Honda's Perspective on Plug-In Hybrid Opportunities and Challenges

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American Honda Motor Co., Inc.

January 22, 2007

Honda wants to be a company that society wants to exist

- Genuine concern for environmental and safety issues
- High targets, ‘Challenging Spirit’
- Pursuit of new technology
- Solutions that also satisfy customer needs

3 Issues for the Future Automobile:

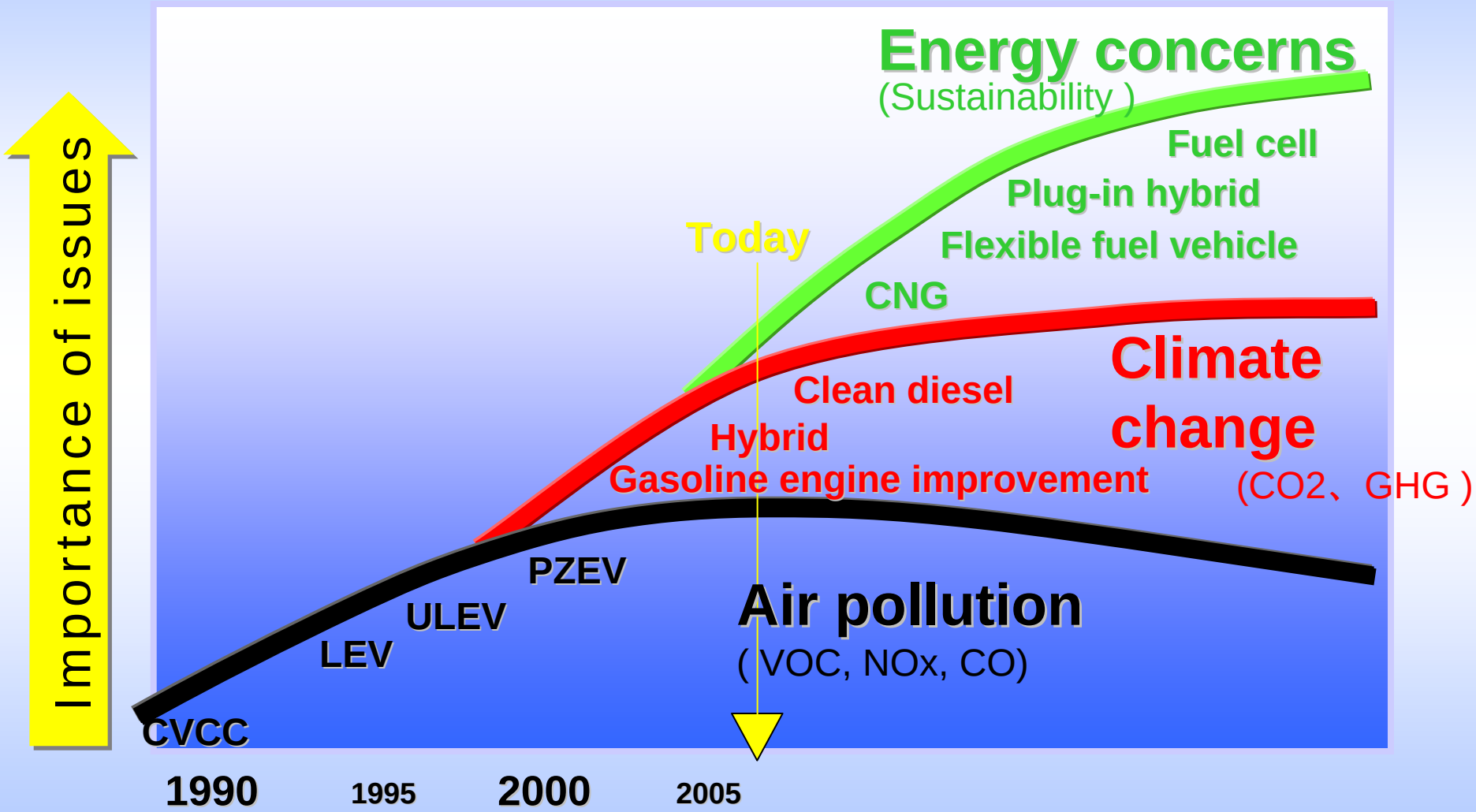
Energy Supply & Demand
Sustainability

Climate Change

Urban Air Quality

Emissions & Energy Issues

& Technology Directions



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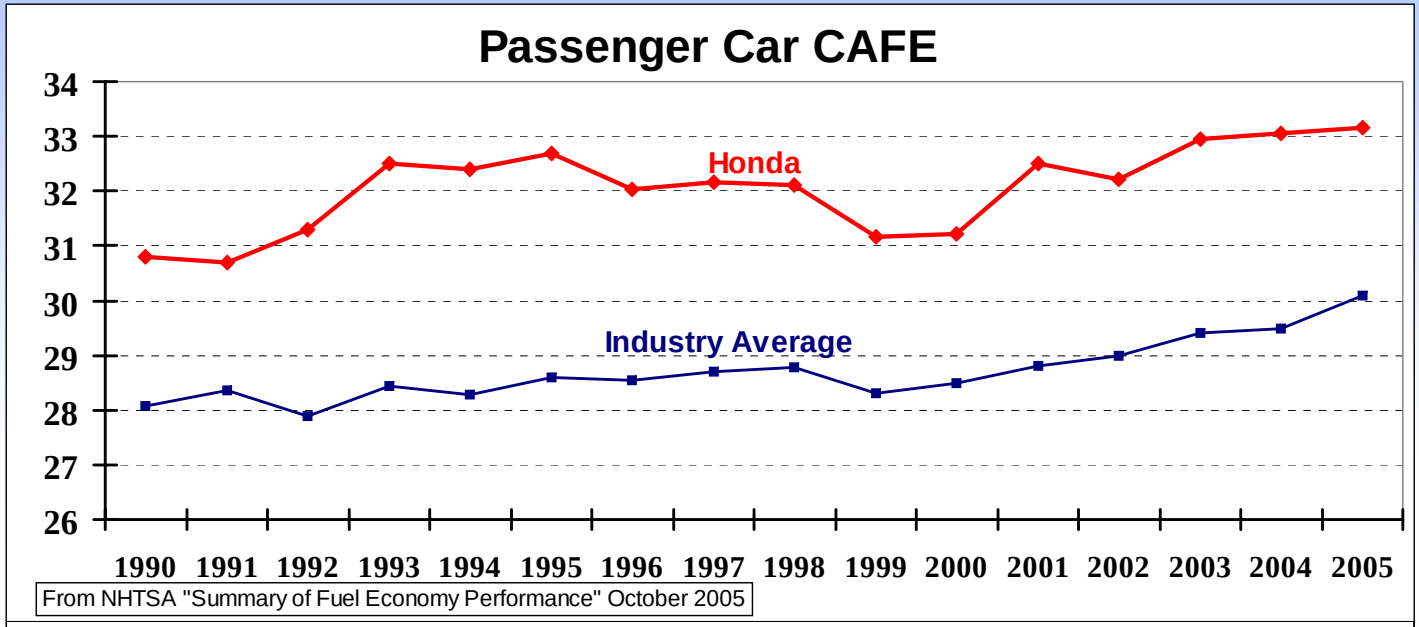
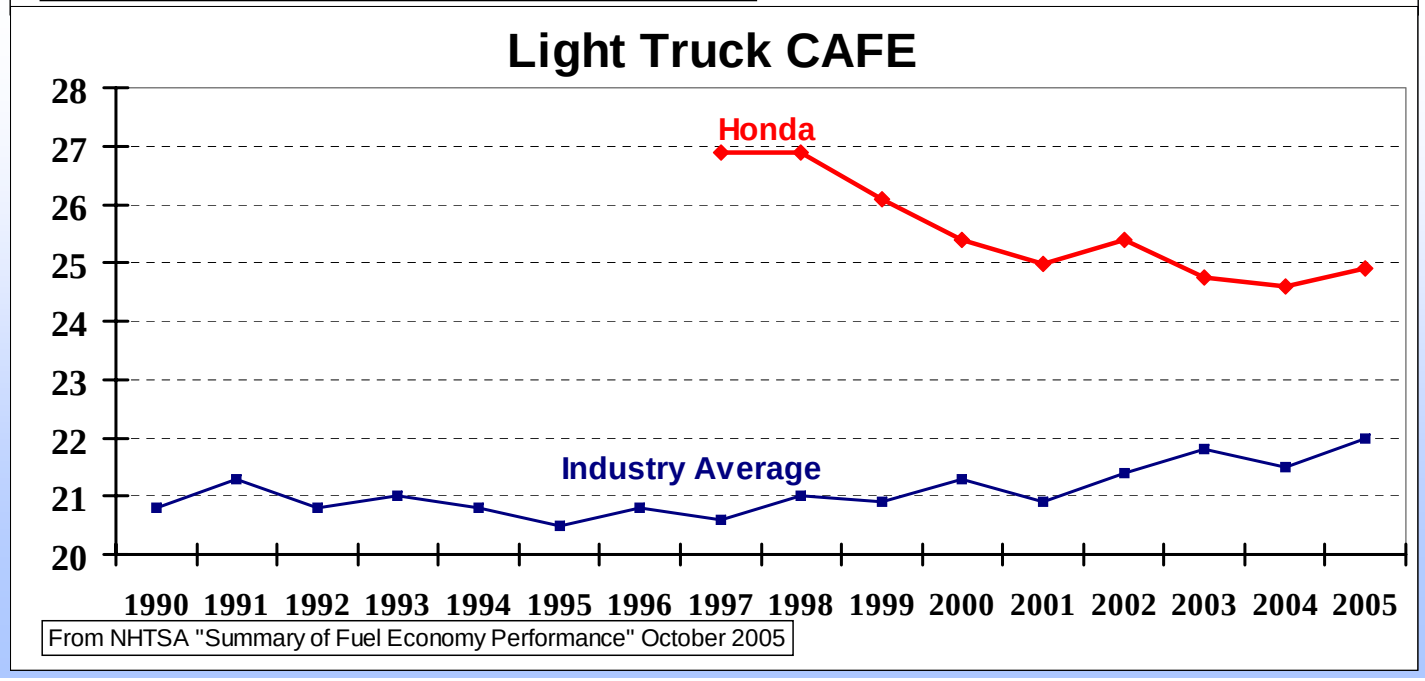
The Power of Dreams

Honda Commitment to Efficiency





Honda Hybrid Vehicle Development

Environment

5th Dedicated Hybrid
- All new
- More affordable

2009

4th CIVIC HYBRID

Nov. 2005

Higher power added to increase use of hybrid vehicles

Hybrid Technology Expanded to our volume leader vehicle

1st insight

Dec. 1999

2nd CIVIC Hybrid

Mar. 2002

3rd ACCORD

Enhanced Fuel Economy for V6 engine

Dec. 2004

Excitement

Plug-In Hybrid Development

Ability to Run on Electricity Is Attractive

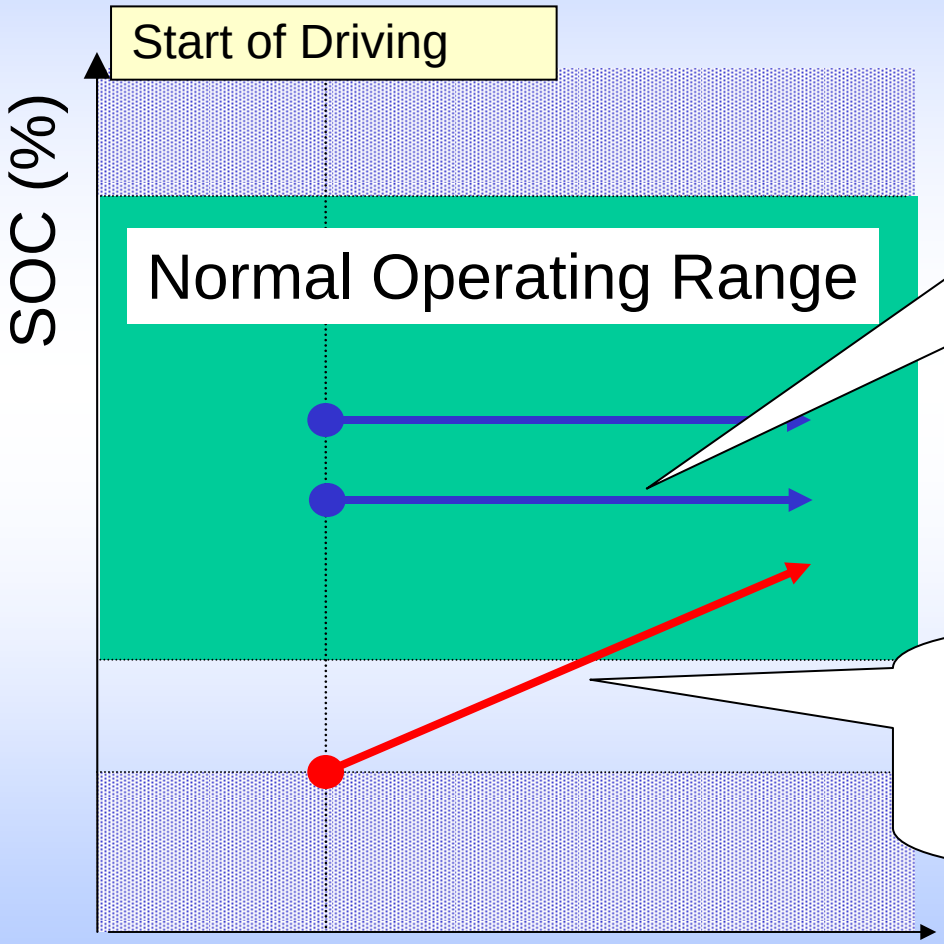
Reuters, January 7, 2007:

> Motoatsu Shiraishi, President of Honda Research and Development, said, "We are studying what kind of conditions would enable a plug-in"

Challenges for Market Acceptance

- Battery size and weight
  - Space required reduces vehicle utility
  - Extra weight reduces fuel economy and performance
- Emission control
  - Evaporative purge if engine does not operate for several days
  - Emissions when engine turns on
- Larger motor and power electronics
- **Safe off-board charging**
- **Battery durability**
- **Battery cost**

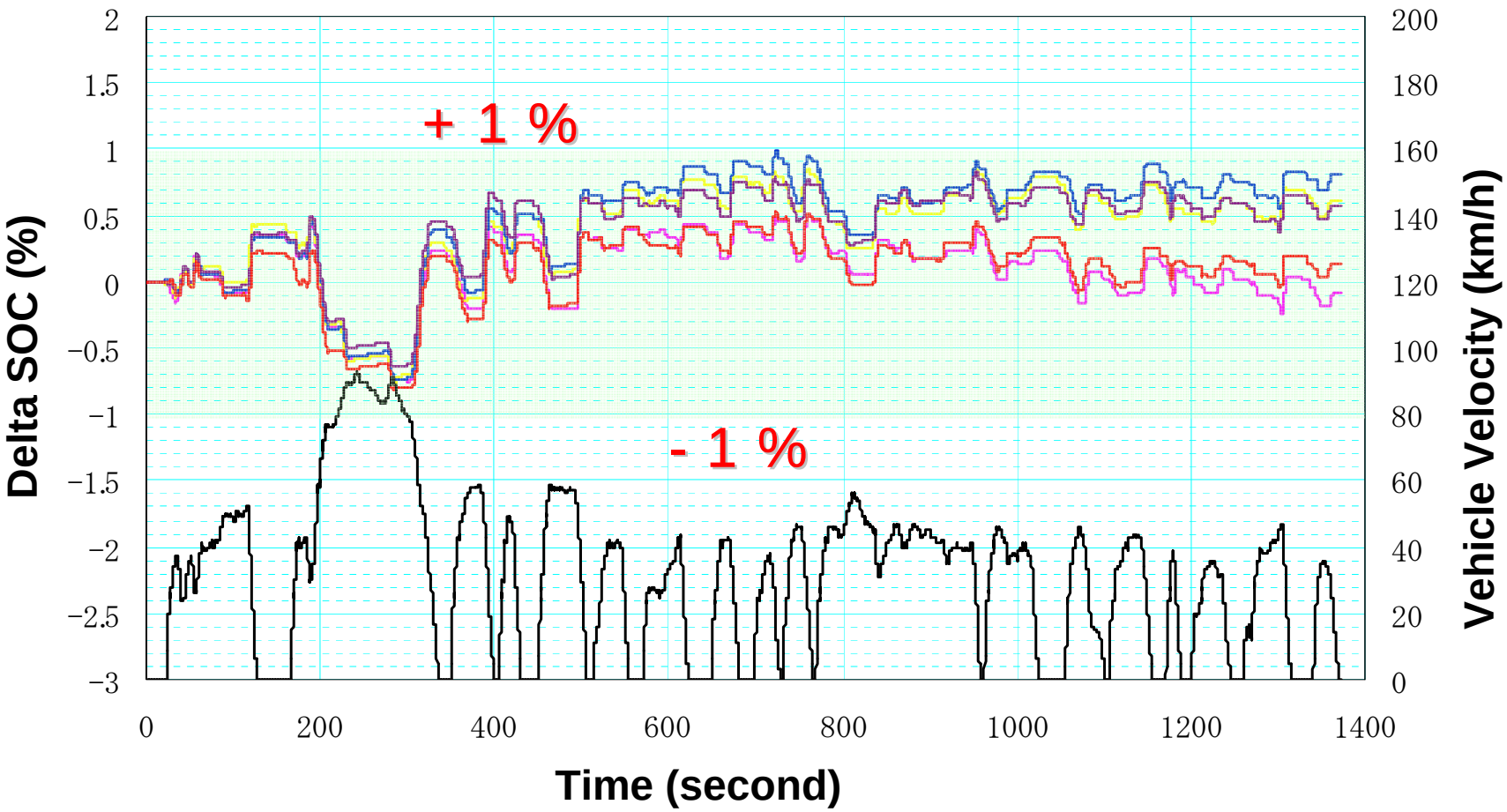
Hybrid – SOC Normal Operating Range



Control SOC with a balance of discharging and charging of energy

Recover energy by limiting assist and increased regeneration and recharging

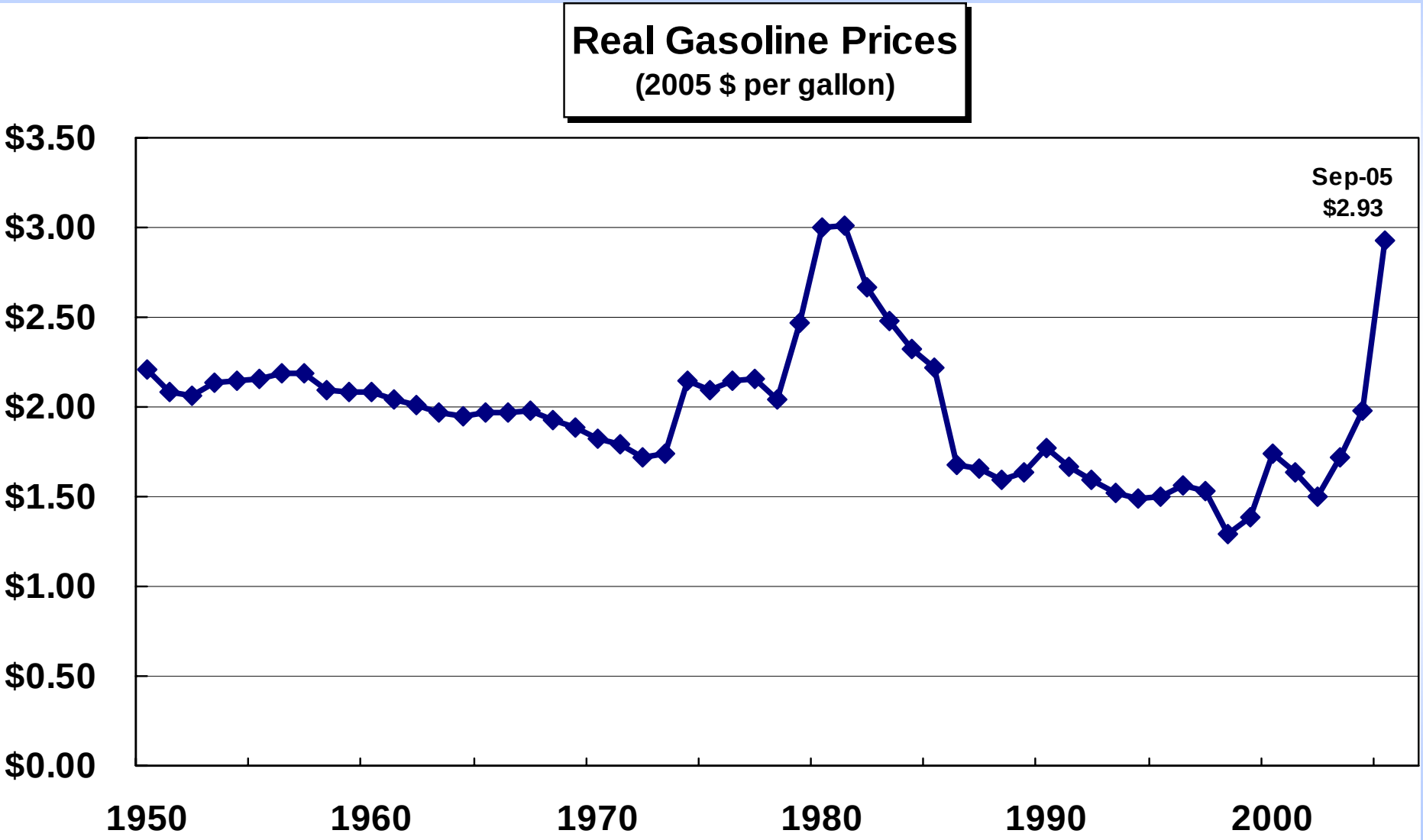
SOC Changes Over FTP Cycle



Customer Demand

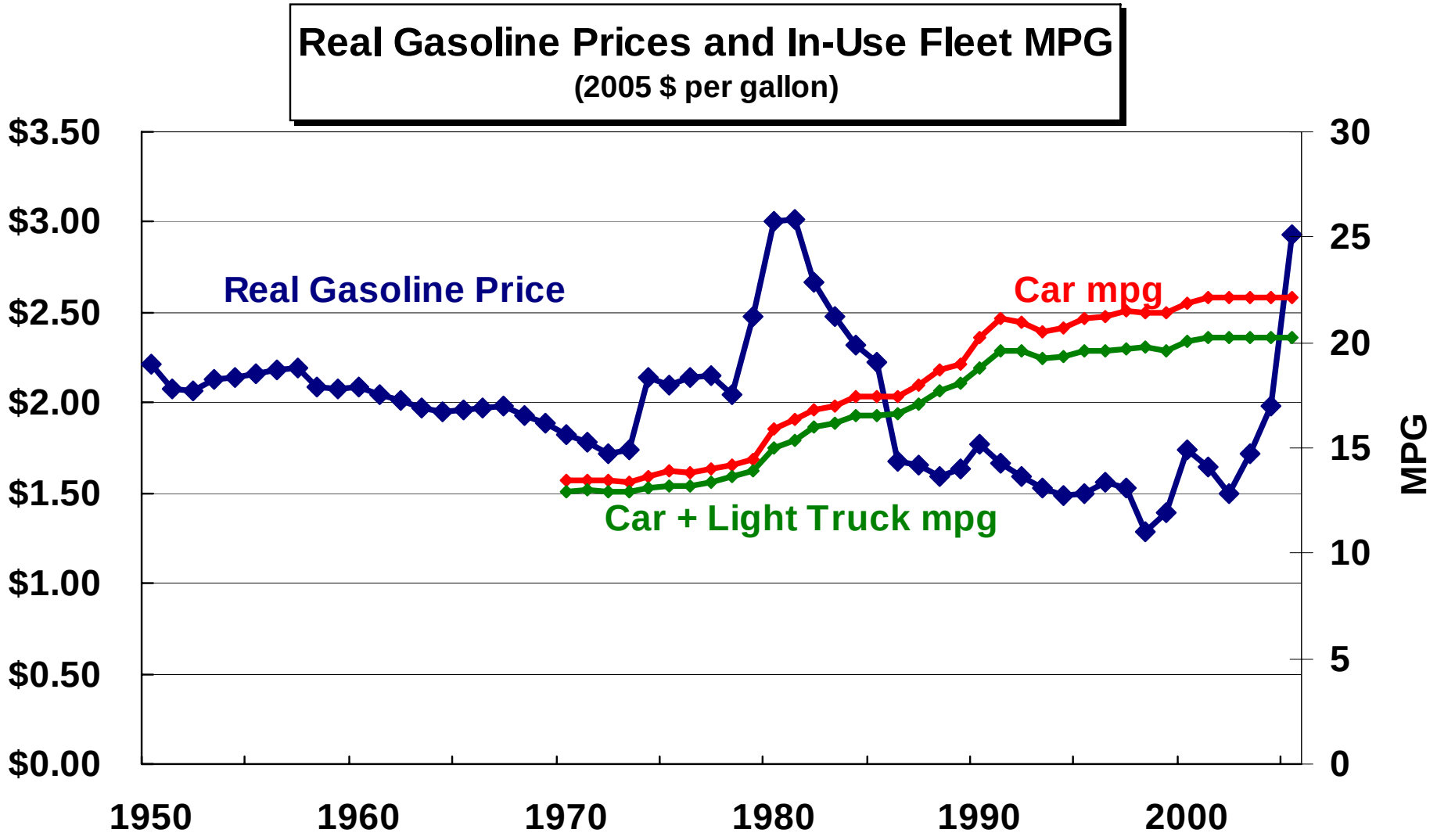
- Real fuel costs are low
- Most customers greatly discount the value of fuel savings
- Most customers value other attributes higher than fuel economy

Real Gasoline Price



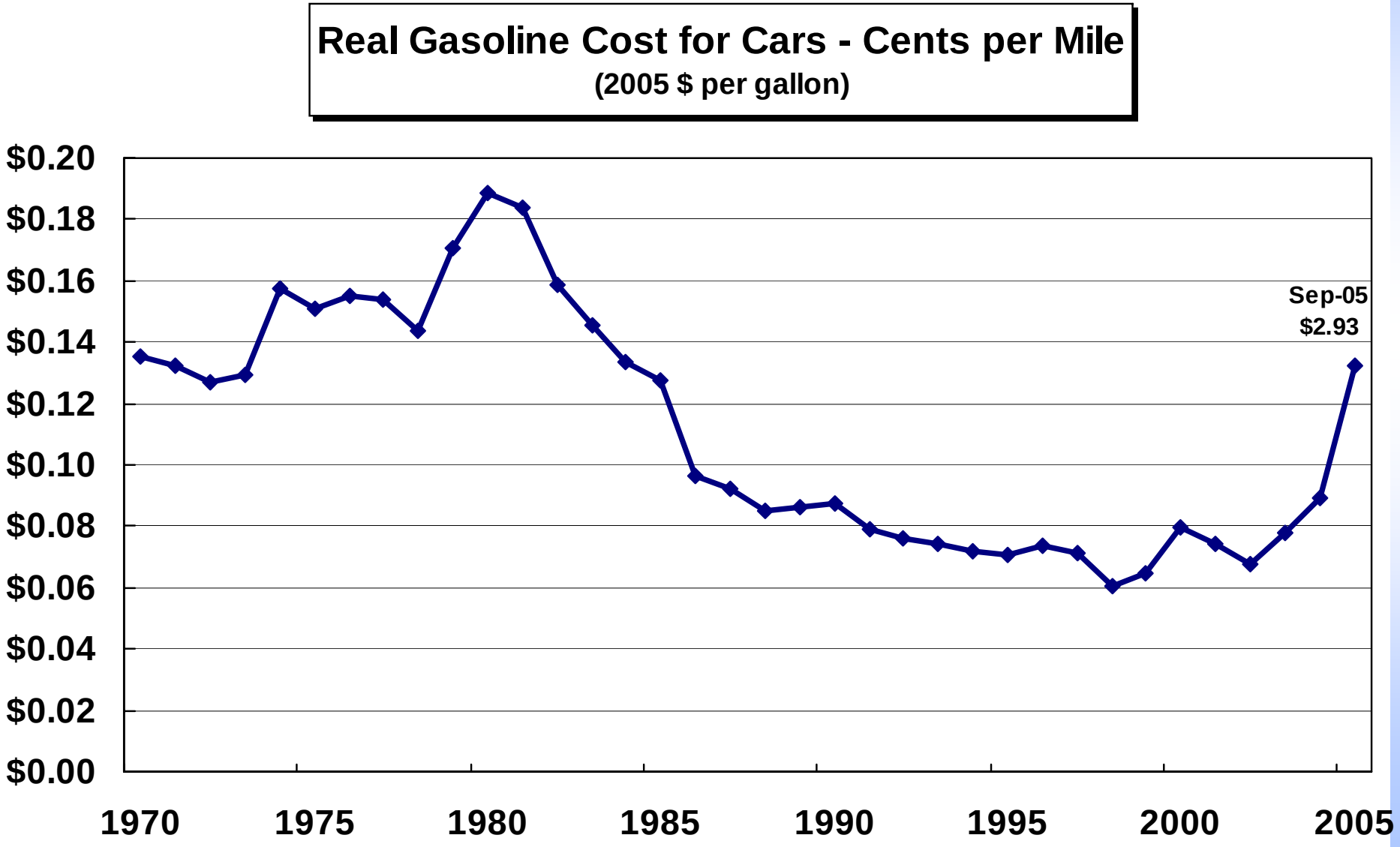
Motor Gasoline Retail Prices, U.S. City Average, adjusted using CPI-U

Fleet Fuel Economy

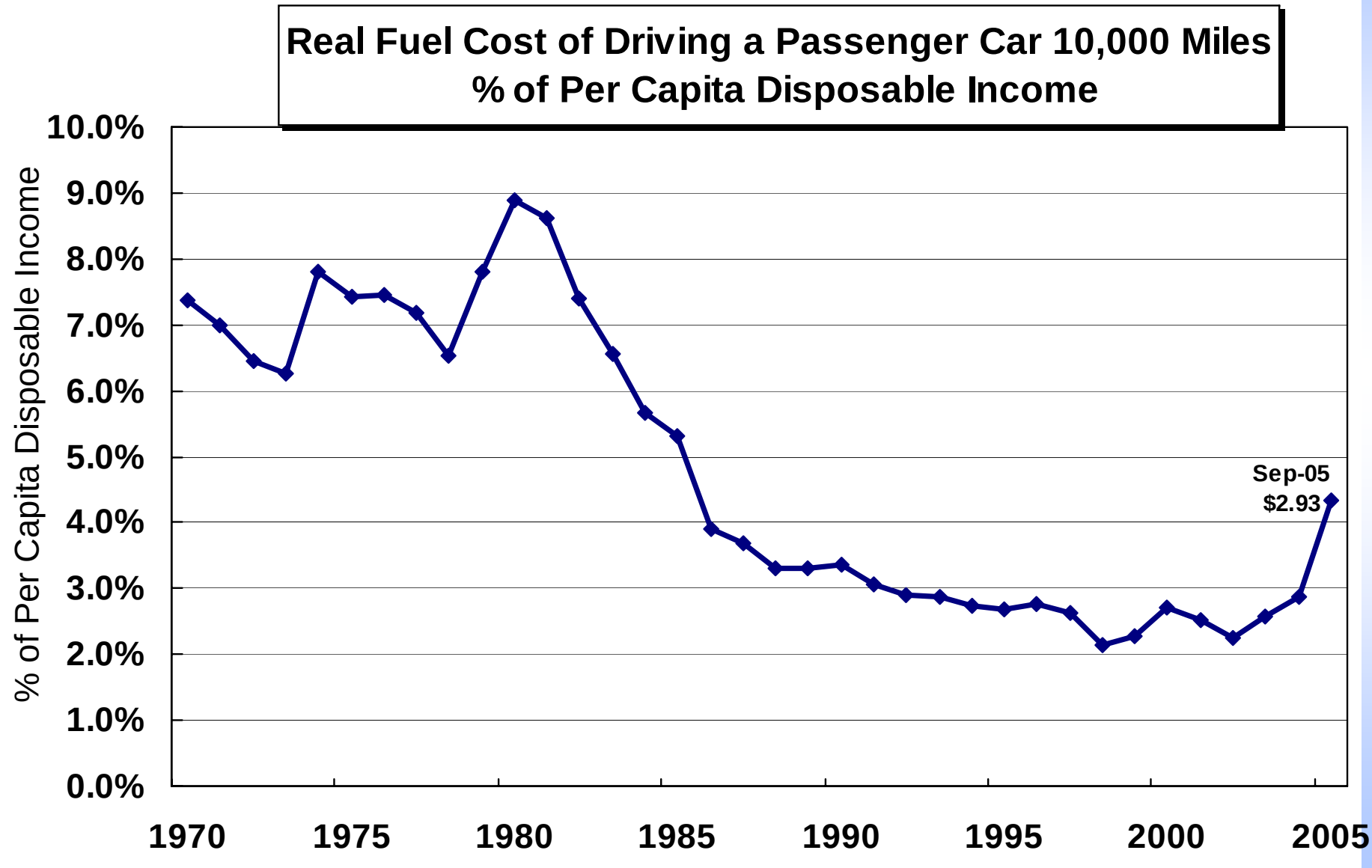


In-Use MPG from Transportation Energy Data Book: 2004

Gasoline Cost per Mile

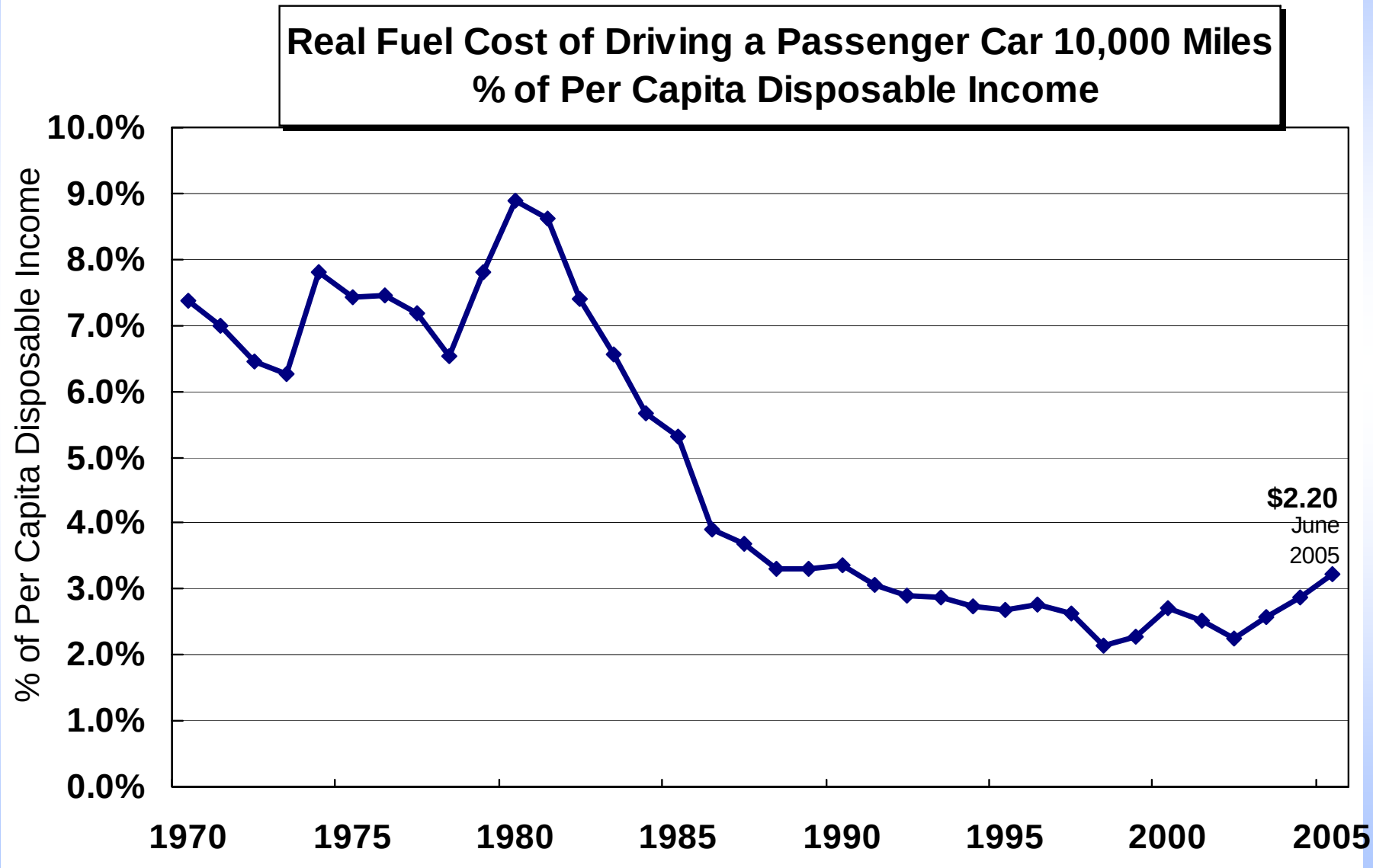


Real Fuel Cost - % of Disposable Income



Per Capita Disposable Income from BEA, Table 2.1, Personal Income and It's

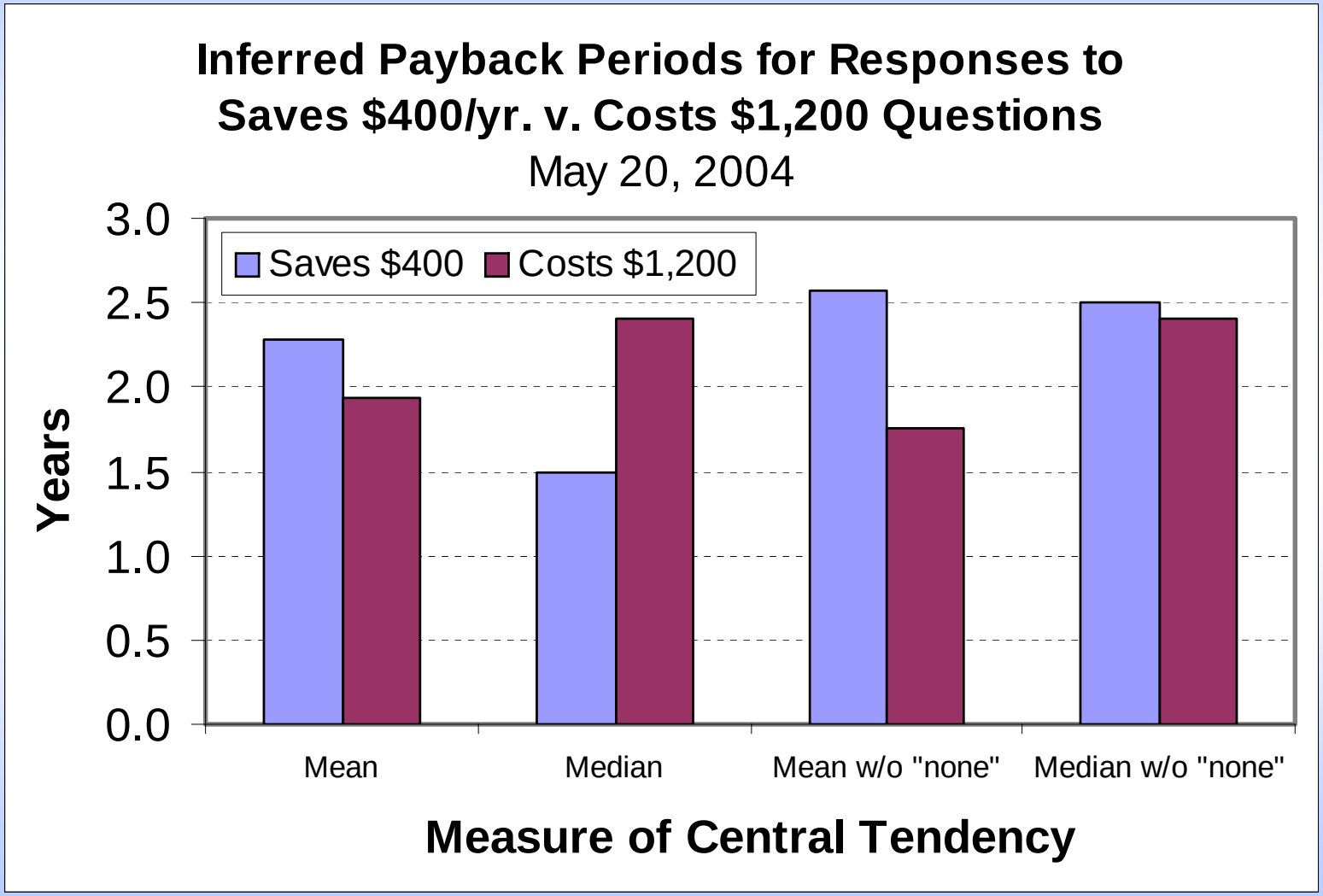
Real Fuel Cost - % of Disposable Income



Per Capita Disposable Income from BEA, Table 2.1, Personal Income and It's Disposition

Consumer Payback Period – Fuel Savings

A random sample of consumers gave generally consistent answers to the same question asked from two directions.



Turrentine & Kurani, 2004

In-depth interviews of 60 California households' vehicle acquisition histories found *no evidence* of economically rational decision-making about fuel economy.

- Out of 60 households (125 vehicle transactions) 9 stated that they compared the fuel economy of vehicles in making their choice.
- 4 households knew their annual fuel costs.
- None had made any kind of quantitative assessment of the value of fuel savings.

Plug-In Hybrid Payback - ACEEE

Table 8, Plug-In Hybrids, ACEEE, Sep 2006			Calculated
	Hybrid	**Plug-In, 40-Mile range**	**Plug-In vs. Hybrid**
Near-term Incremental costs			
Battery - $/kWh	$2,000	$1,500	
Battery – total cost	$2,000	$17,500	$15,500
Other incremental costs	$1,500	$1,500	0
Annual fuel savings	$480	$705	$225
Payback (years)	**7.3**	27.0	**68.9**
Long-term Incremental costs			
Battery - $/kWh	$400	$295	
Battery – total cost	$600	$3,500	$2,900
Other incremental costs	$1,000	$1,000	
Annual fuel savings	$480	$705	$225
Payback (years)	2.9	**6.4**	**12.9**

Assumptions – 12,000 miles per year, hybrid FE of 50 mpg, conventional vehicle FE of 30 mpg, 50% of plug-in miles on electricity, $3.00/gal, 4.0 miles per kWh, $0.09/kWh, no discount of fuel savings, **no additional cost for motor and power electronics, no FE penalty for additional weight of plug-in batteries, no battery replacement for plug-in**

Plug-In Hybrid Payback – METI

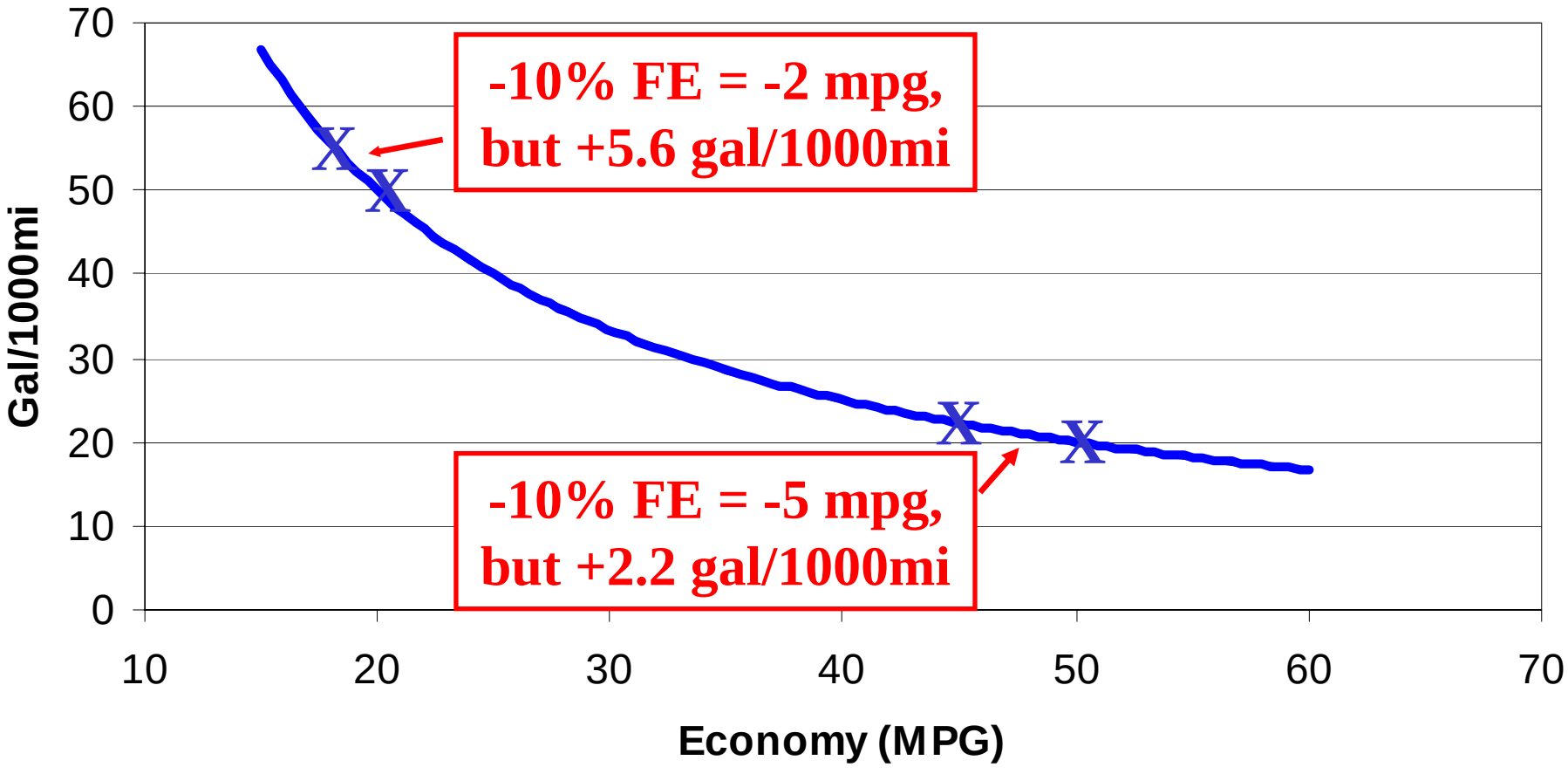
Japan Ministry of Economy, Trade, and Industry – 2015 targets for **new** (not improved) PHEV Li-ion battery:

- Energy density x 3
- Power density x 1.25
- Cost = 1/10

ACEEE Hybrid v. METI PHEV w/ **NEW** Li-ion			Calculated
	Hybrid	**Plug-In, 40-Mile range**	**Plug-In vs. Hybrid**
Long-term Incremental costs			
Battery - $/kWh	$400	$200	
Battery – total cost	$600	$2,650	$2,050
Other incremental costs	$1,000	$1,000	
Annual fuel savings	$480	$692	$212
Payback (years)	2.9	**5.3**	**9.7**

Assumptions – 12,000 miles per year, hybrid FE of 50 mpg, conventional vehicle FE of 30 mpg, 50% of plug-in miles on electricity, $3.00/gal, 4.0 miles per kWh, $0.09/kWh, no discount of fuel savings, **3% FE penalty for additional weight of plug-in batteries, no additional cost for motor and power electronics, no battery replacement for plug-in**

Economy vs Consumption



Actual Fuel Savings

- Annual fuel savings (15,000 miles/year):
  - 100 mpg PHEV vs. 50 mpg hybrid – 150 gallons
  - 17.7 mpg truck vs. 15 mpg truck – 152 gallons
  - ➢ **18% truck improvement matches PHEV**
- 10% PHEV sales:
  - 3.1% reduction on overall fleet fuel consumption
    - ~ 2% reduction in energy consumption and GHGs
  - ➢ **1-2 years of CAFE increases more effective than 10% PHEV**

Plug-In Hybrid Future

Other Impacts

- Battery durability will be shorter
  - Deep discharge cycles
  - Higher loads at lower SOC
- Battery pack uses ~ 4 cu. ft.
  - Reduced vehicle utility
- Battery pack adds 200-250 lbs
  - Lower FE and performance
- Emission control risk
  - Evaporative purge if engine does not operate for several days
  - Emissions when engine turns on
- Requires safe off-board charging system operation
  - Limits market
  - Affects resale value

Market Acceptance

- **Further battery development likely to create niche market**
- **Energy storage breakthrough or oil shortages needed for mass market acceptance**

Recommendations

- **Performance requirements/incentives**
- **Battery R&D – Energy storage breakthrough**
- The Department of Energy held a Workshop on Plug-In Hybrid Electric Vehicles on May 4-5, 2006 to discuss issues and questions on plug-in hybrid research needs
  - Workshop papers are excellent resources for planning future research and development for plug-in hybrids
  - Should be read by everyone interested in promoting plug-in hybrid vehicles
  - The Department of Energy's work in this area should be supported and funded by Congress

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