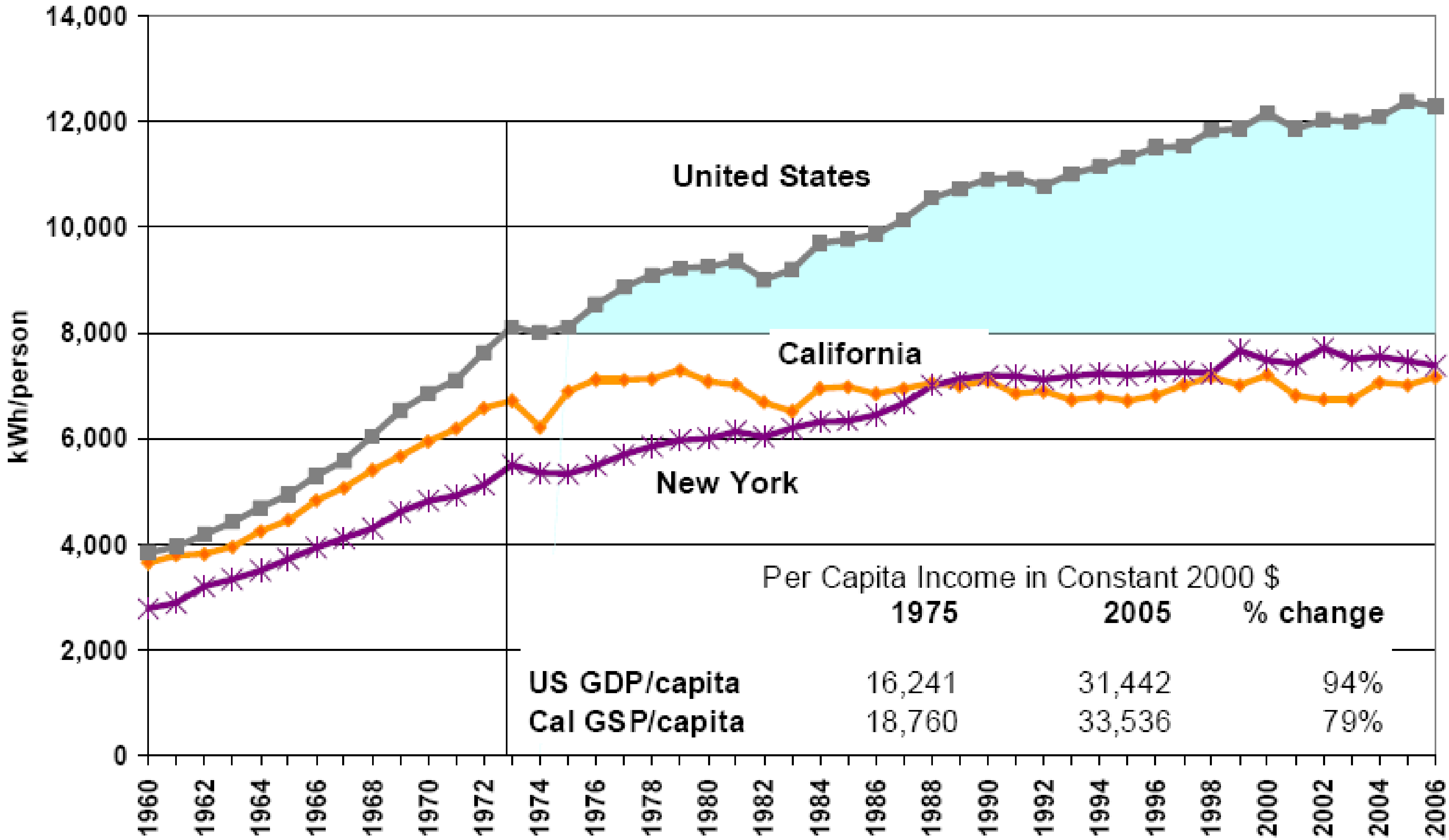

Per Capita Electricity Consumption, California, New York, & USA: How do CA and NY do it? VT has reduced consumption/capita

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Lesson: Price is Important

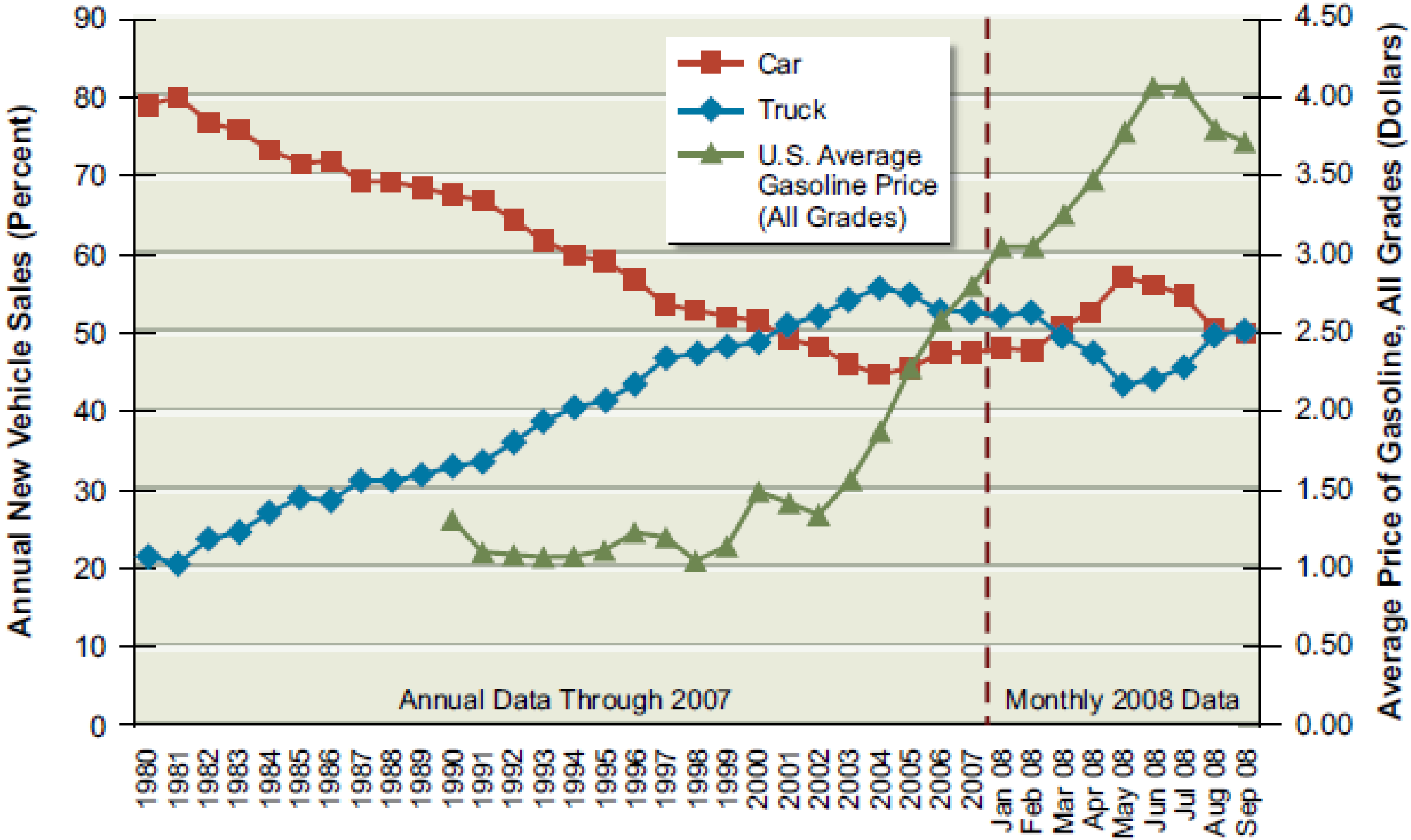

FIGURE 3.2 *U.S. car and light truck percentage of new vehicle sales versus average price of gasoline (all grades).*

TABLE 3.2 Potential Reductions in Vehicle Petroleum Use and Greenhouse Gas Emissions from Vehicle Efficiency Improvements Through 2035

	Petroleum Consumption (gasoline equivalent)		Greenhouse Gas Emissions	
Propulsion System	Relative to Current Gasoline ICE	Relative to 2035 Gasoline ICE	Relative to Current Gasoline ICE	Relative to 2035 Gasoline ICE
Current gasoline	1.00		1.00	
Current turbocharged gasoline	0.90		0.90	
Current diesel	0.80		0.80	
Current hybrid	0.75		0.75	
2035 gasoline	0.65	1.00	0.65	1
2035 turbocharged gasoline	0.60	0.90	0.60	0.90
2035 diesel	0.55	0.85	0.55	0.85
2035 HEV	0.40	0.60	0.40	0.60
2035 PHEV	0.20	0.30	0.35–0.45	0.55–0.70
2035 BEV	None		0.35–0.50	0.55–0.80
2035 HFCV	None		0.30–0.40	0.45–0.60

Note: These estimates assume that vehicle performance (maximum acceleration and power-to-weight ratio) and size remain the same as today's average new-vehicle values. That is, the improvements in propulsion efficiency are used solely to decrease fuel consumption rather than to offset increases in vehicle performance and size.

TABLE 3.3 Estimated Additional Cost to Purchaser of Advanced Vehicles Relative to Baseline 2005 Average Gasoline Vehicle

	Additional Retail Price (2007 dollars)	
Propulsion System	Car	Light Truck
Current gasoline	0	0
Current diesel	1,700	2,100
Current hybrid	4,900	6,300
2035 gasoline	2,000	2,400
2035 diesel	3,600	4,500
2035 hybrid	4,500	5,500
2035 PHEV	7,800	10,500
2035 BEV	16,000	24,000
2035 HFCV	7,300	10,000

Note: Cost and price estimates depend on many assumptions and are subject to great uncertainty. For example, different companies may subsidize new vehicles and technologies with different strategies in mind. Costs listed are additional costs only, relative to baseline average new car and light truck purchase prices (in 2007 dollars) that were calculated as follows:

—Average new car: \$14,000 production cost × 1.4 (a representative retail price equivalent factor) = an average purchase price of \$19,600.

—Average new light truck: \$15,000 × 1.4 = \$21,000.

Plausible Shares of Advanced Light-Duty Vehicles in the New Vehicle Market by 2020 and 2035

	Plausible LDV Market Share by	
Propulsion System	2020	2035
Turbocharged Gasoline SI	15-25%	25-35%
Diesels	6-12%	10-20%
Gasoline Hybrids	10-15%	15-40%
Plug-in Hybrids	1-3%	7-15%
Hydrogen Fuel Cell Vehicles	0-1%	3-6%
Battery Electric Vehicles	0-2%	3-10%

AMERICA'S ENERGY FUTURE

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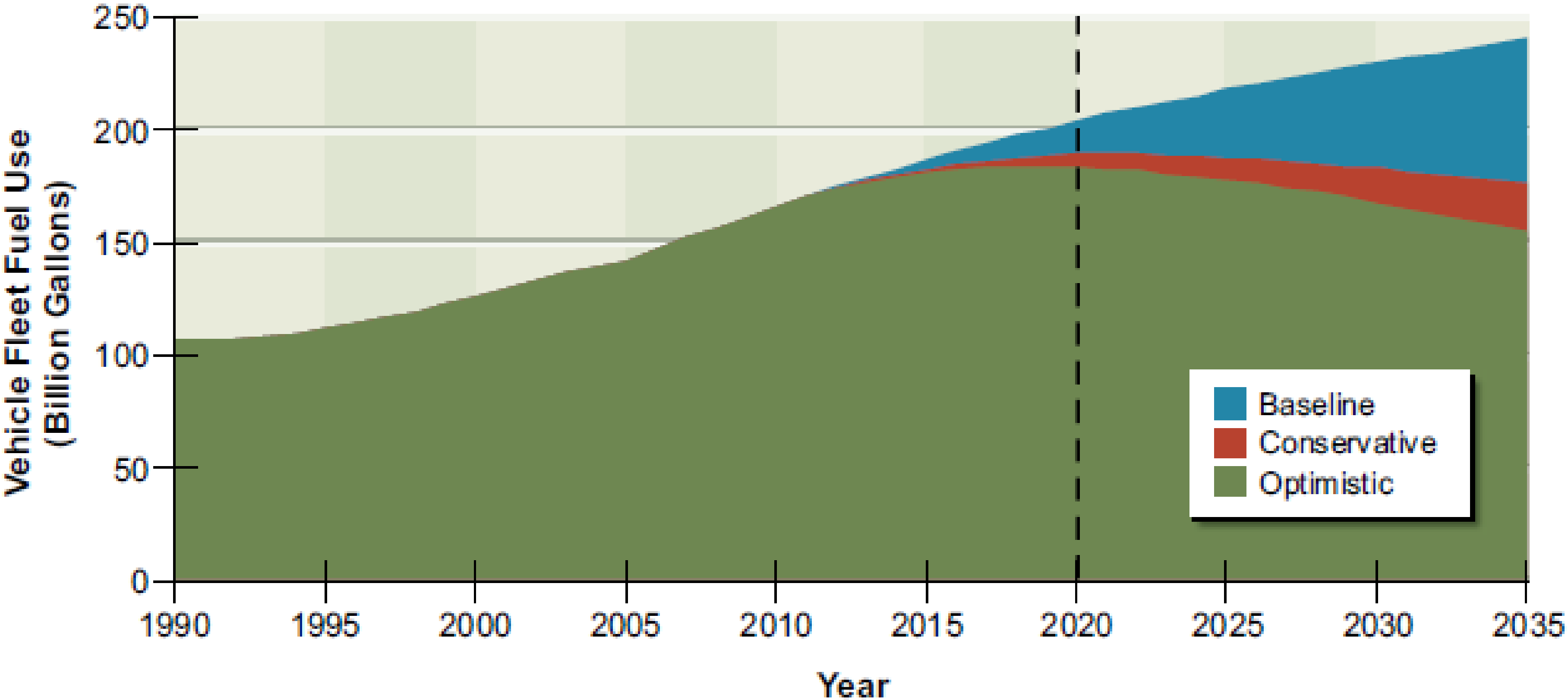
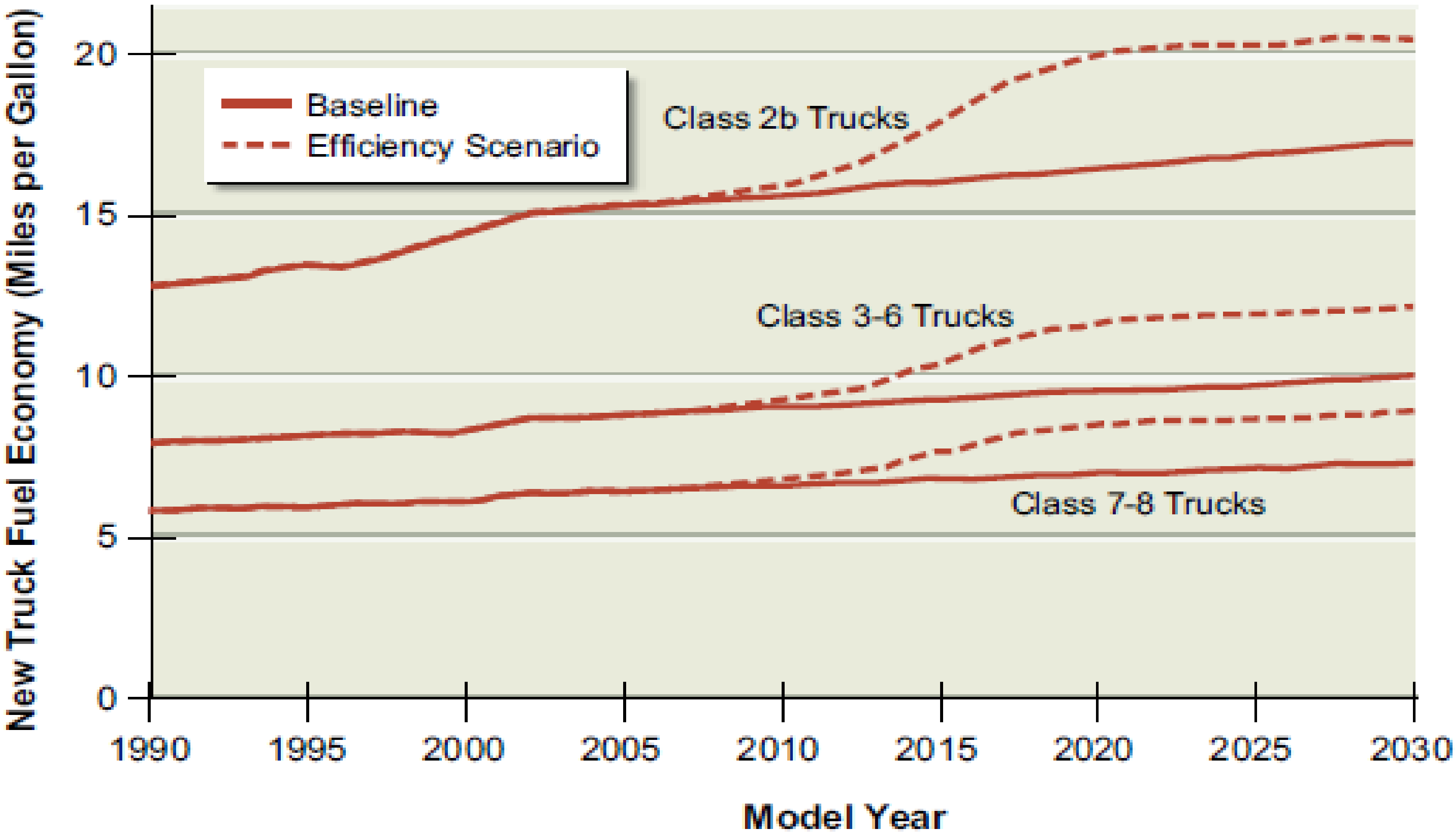


FIGURE 3.4 *Corresponding fuel use for the U.S. in-use light-duty-vehicle fleet. Source: Cheah and Heywood, 2008.*


New Truck Fuel Economy (Miles per Gallon)
20
15
10
5
0
Baseline
Efficiency Scenario
Class 2b Trucks
Class 3-6 Trucks
Class 7-8 Trucks
1990
1995
2000
2005
2010
2015
2020
2025
2030
Model Year

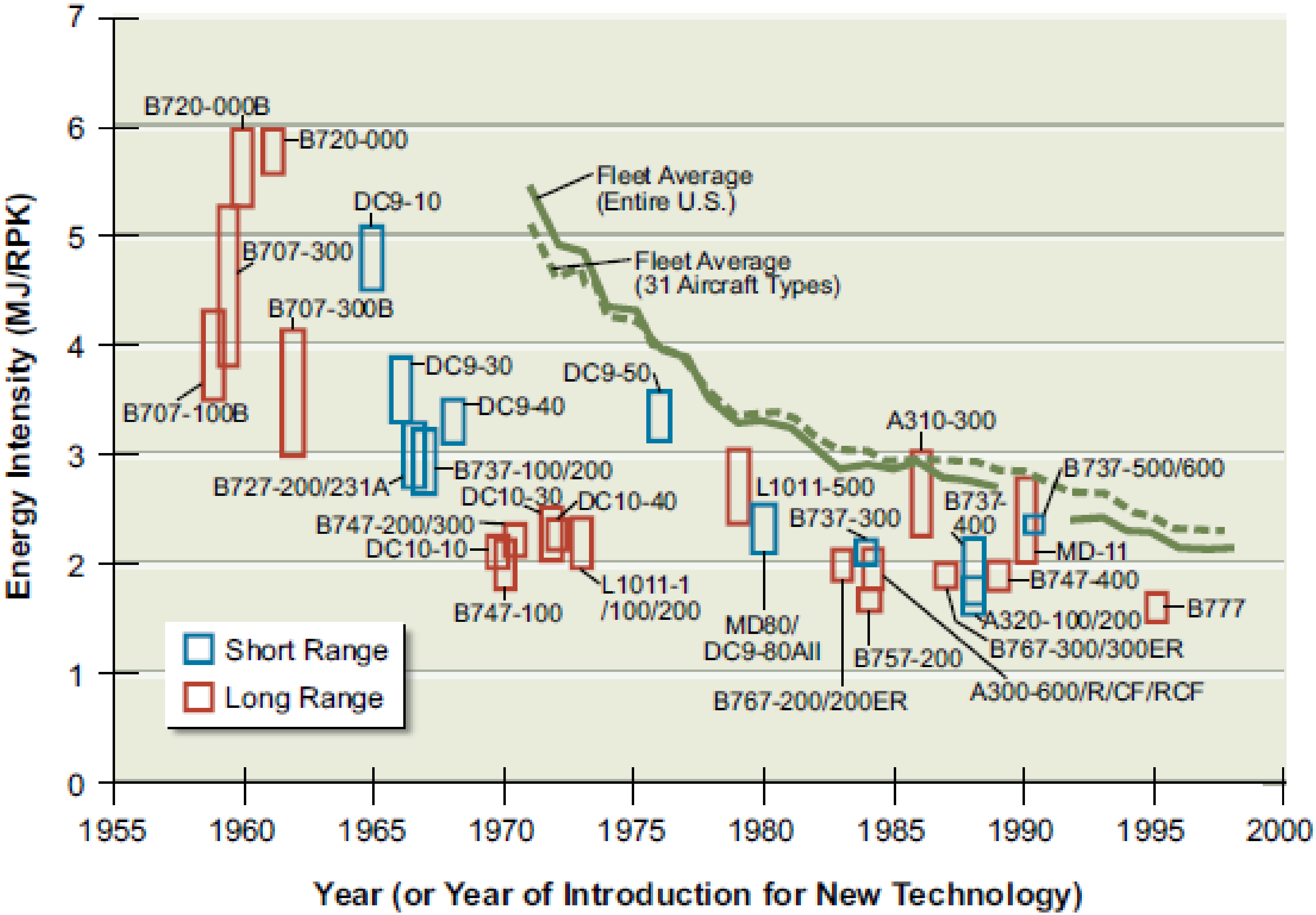


FIGURE 3.5 *Commercial aircraft efficiency trends. The dotted line is the fleet average for only the 31 aircraft types shown.*

Potential for Cost-Effective Annual U.S. Energy Savings (in quads) Achievable with Energy Efficiency Technologies in 2020 and 2030

	Conservative Estimate		Optimistic Estimate	
	2020	2030	2020	**2030**
Buildings, primary (source) electricity	9.4	14.4	9.4	**14.4**
Residential	4.4	6.4	4.4	6.4
Commercial	5.0	8.0	5.0	8.0
Buildings, natural gas	2.4	3.0	2.4	**3.0**
Residential	1.5	1.5	1.5	1.5
Commercial	0.9	1.5	0.9	1.5
Transportation, light-duty vehicles	2.0	8.2	2.6	**10.7**
Industry, manufacturing	4.9	4.9	7.7	**7.7**
Total	18.6	30.5	22.1	**35.8**

Note: Savings are relative to the reference scenario of the EIA's *Annual Energy Outlook 2008* (EIA, 2008a) or, for transportation, a similar scenario developed by the panel. See Table 1.2 for more information on the baselines used in the panel's analysis of the buildings, transportation, and industry sectors.

1 Quad = 8 Billion Gallons; 10.7 Quads = 85.6 Billion Gallons

Currently US use about 140 billion gallons/year of gasoline

Sound Bites

- The energy source that is cheapest, least CO_2 & pollution emissions, most sustainable, & offers the greatest benefit to national security is efficiency.
- Energy efficiency that saves money as well as BTU:

USA energy use: 100 quadrillion BTU

DOE 2030 Forecast: 118 quads

Energy efficiency potential: 83 quads – 1985 level

- Savings in the buildings sector alone could remove the need to build net new electricity generation through 2020.