EESI Hill Briefing
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Low-Hanging Fruit:
The Economics of Energy Efficiency

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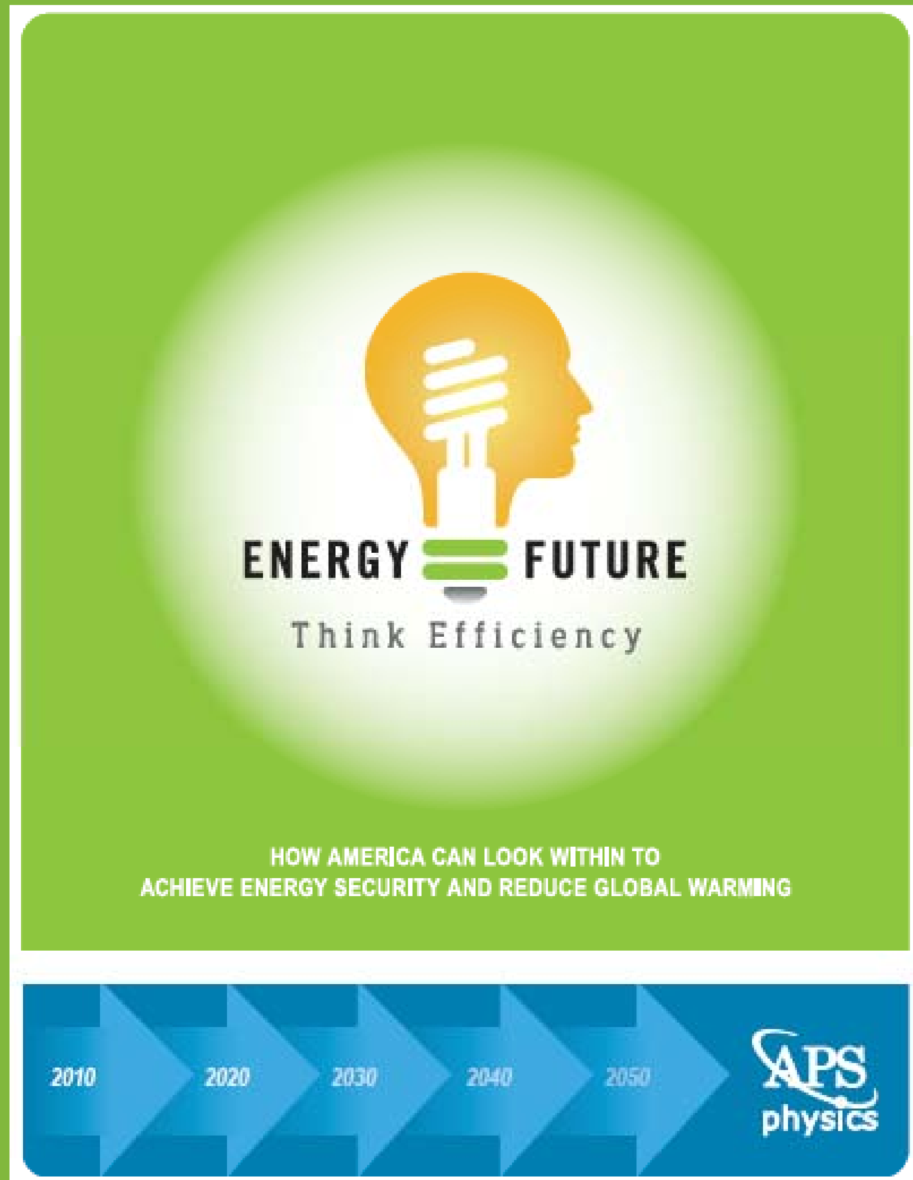

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Study Group and Review Panel Members

Study Group

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- Leon Glicksman, MIT
- David Goldstein, NRDC
- David Goldston (*Vice-Chair*), Harvard
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End Use Energy Efficiency

- What is it?
- Why does it matter?
- How do we categorize it?
- How can we improve it?
  - What are the costs?
  - How long will it take?
  - How can science and technology help?
  - Why are policies important?
- What actions are needed?

End Use Energy Efficiency

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End Use Energy Efficiency

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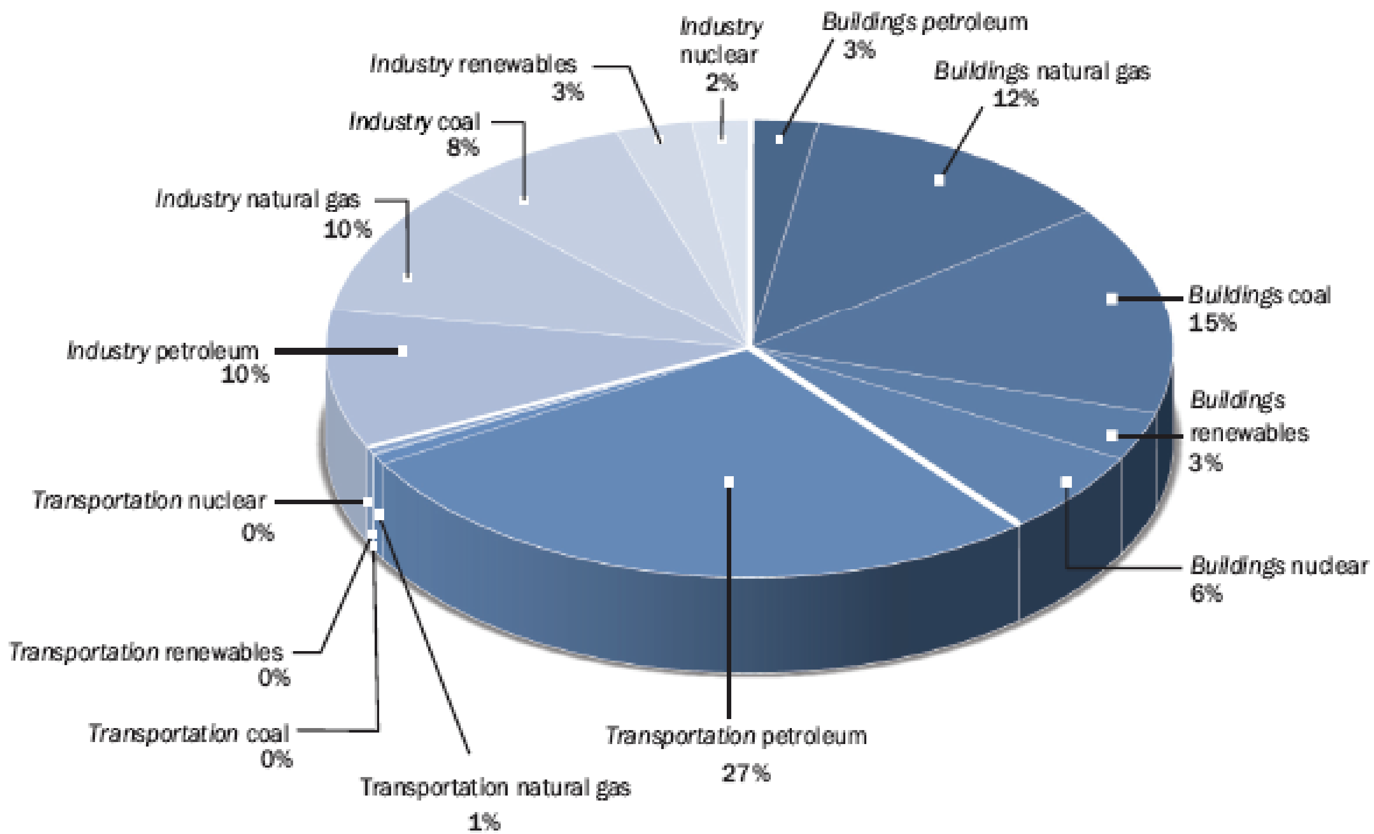
Figure 1

Energy usage in the U.S.

Distribution of U.S. energy usage in 2006, grouped by end-use sector (transportation, buildings and industry). Annual consumption for 2007 was 101.6 quads (10^{15} BTU).



End Use Energy Efficiency

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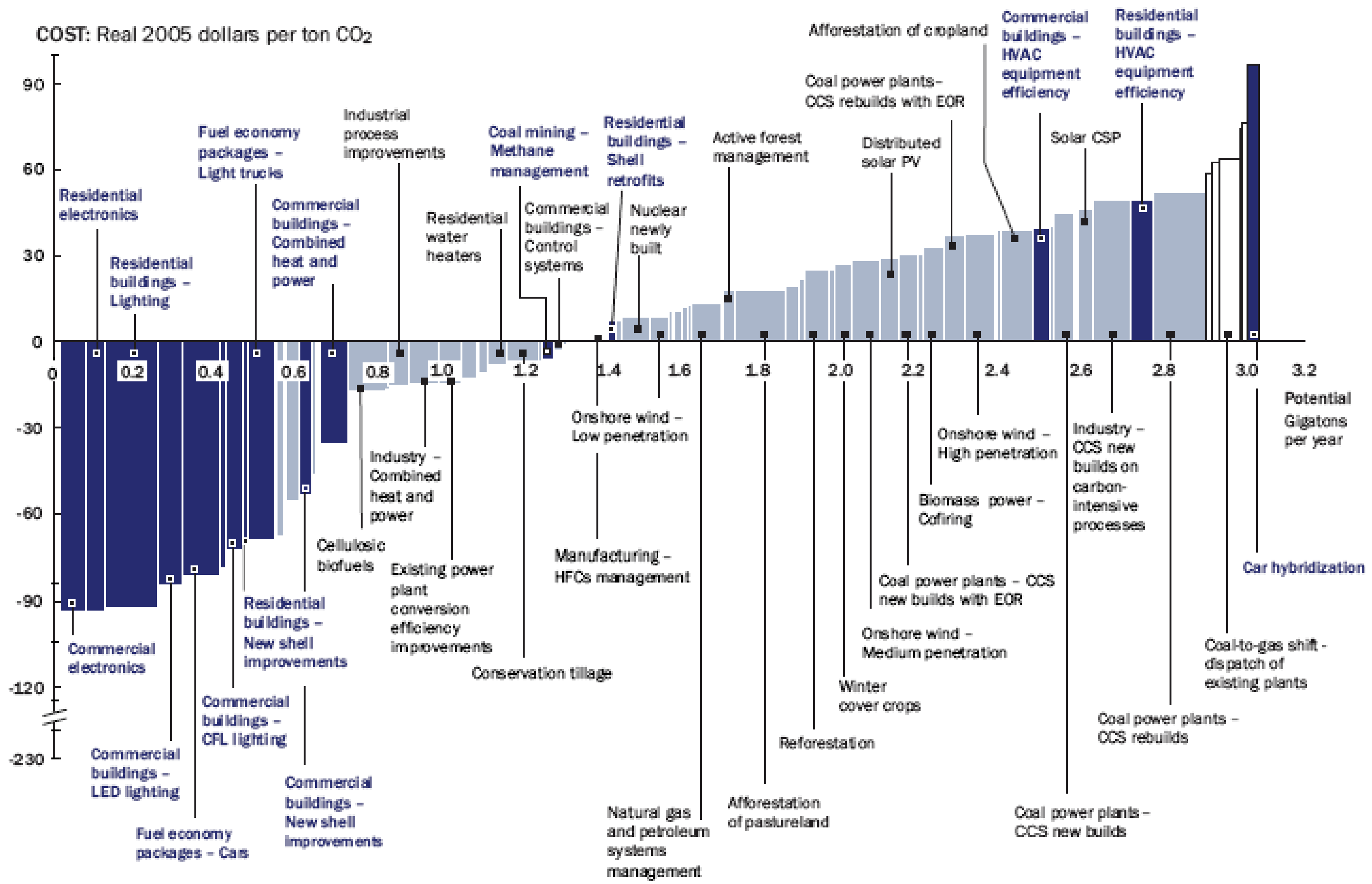
- How can we improve it?
  - What are the costs?

Figure 2

U.S. mid-range abatement curve - 2030

Carbon dioxide abatement: estimated removal cost per ton of CO_2 in 2005 dollars and removal potential in gigatons/yr for various strategies.

Abatement costs <$50 per ton



Source: *Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?*, Executive Report, McKinsey & Company, December 2007

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End Use Energy Efficiency

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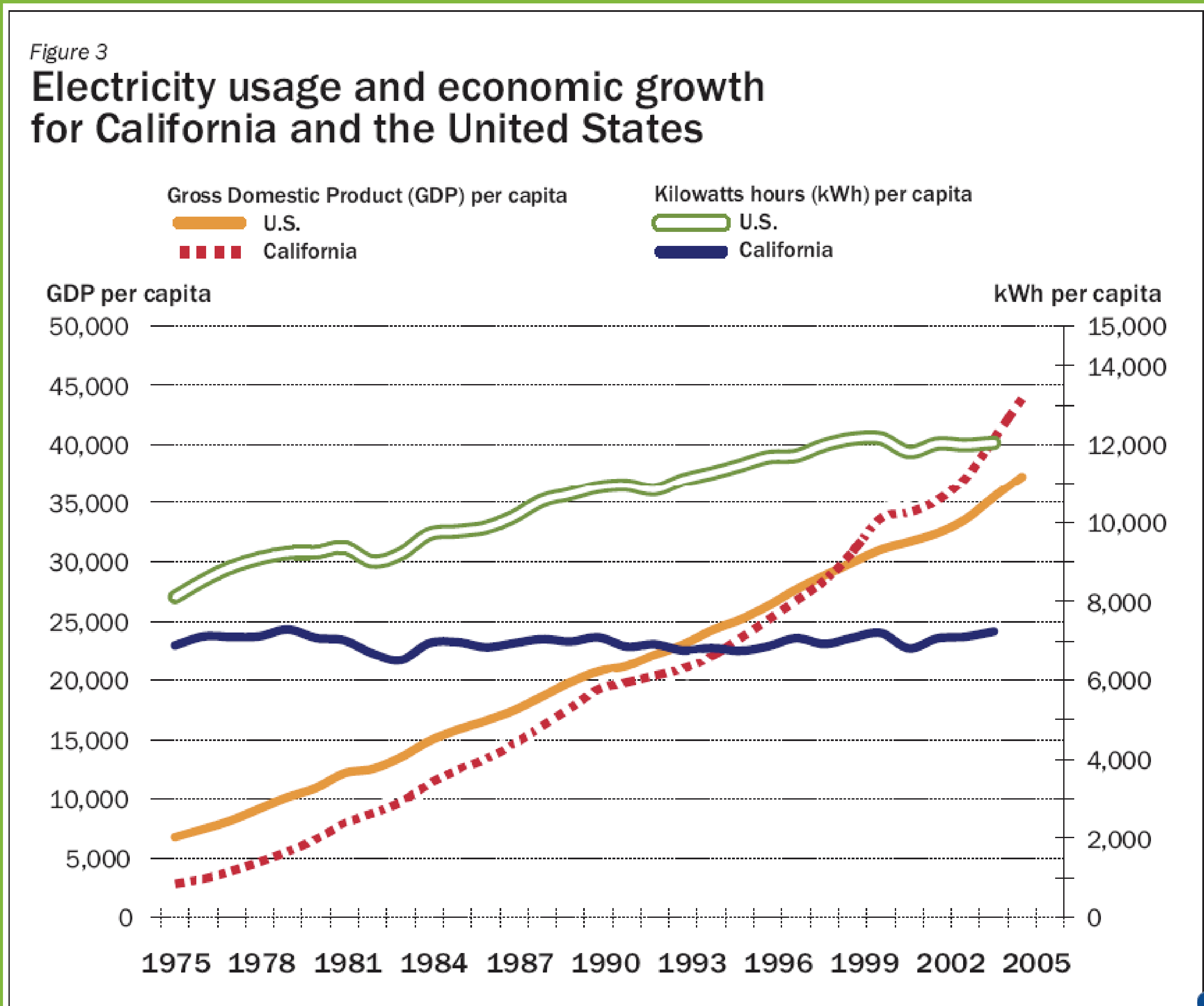


Source: California Energy Commission

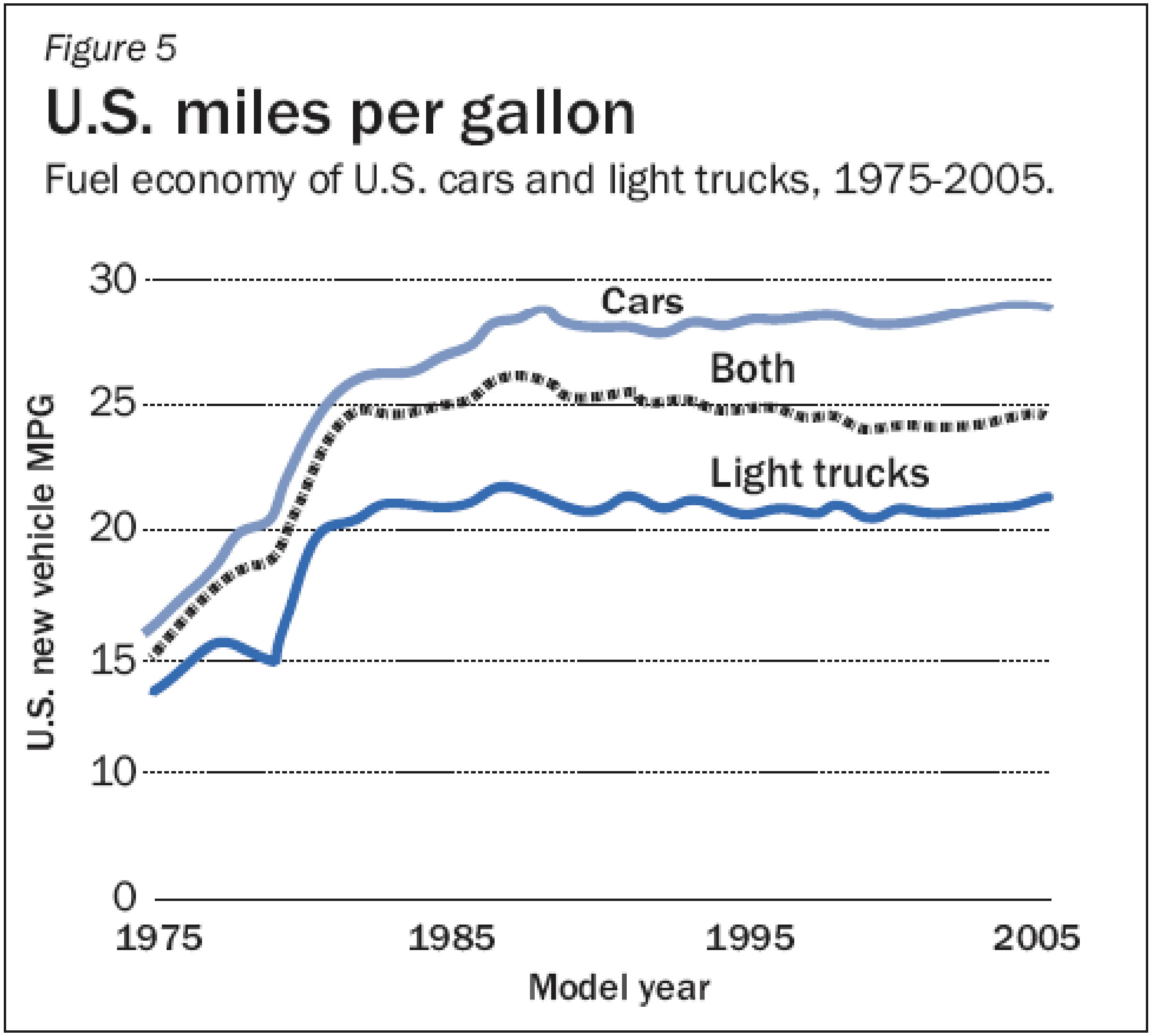
Overarching Conclusions

- Improving energy efficiency is a relatively easy and inexpensive way to significantly reduce the nation's demand for imported oil and its greenhouse gas emissions without causing any loss of comfort or convenience.

- Numerous technologies exist today to increase the efficiency of our vehicles and buildings in ways that could save individual consumers money. But without federal policies to overcome market barriers, the U.S. is unlikely to capitalize on these technologies.

- Far greater increases in energy efficiency are available in the future, but realizing these potential gains will require a larger and better focused federal research and development program than exists today.

Transportation

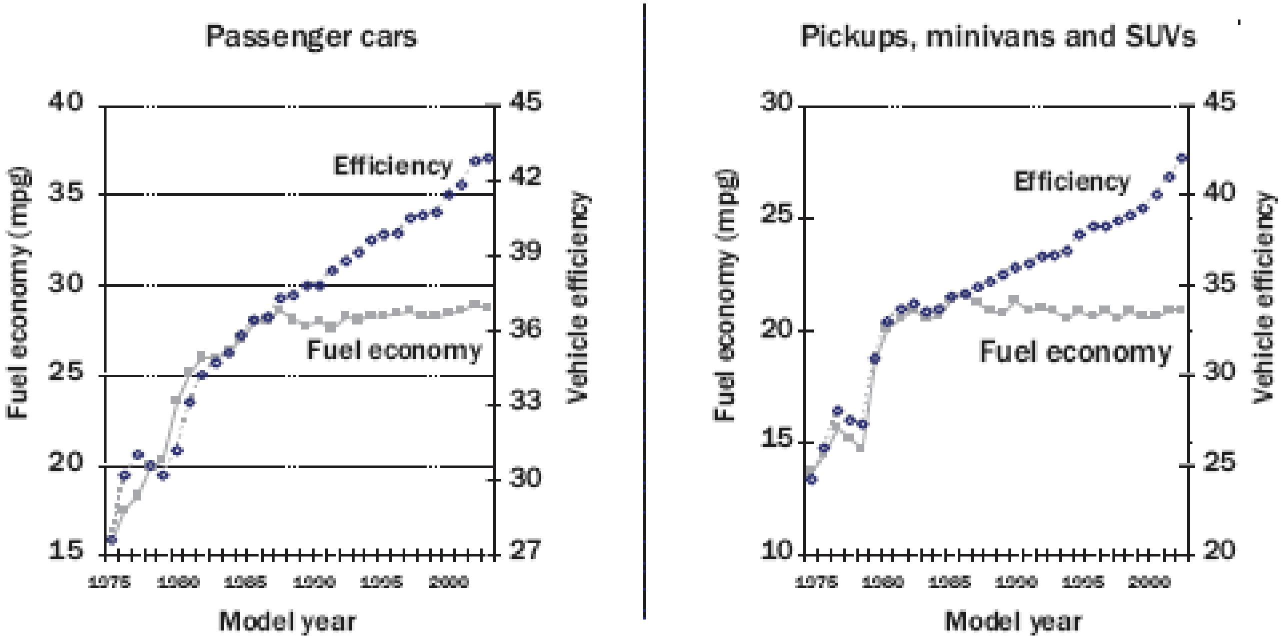


Sources: U.S. Environmental Protection Agency, National Highway Traffic Safety Administration

Figure 6

U.S. fuel economy vs. fuel efficiency

Fuel economy and fuel efficiency for cars and light trucks in the United States for the period 1975 to 2004. (The unit of efficiency in this figure only is ton-miles per gallon. This is the fuel efficiency mentioned in the text multiplied by the weight of the vehicle.)

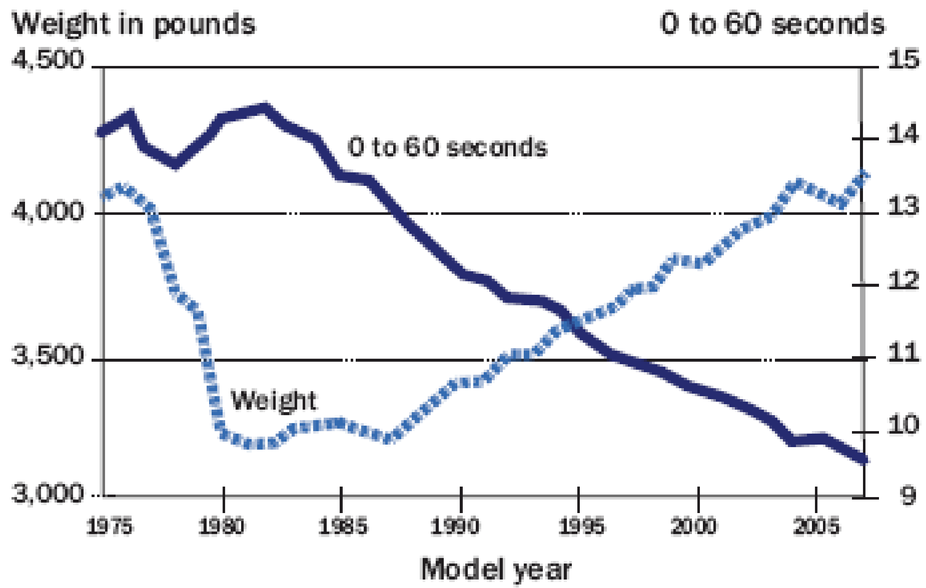


Source: Lutsey and Sperling, 2005

Figure 7

Vehicle weight and acceleration, 1975-2007

Vehicle weight initially decreased to help meet the new standards, but has increased ever since.

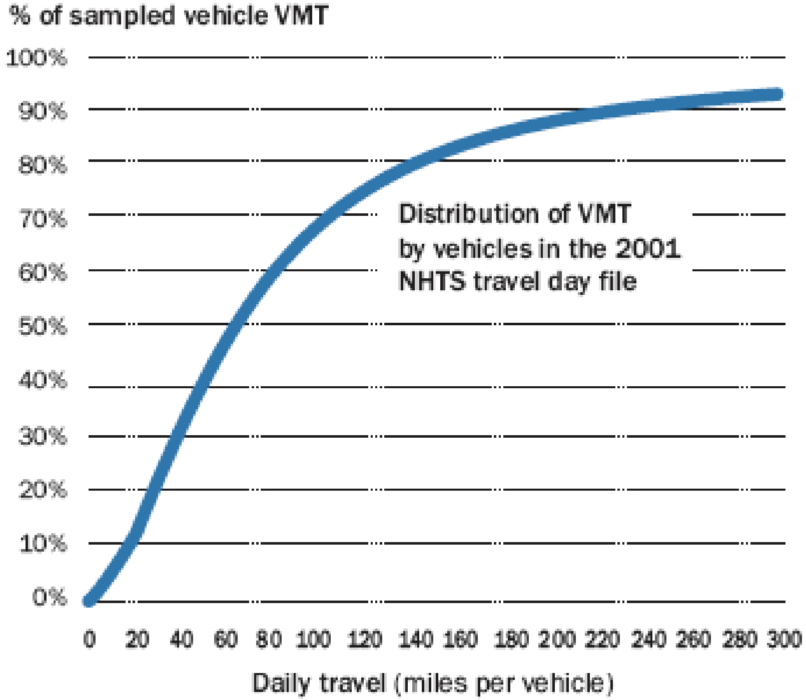


Source: Environmental Protection Agency, 2007

Figure 11

On the road

Percent of sampled vehicle miles traveled (VMT) as a function of daily travel.

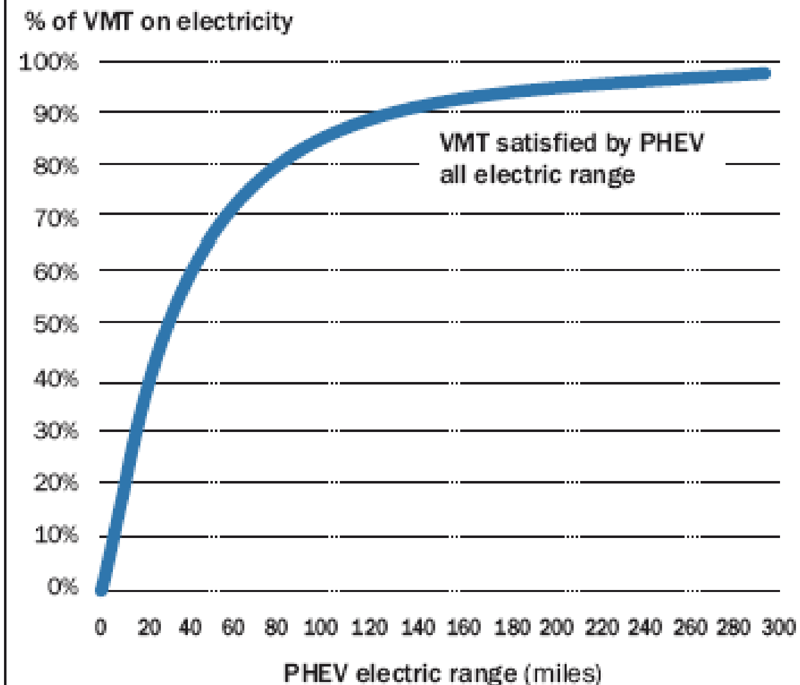


Sources: Santini and Vyas 2008; Vyas and Santini 2008

Figure 12

Electric-powered driving

Fraction of vehicle miles traveled (VMT) driven on electricity as a function of the plug-in hybrid electric vehicle (PHEV) electric range.



Sources: Santini and Vyas 2008

Table 1

Energy density per volume

Gasoline	34.6 MJ/l = 9.7 kWh/l
Diesel fuel	38.6 MJ/l = 10.7 kWh/l
Ethanol	24 MJ/l = 6.4 kWh/l
Hydrogen at 1 atmosphere pressure	0.009 MJ/l = 0.0025
Hydrogen at 10,000 psi	4.7 MJ/l = 1.3 kWh/l
Liquid hydrogen	10.1 MJ/l = 2.6 kWh/l
NiMH battery	0.3-1.0 MJ/l = 0.1-0.3 kWh/l
Lithium-ion battery (present time)	0.7 MJ/l = 0.2-kWh/l

Energy density per weight[13]

(1 MJ = 0.278 kWh)

Gasoline	47.5 MJ/kg = 13.2 kWh/kg
Diesel fuel	45.8 MJ/kg = 12.7 kWh/kg
Ethanol	30 MJ/kg = 7.9 kWh/kg
Hydrogen at 10,000 psi	143 MJ/kG = 39 kWh/kg
Liquid hydrogen	143 MJ/kG = 39 kWh/kg
NiMH battery	0.34 MJ/kg = 0.1 kWh/kg
Lithium-ion battery (present time)	.5 MJ/kg = 0.14 kWh/kg
Lithium-ion battery (future)	1 MJ/kg? = 0.28?

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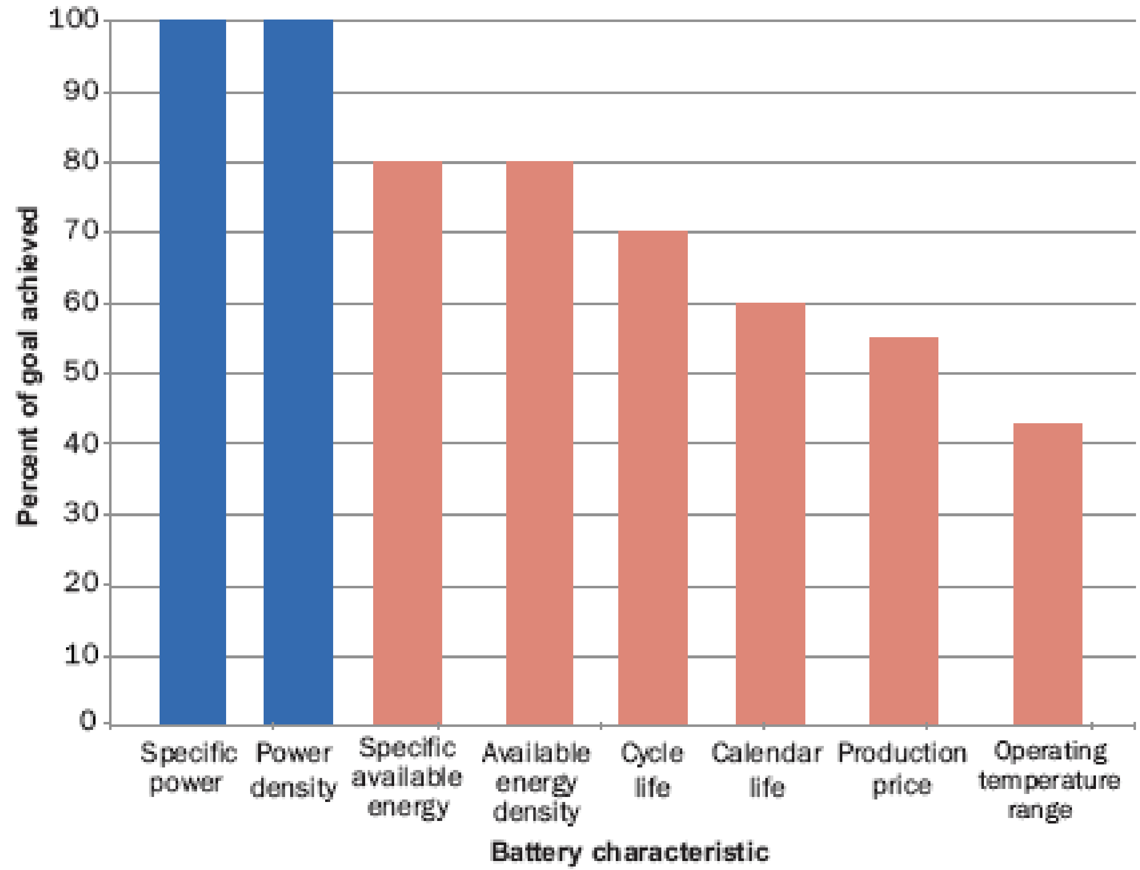
Figure 17

Battery capabilities

Battery capabilities with PHEV comparisons of 40-mile electric range goals.



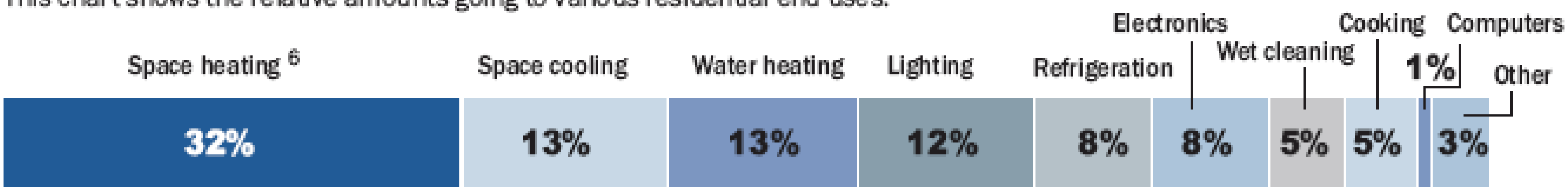
Source: Environmental Protection Agency (Adapted from a figure provided by Srinivasan, 2007)

Buildings

Figure 18

Residential energy end usage

In 2006 the residential sector consumed 21.8 quads[4] of primary energy.
This chart shows the relative amounts going to various residential end uses.[5]



Source: Energy Data Book (2007); EERE, U.S. Department of Energy

4. 1 Btu = British thermal unit, the amount of heat it takes to raise the temperature of 1 pound of water by 1 degree Fahrenheit. 1 quad = 1 quadrillion Btu = 10^{15} Btu. 1 Btu is also equal to 1054 joules, 1 joule being the metric unit of energy.

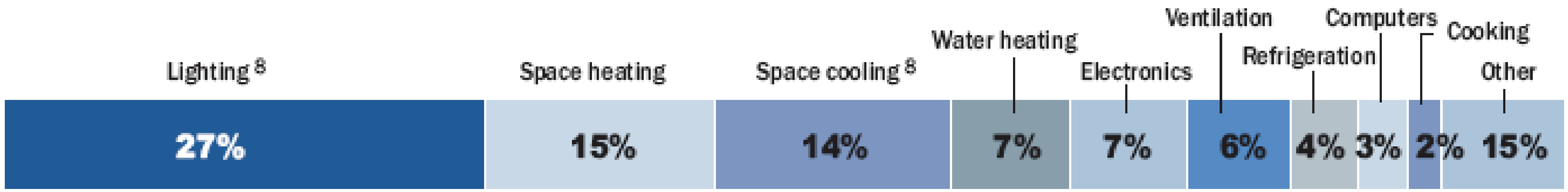
5. Numbers differ slightly from those in the DOE Building Energy Databook as the 4.7% adjustment has been eliminated and distributed proportionally to all other categories.

6. Energy for "space heating" is the energy used to heat a building. Energy used to heat domestic hot water is included in the category "wet cleaning

Figure 19

Commercial energy end usage

In 2006 the commercial sector consumed 17.9 quads of primary energy. This chart shows the relative amounts going to various end uses.[7] The category "Other" includes non-building commercial use such as street lighting, lighting in garages, etc.



Source: Energy Data Book (2007); EERE, U.S. Department of Energy

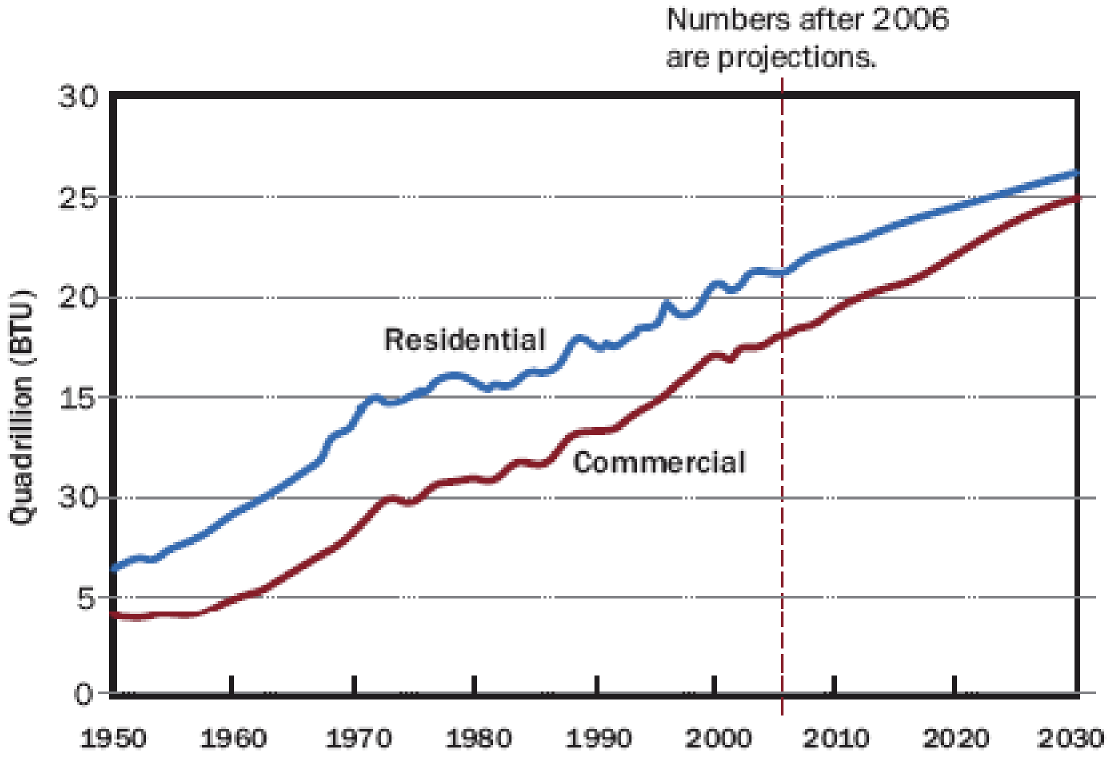
7. Numbers differ slightly from those in the DOE Building Energy Databook as the 5.5% adjustment has been eliminated and distributed proportionally to all other categories. Non-building commercial use includes electricity for street lights, water treatment plants, airport lights, etc. All these numbers for energy uses should be viewed as rough approximations — more useful for comparing the relative sizes of various energy uses than as precise figures of any specific energy use.

8. Since lighting and space cooling are predominantly accomplished with electric energy, their relative importance compared to other end uses depends strongly on whether the focus is on primary (source) energy or site energy.

Figure 20

Total primary energy consumptions for buildings

Primary energy use (including that associated with electric use) for the residential and commercial sectors in Quad (10^{15} Btu).

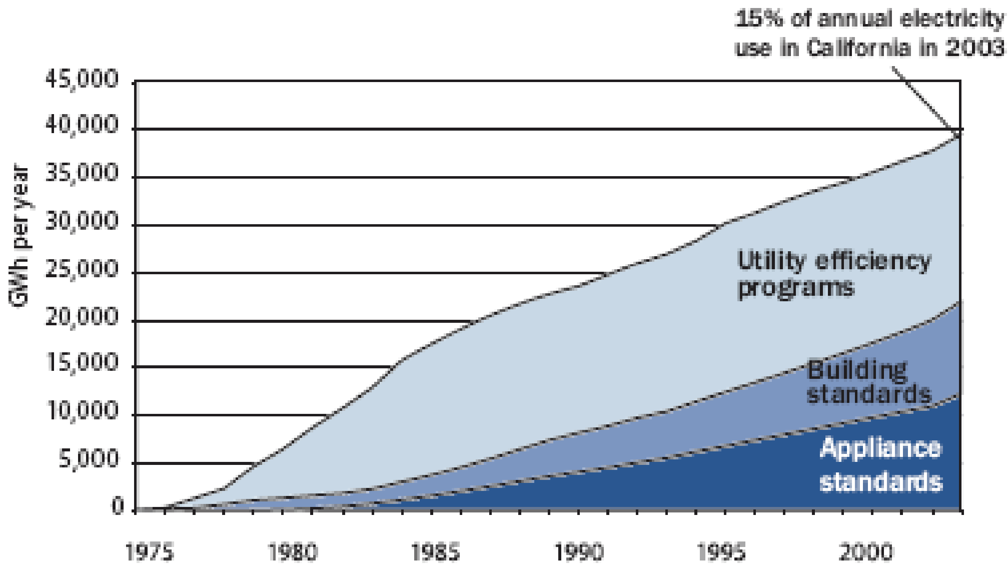


Source: EIA 2008 Annual Energy Outlook

Figure 22

Electric savings from California's energy efficiency programs

Annual electric energy savings in California since 1975 associated with appliance standards, building energy standards and utility DSM programs.



Source: Art Rosenfeld, California Energy Commission

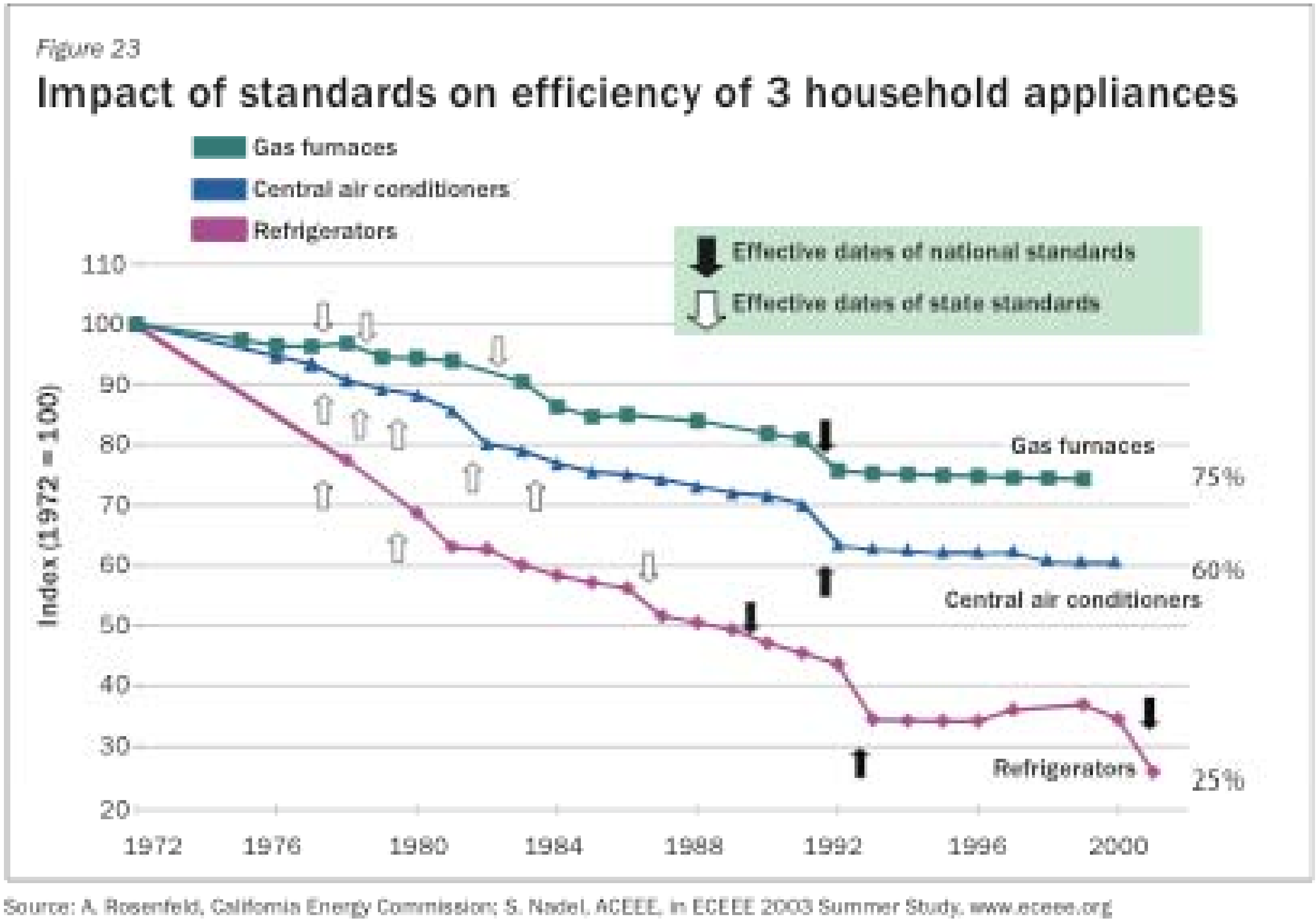


Figure 23
Impact of standards on efficiency of 3 household appliances
Gas furnaces
Central air conditioners
Refrigerators
Effective dates of national standards
Effective dates of state standards
110
100
90
80
70
60
50
40
30
20
Index (1972 = 100)
1972
1976
1980
1984
1988
1992
1996
2000
Gas furnaces
75%
Central air conditioners
60%
Refrigerators
25%
Source: A. Rosenfeld, California Energy Commission; S. Nadel, ACEEE, in ECEEE 2003 Summer Study, www.eceee.org

End Use Energy Efficiency

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- What actions are needed?

R&D

Sample List of Opportunities

- Fuel Cells
- Batteries and Electrical Energy Storage
- Solid-State Lighting
- Catalysts
- Thermoelectric Devices
- Lightweight Materials
- Advanced Windows
- Advanced Ventilation
- Ultrathin Thermal Insulators
- Thermodynamic Cycles
- Behavioral Research

Recommendations

- Policies should be established to achieve 50 mpg by 2030
- Federal transportation R&D portfolio should have broader focus
- Grid improvements & time of use electricity metering needed for PHEVs
- Social science research required to better understand consumer behavior
- Set federal goal: buildings sector primary energy use in 2030 no more than in 2008
- Federal R&D program needed to achieve ZEB by 2030
- LEED certification should give energy efficiency highest priority
- Federal R&D funding for next generation building technologies should increase significantly
- Low-energy residential buildings R&D and demonstration program should be expanded
- DOE should comply with legislation to develop cost-effective, achievable appliance standards
- Federal government should use carrot & stick approach to get states to adopt DSM programs
- Energy standards for buildings such as those in California should be implemented nationwide
- DOE Office of Science should be funded at levels specified in America COMPETES Act
- DOE should fold long-term applied research into its programs more seriously than at present
- DOE should fully comply with 2005 EPACT mandate to coordinate basic and applied research
- ARPA-E, if funded, needs its purpose better defined: time horizon, private-sector coupling
- In transportation, closely connected long-term basic & applied research need more support
- In buildings, neglected long-term applied research in EERE needs much more attention

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