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Oil, the Economy and Climate:
Transportation Energy in the 21st Century

ACEEE::30th Transportation Efficiency in the 21st Century
November 12, 2010
Washington, DC

Our transportation system faces serious threats to its sustainability.

- **GHG mitigation**: Can transport be 60-80% below 2005 levels by 2050? (Greene & Plotkin, Pew Center for Global Climate Change, forthcoming)
- **Energy Security**: Can the U.S. achieve oil independence? (*Energy Policy*, 2009, v. 34, #4, pp. 1614-1621)
- **Energy Sustainability:** Can we accomplish a massive energy transition for the public good?
- ***Traffic congestion***
- ***Safety***
- ***Sustainable finance***

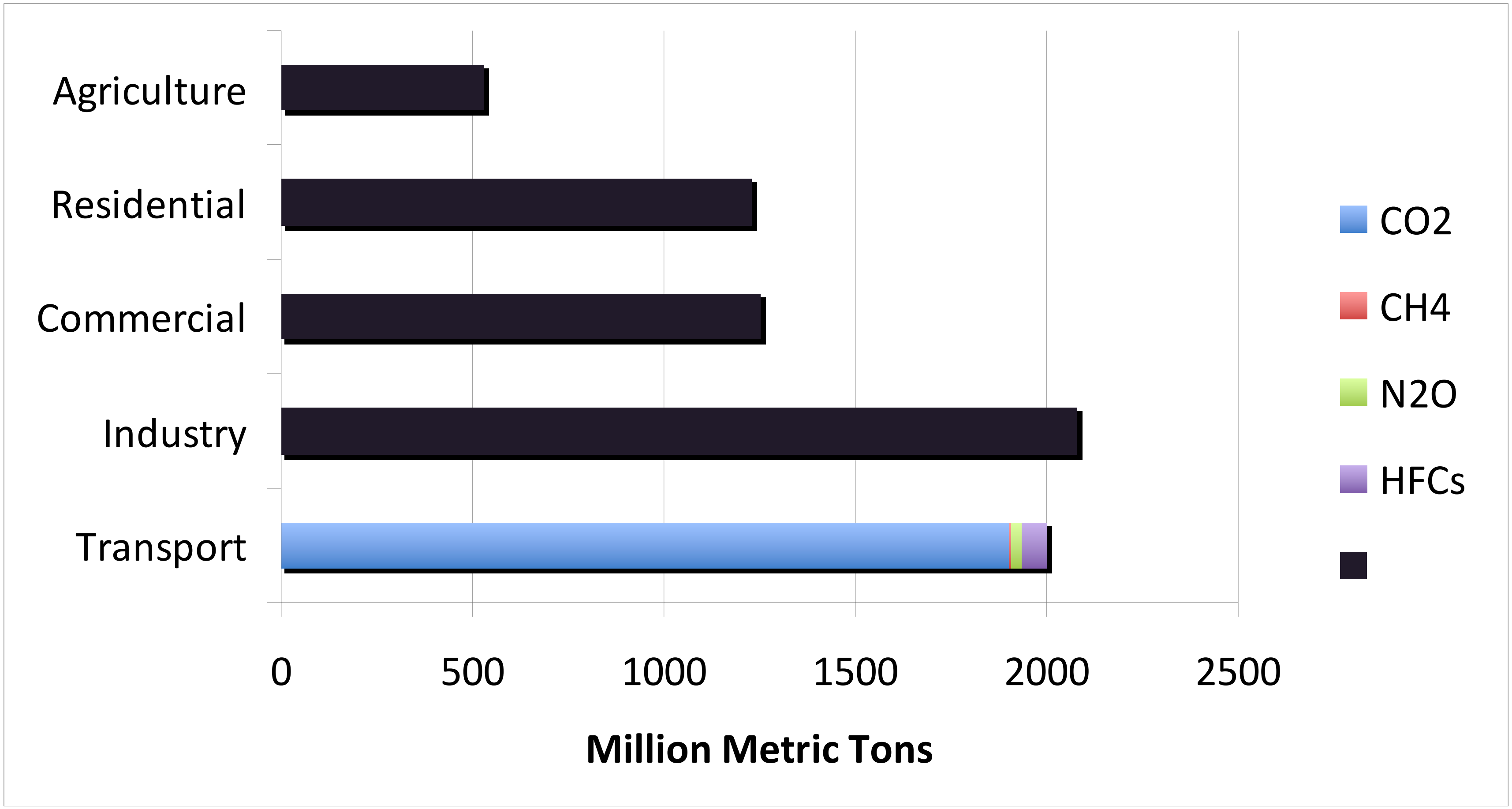
The most recent joint statement by the National Academies of the G8+5 is strongly worded and endorses a 50% reduction in global emissions over 1990 levels by 2050.

"The IPCC 2007 Fourth Assessment of climate change science concluded that large reductions in the emissions of greenhouse gases, principally CO_2, are needed soon to slow the increase of atmospheric concentrations, and avoid reaching unacceptable levels. However, ***climate change is happening even faster than previously estimated***; global CO_2 emissions since 2000 have been higher than even the highest predictions, Arctic sea ice has been melting at rates much faster than predicted, and the rise in the sea level has become more rapid. Feedbacks in the climate system might lead to much more rapid climate changes. ***The need for urgent action to address climate change is now indisputable.*** For example, limiting global warming to 2°C would require a very rapid worldwide implementation of all currently available low carbon technologies."

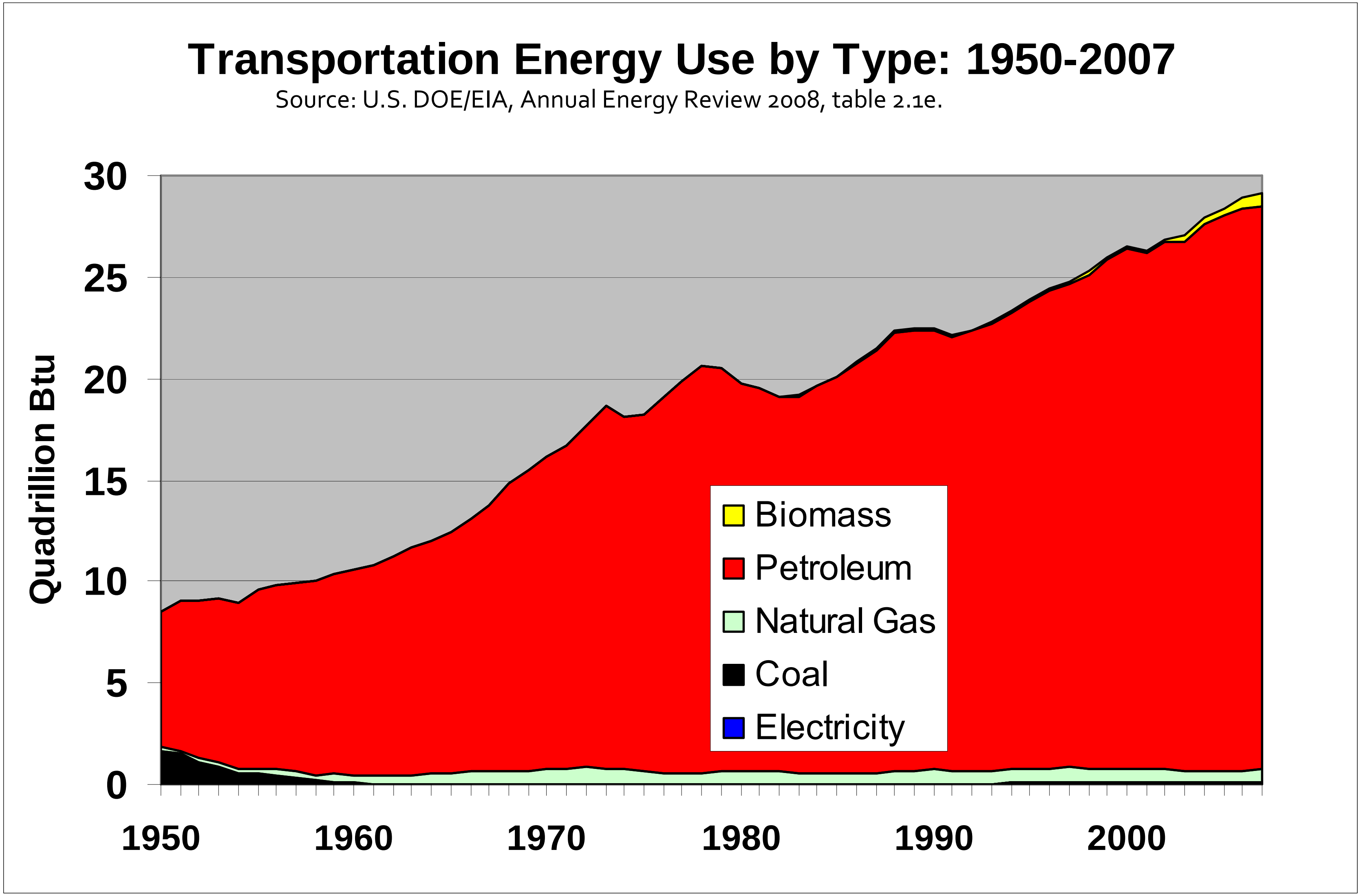
(May 2009)

Emphasis added.

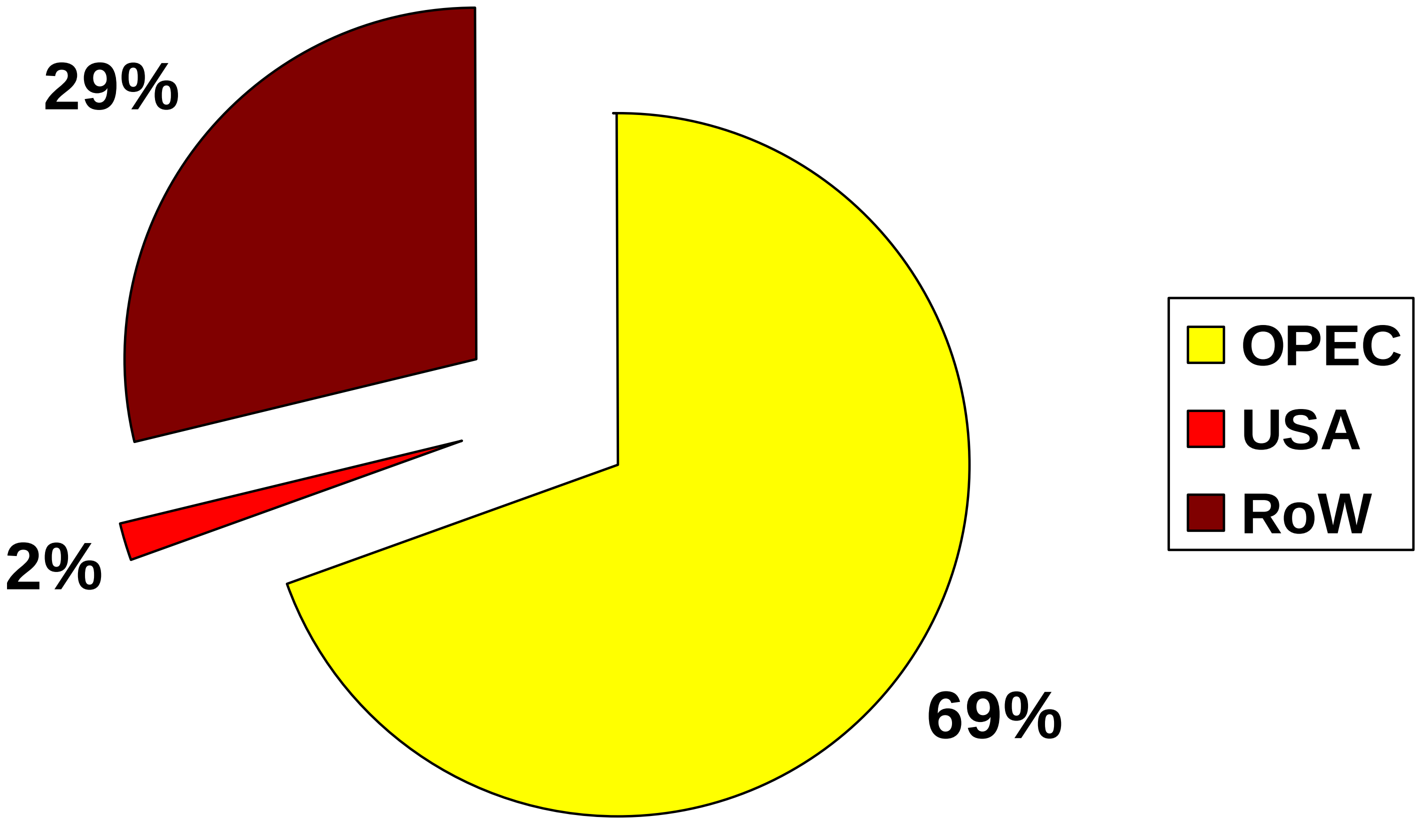
The U.S. transportation system emits more CO_2 than any country in the world except China.



Our transportation system uses oil at the rate of over 6,300 gallons per second, more than any nation's total use. Transportation: 2/3 U.S. oil, > 4/5 of light products.



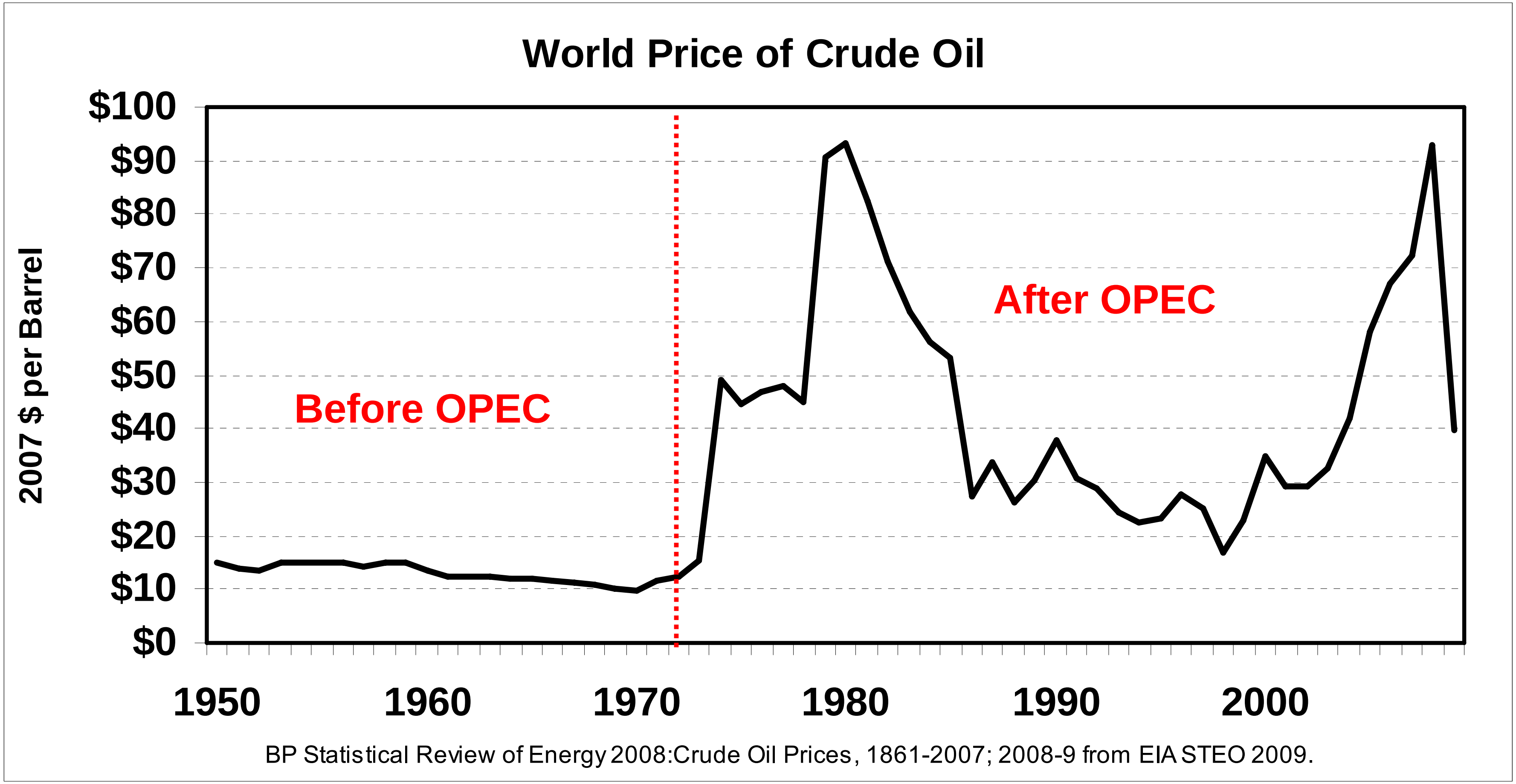
OPEC members own 69% of the world's proven oil reserves and more than half of ultimate resources of conventional oil. Nationalized oil companies own more than 80%.



Source: U.S. Energy Information Administration, 2006.

"The real problem we face over oil dates from after 1970: a strong but clumsy monopoly of mostly Middle Eastern exporters operating as OPEC." Prof. M. Adelman, MIT, 2004.

RANDOM WALK? Hamilton, *The Energy Journal*, 2009, v. 20, #2, pp. 179-206.



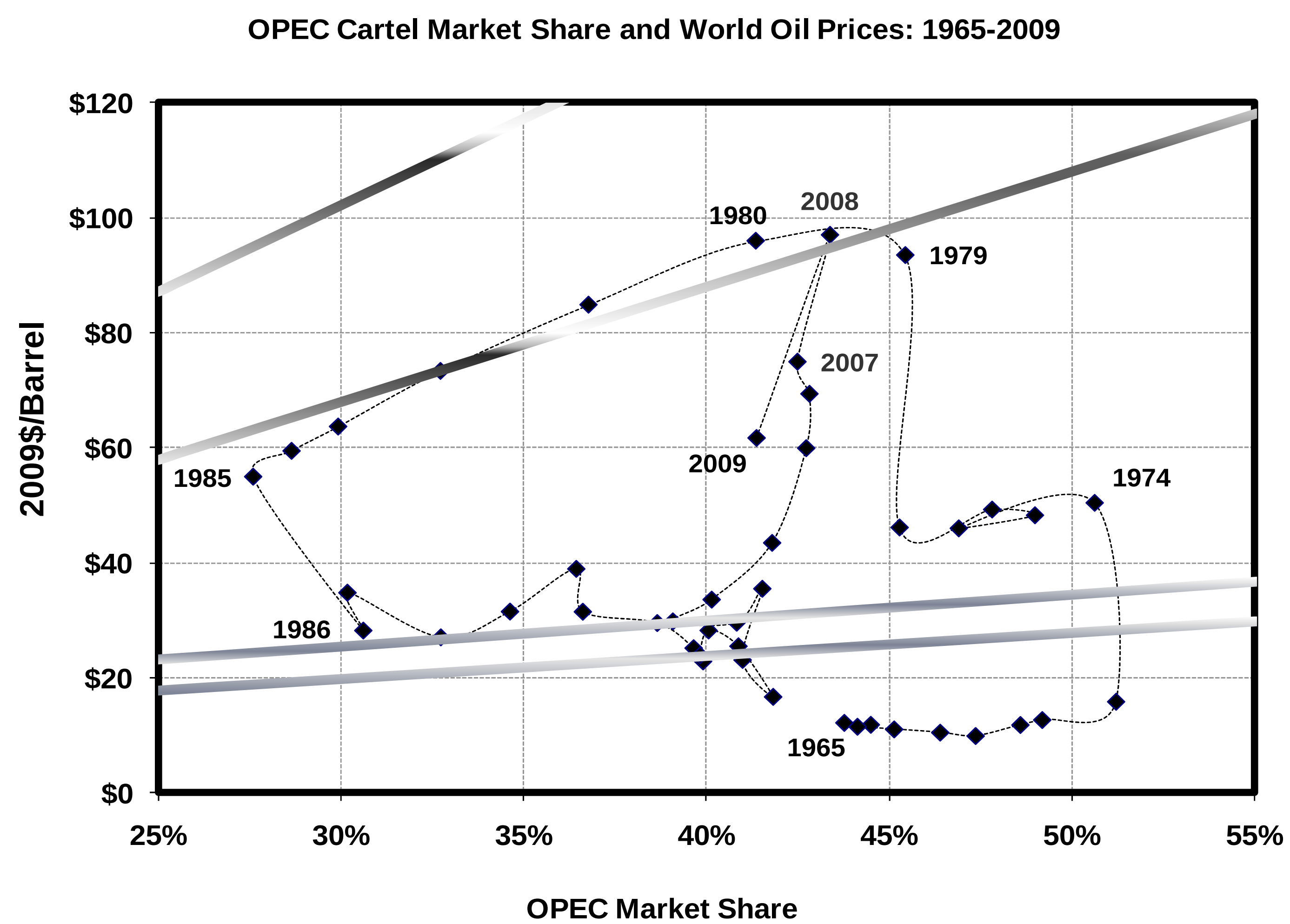
The economic theory of the behavior of partial monopolists, like the OPEC oil cartel, was developed more than half a century ago by Heinrich von Stackelberg.

$$P = \frac{C}{1 + \left(\frac{1}{\beta(P)} \mathbf{S} \left(\mu(P) + 1 \right) \right)}$$

P = profit maximizing price
C = marginal cost of producing oil
β = price elasticity of world oil demand
S = OPEC share of world oil market (0 < S < 1)
μ= non-OPEC supply response (-1 < **μ** < 0)

Oil prices are uncertain because short-run elasticities are 1/10th as large as long-run elasticities.

In 1979 Saudi Arabia produced 9.5 mmbd of crude oil. In 1985 they produced 3.4 mmbd. OPEC production was cut from 29.4 mmbd to 15.4 mmbd.

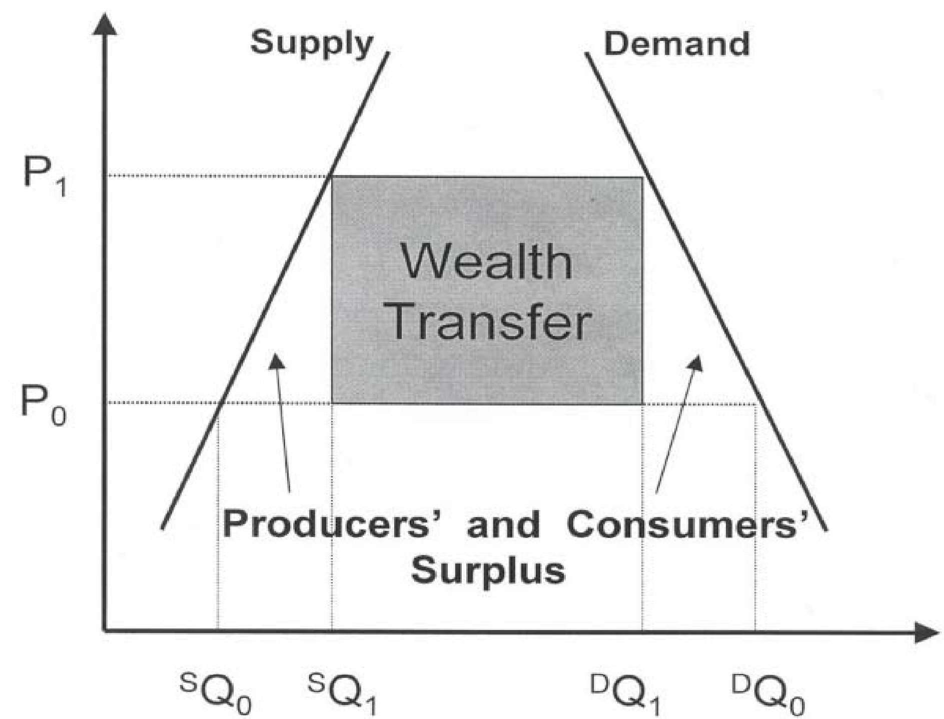


Source: 1965-2009 BP Statistical Review 2010. Oil Production - barrels and Oil - crude oil prices since 1861.

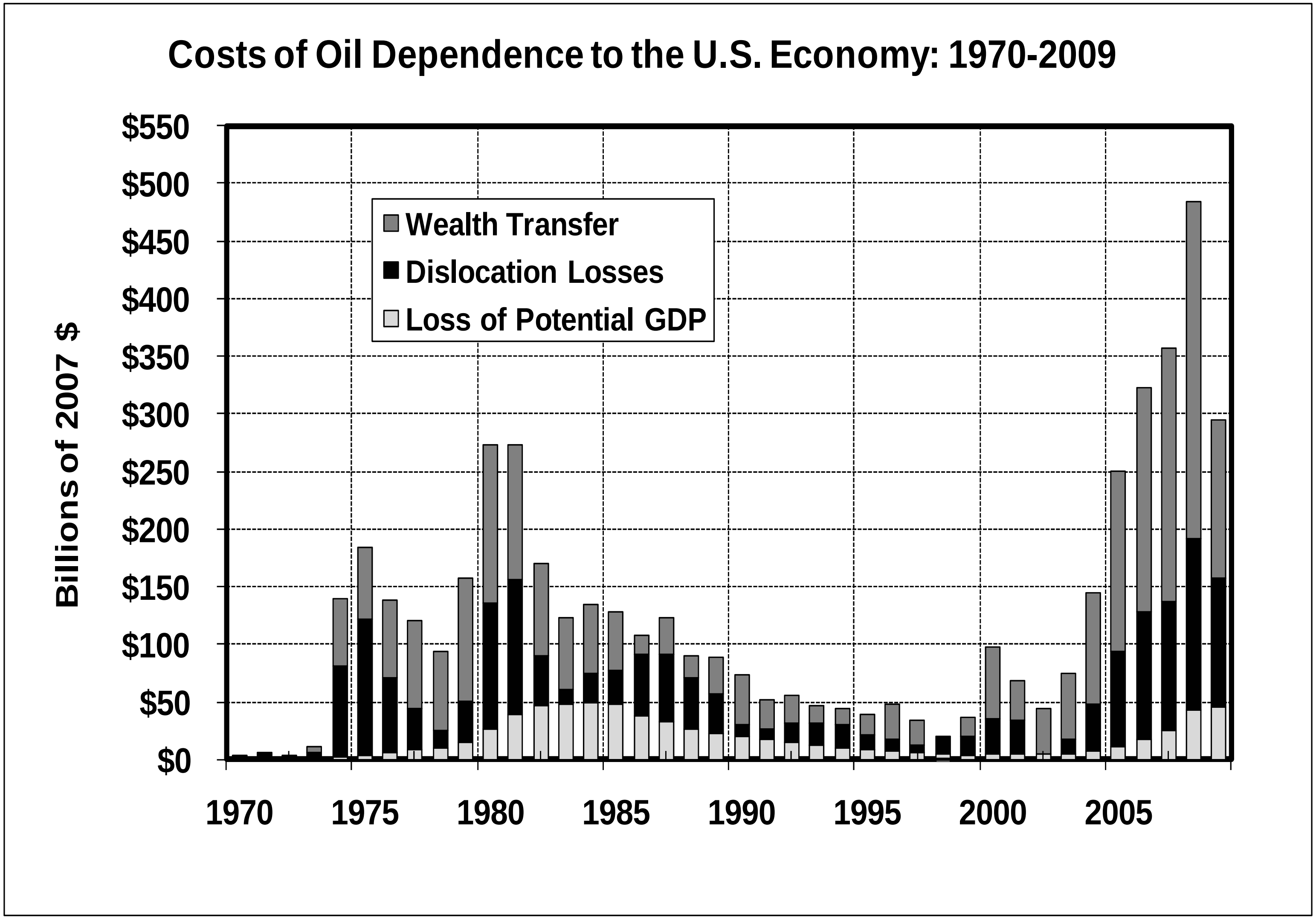
Why should we care?

1. Loss of potential GDP = producers' & consumers' surplus losses in oil markets (dynamic).
2. Dislocation losses of GDP due to oil price shocks (temporary).
3. Transfer of wealth due to monopoly pricing and price shocks (requires counterfactual competitive price).

Transfer of wealth is not a loss of GDP but a change in the ownership of GDP. It can occur in disrupted and undisrupted markets and occurs whether or not OPEC is the cause of the disruption.



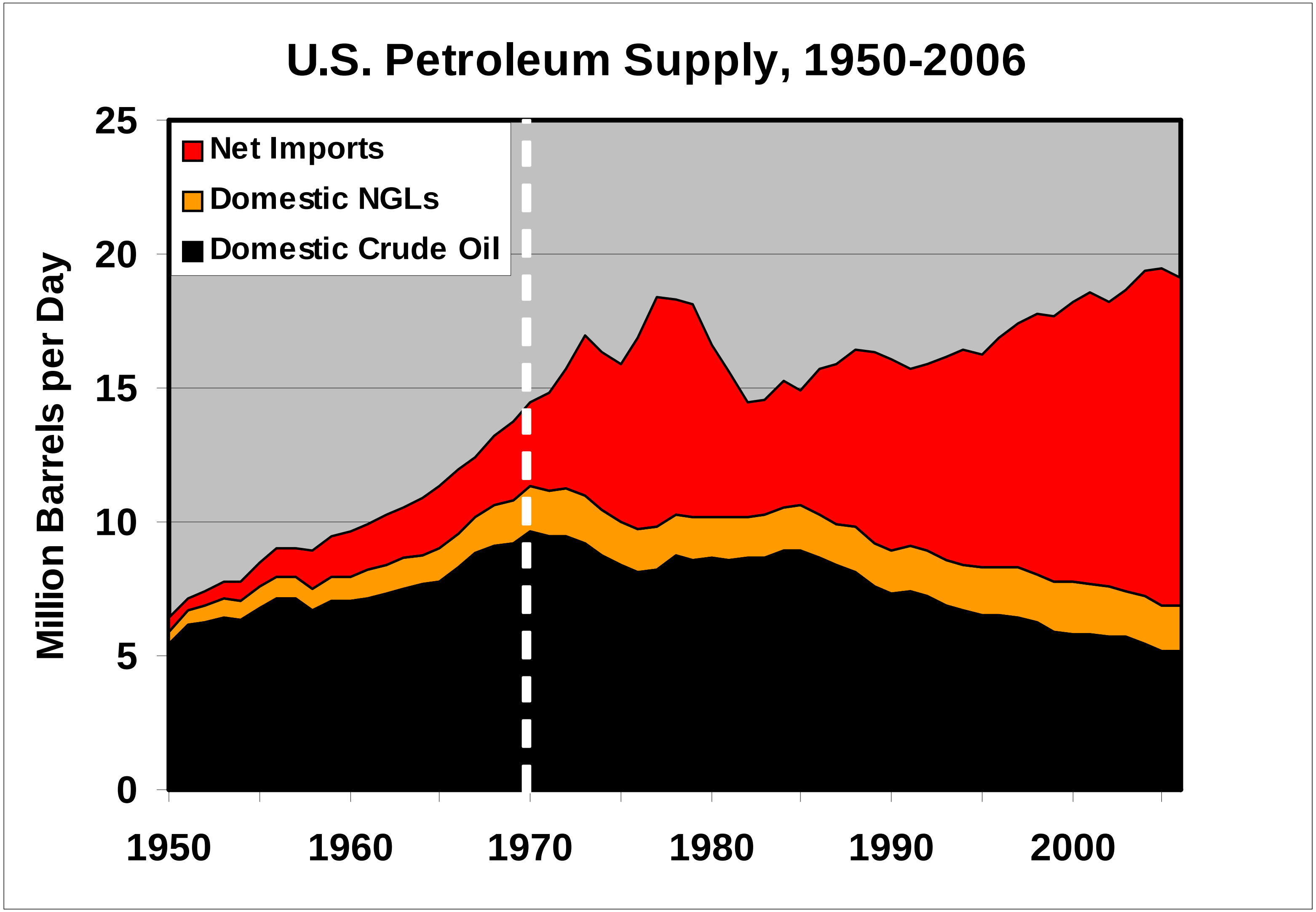
How much? A lot. ($1T: 2007-9)



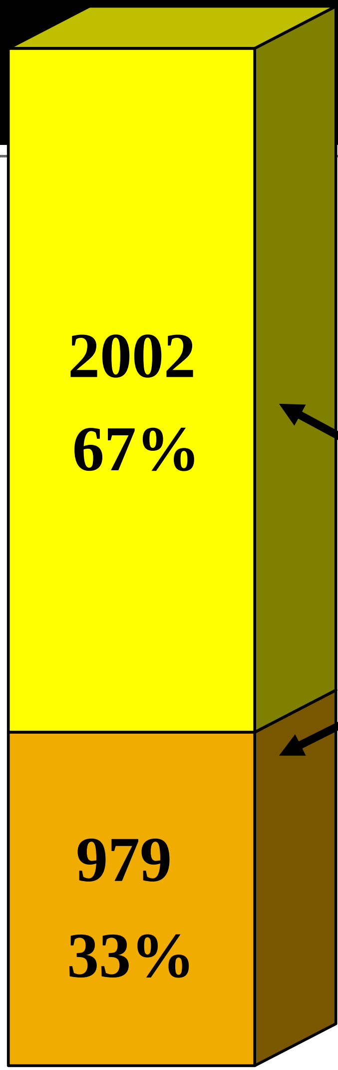
Oil independence: Now what do we mean by that?

- Oil independence is NOT:
  - Use no oil
  - Import no oil
- Oil independence is:
  - Reduce the *economic* costs of oil dependence to an acceptable level, e.g., less than 1% of GDP with 95% probability.
  - Huh? It's a measurable goal.
    - Greene, D.L., "Measuring energy security: can the United States achieve oil independence?", *Energy Policy*, 2010, v. 38, pp. 1614-1621.
  - Reduced petroleum consumption by 1/3, increase supply of liquid fuels by 1/3.
    - National Commission on Energy Policy, 2004. *Ending the Energy Stalemate*, http://www.bipartisanpolicy.org/library/report/ending-energy-stalemate.

OPEC's market power was strengthened by the growth of world demand, its market share and, what is too often overlooked, the peaking of US crude oil production in 1970.



The RATE of world oil use is alarming!



Billions of Barrels

The 2007 NPC report expects 1.1 trillion barrels of oil production over the next 25 years. More than consumed in in all of human history.

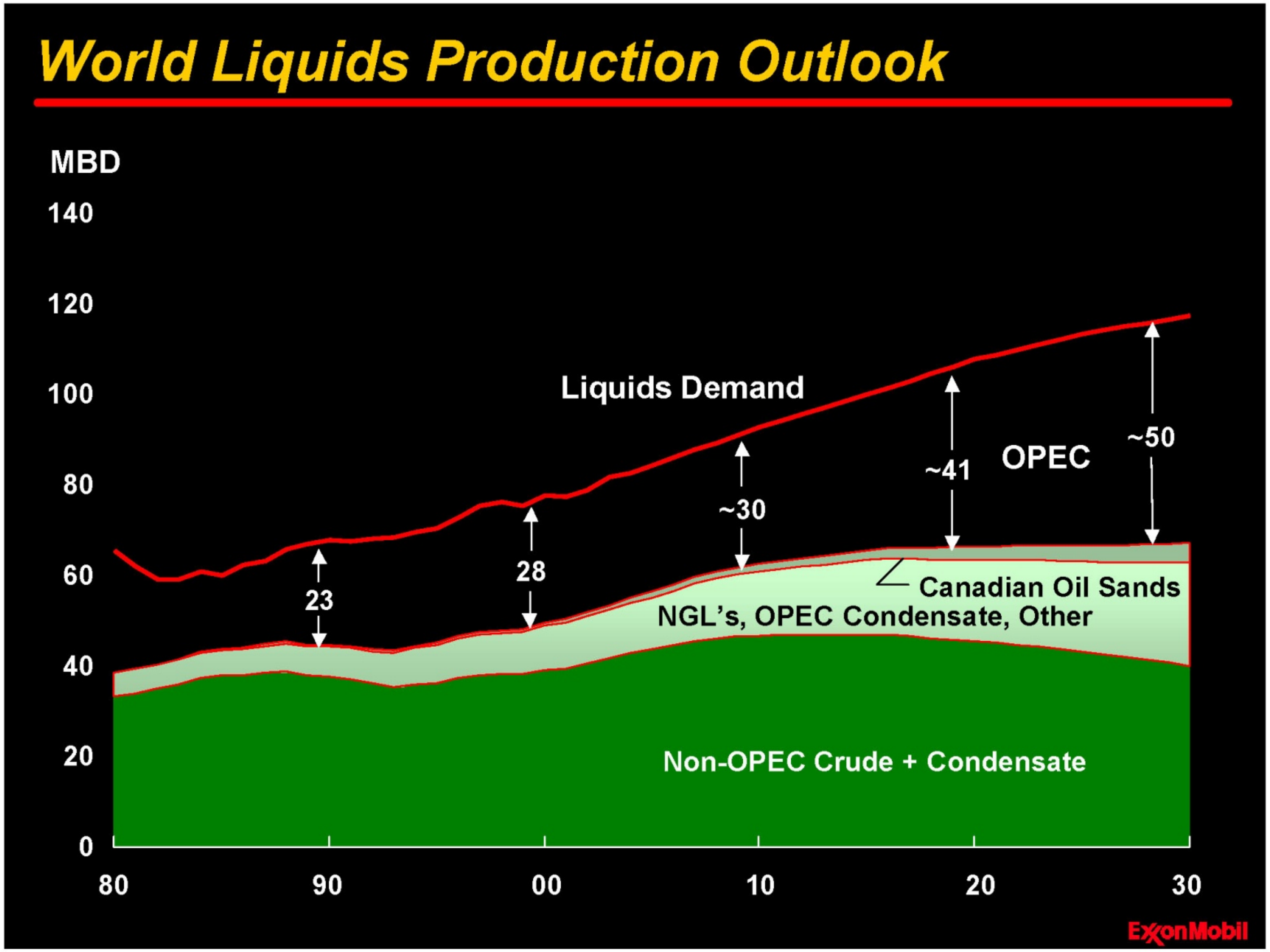
Remaining recoverable crude oil*
Not reserves, ULTIMATE RESOURCES

Cumulative Production to end of 2005

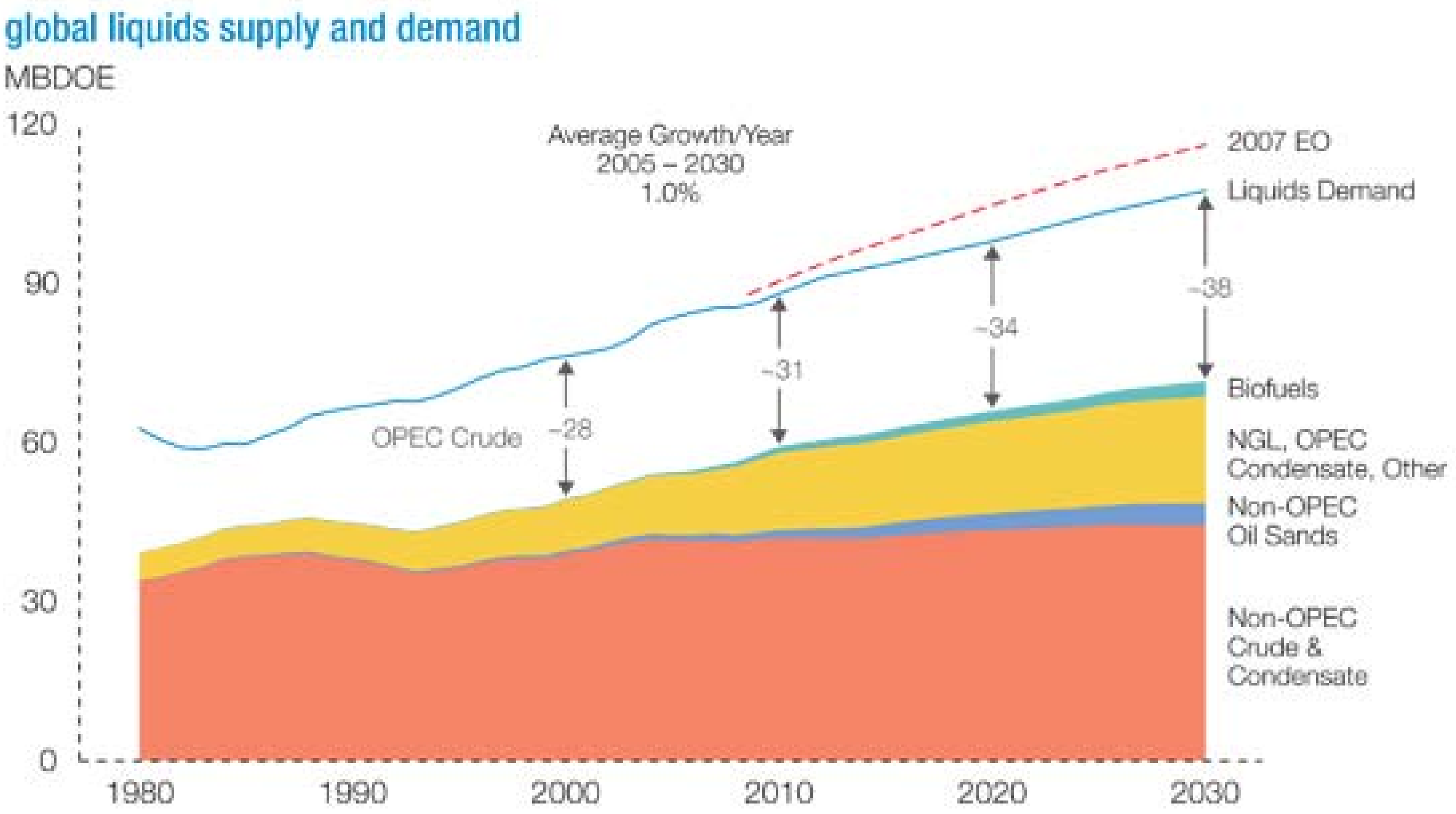
Cumulative Production to the end of 1995 was 710! Over ¼ of all oil ever consumed was consumed in the last 10 years.

* From USGS 2000, USGS 1995, and MMS 1996

Projections of just 3 years ago expected peaking of non-OPEC supply with OPEC filling the gap.
Didn't happen; won't happen.



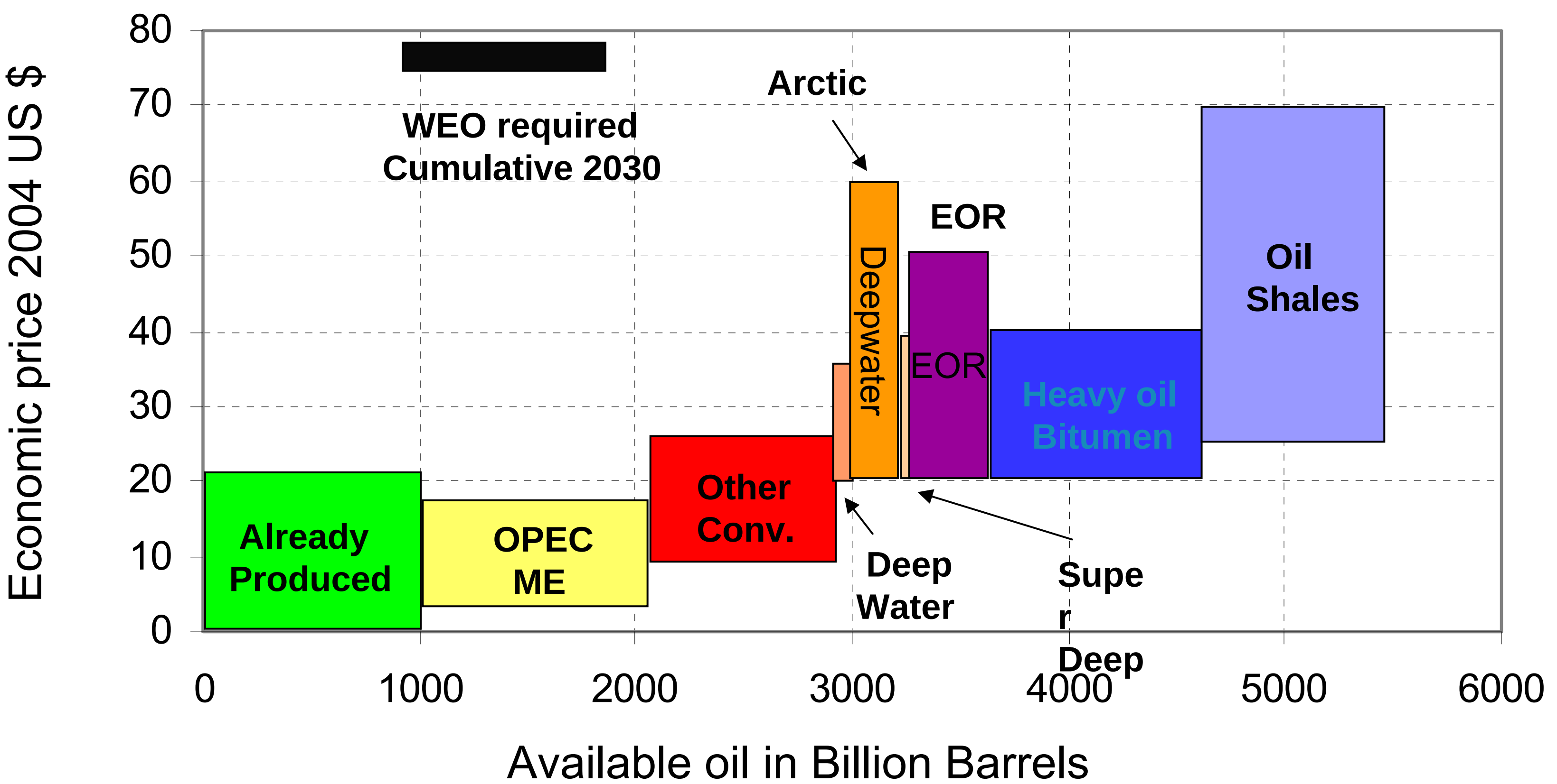
ExxonMobil's current energy outlook, considering recent high oil prices, is not much more optimistic about non-OPEC crude oil supply.



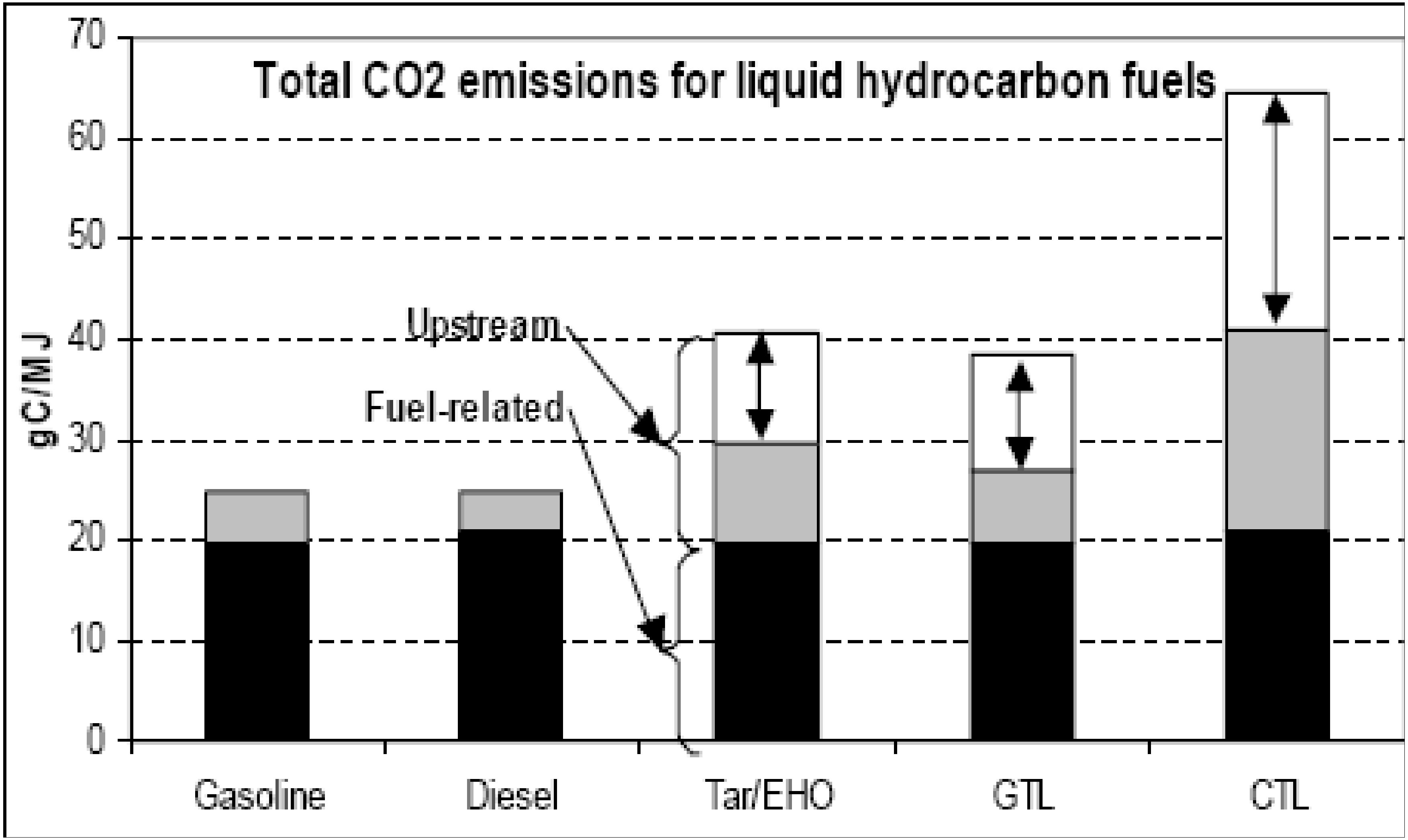
Source: ExxonMobil, The outlook for energy: a view to 2030, January 14, 2009.
http://www.exxonmobil.com/Corporate/energy_outlook.aspx

The path of least resistance? There are vast unconventional resources from which liquid hydrocarbons can be made, compatible with the existing infrastructure, at prices we are willing to pay. And there is coal.

IEA “Resources to Reserves” 2005



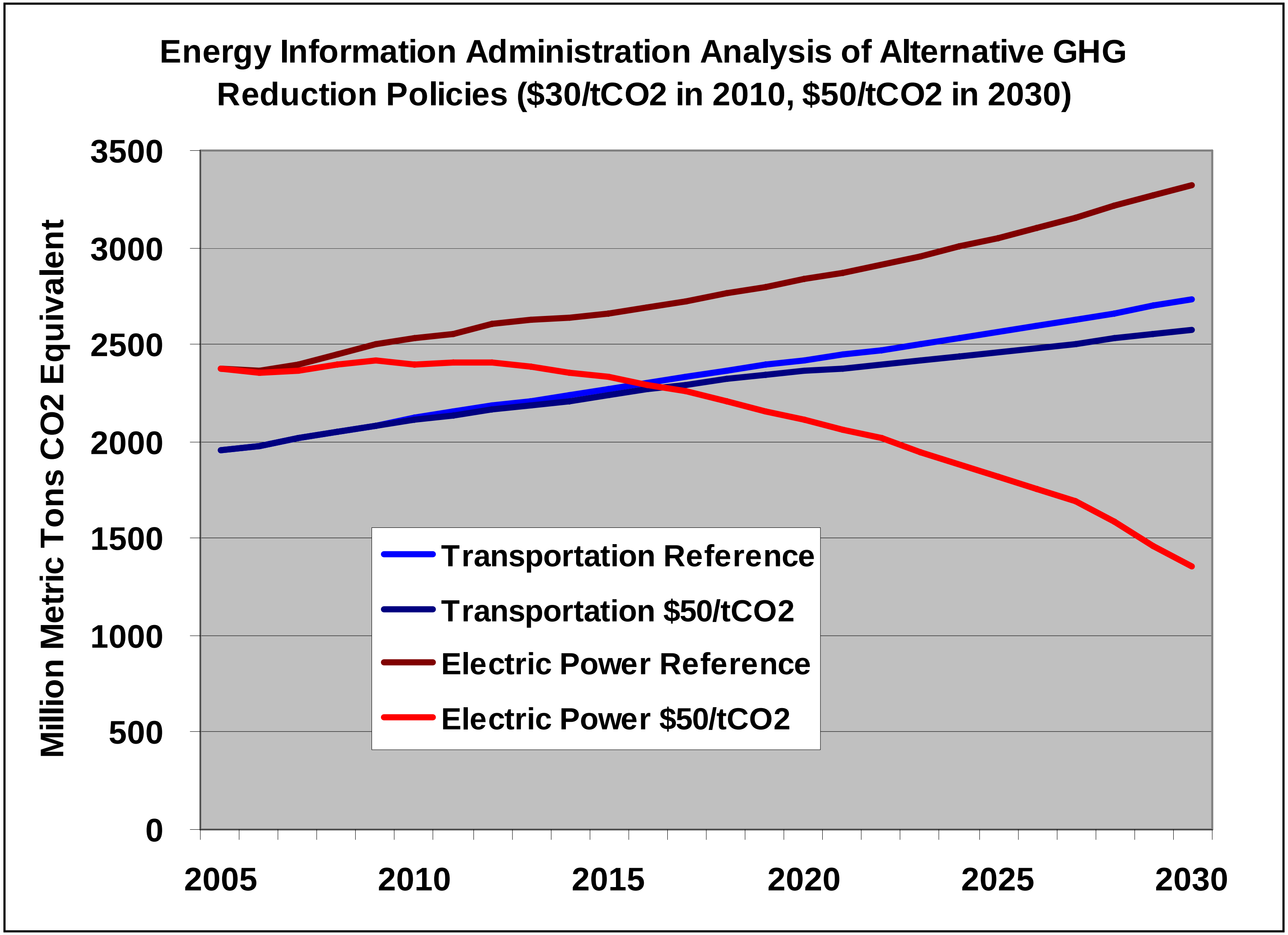
GHG emissions from oil sands could be 20% to 80% higher than gasoline from conventional oil, liquid fuels from coal (CTL) would likely more than double CO_2 emissions (without Carbon Capture & Storage).



Source: Farrell, 2006.

What is transportation's "fair share"? Here's one answer:

A carbon price that would cut CO2 emissions from electricity generation in half by 2030 would do little for transportation. (EIA, 2006). $50/tCO$_2$ approx. $0.50/gal.

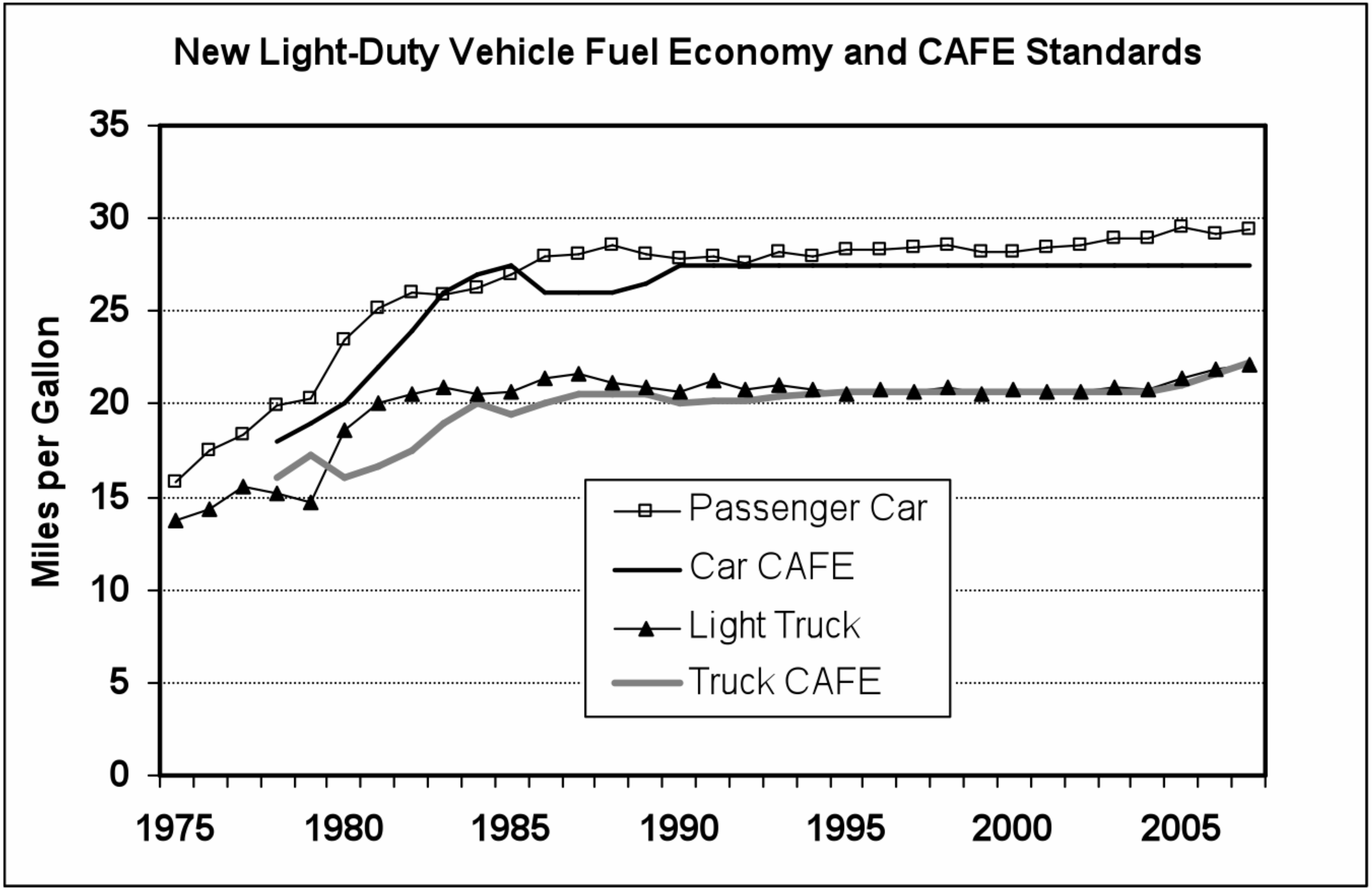


A great deal more can be accomplished by policies designed for real-world transportation markets.

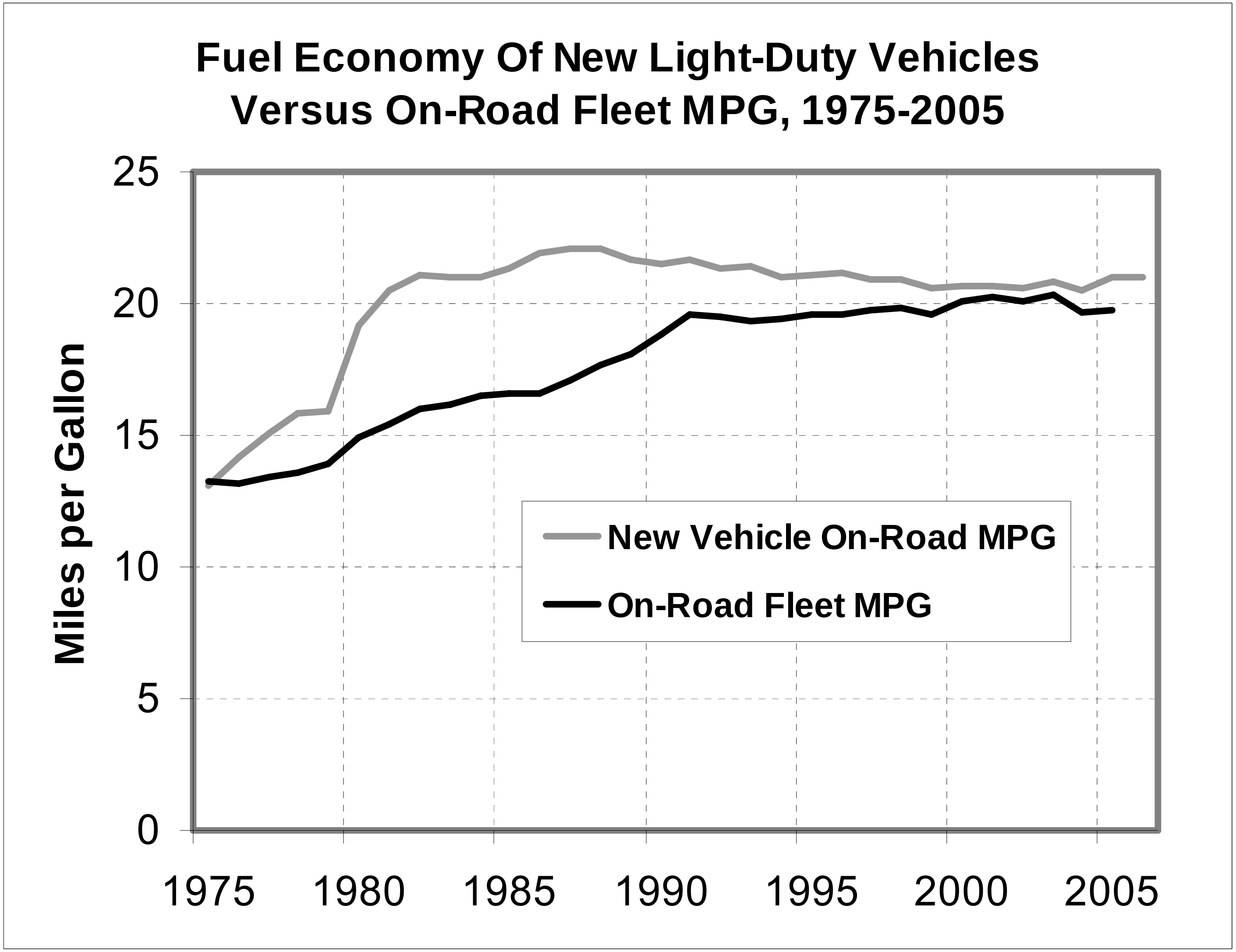
- Undervaluing energy efficiency by half or more:
  - (Greene, D.L., in press. "Uncertainty, Loss-Aversion and Markets for Energy Efficiency, *Energy Economics.)*
- Co-benefits and externalities
- Interdependency with land use
- Interdependency with transportation infrastructure
- Roads as public goods
- Re-pricing transportation without increasing its cost
- Unpredictable evolution of technology requires adaptable policies.
- Requires comprehensive, realistic assessment of mitigation potential.
  - USDOT, 2010, "Transportation's Role in Reducing Greenhouse Gas Emissions", April.
  - Greene and Plotkin, 2010, "Reducing Greenhouse Gas Emissions from US Transportation", Pew Center on Global Climate Change, forthcoming.
- Energy independence by 2030 and a 50% to 80% reduction in 2050 GHG emissions versus 2010 is likely to be cost-effectively achieveable.

THANK YOU.

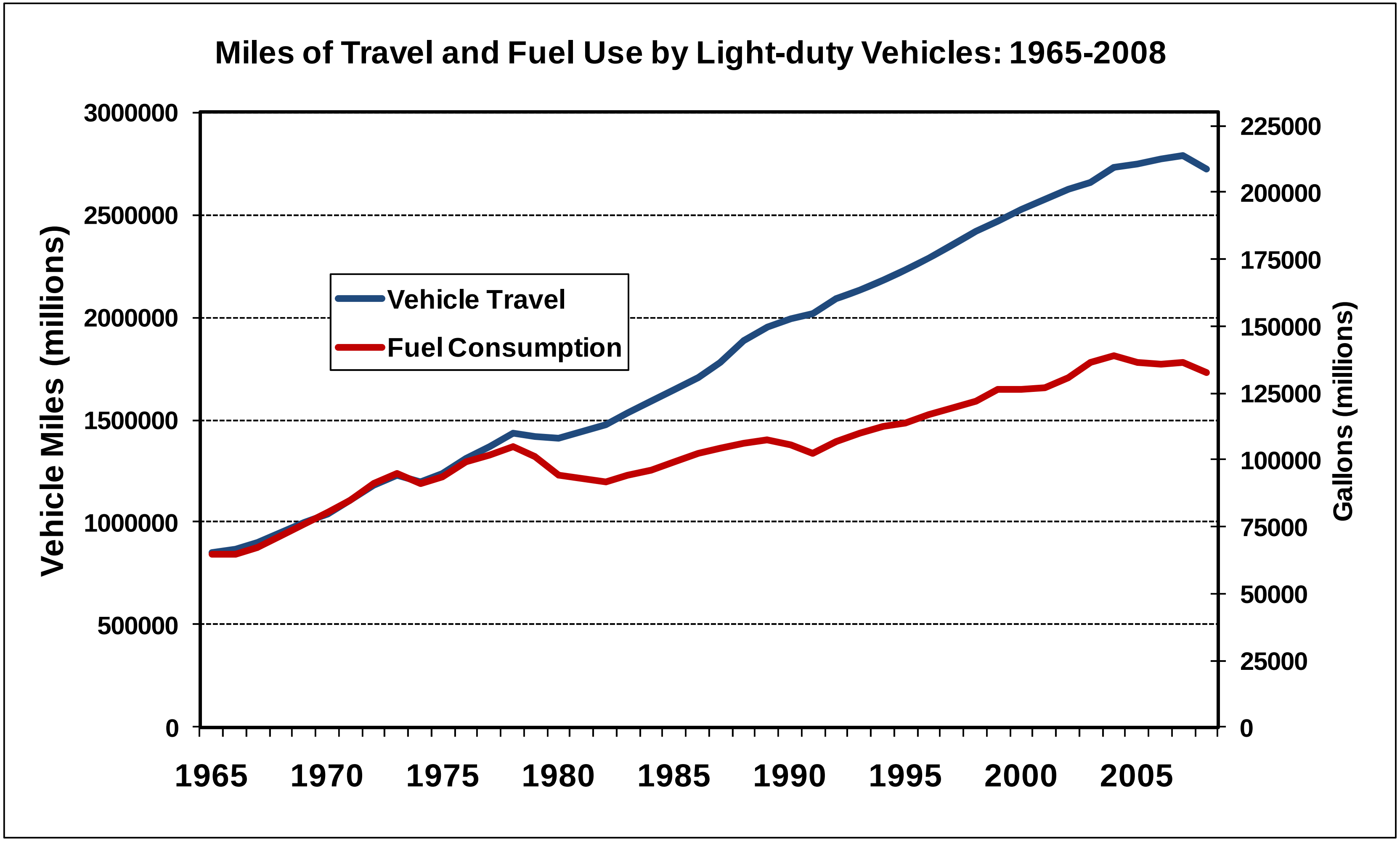
Essentially all of the fuel economy improvement in the US in the past 30 years can be credited to the Corporate Average Fuel Economy standards.



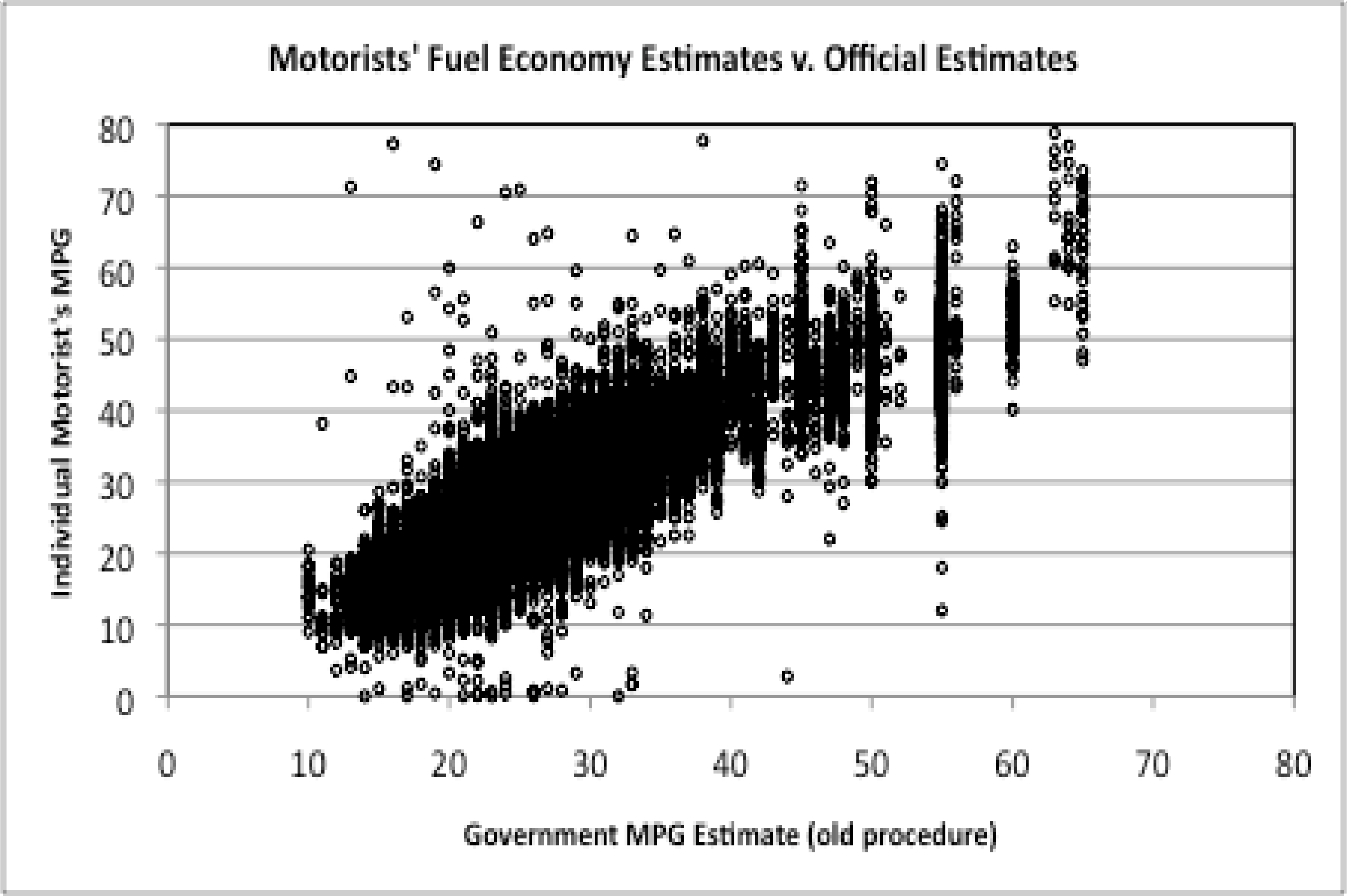
Despite early concerns, EPA test fuel economy improvements translated into real world gains.



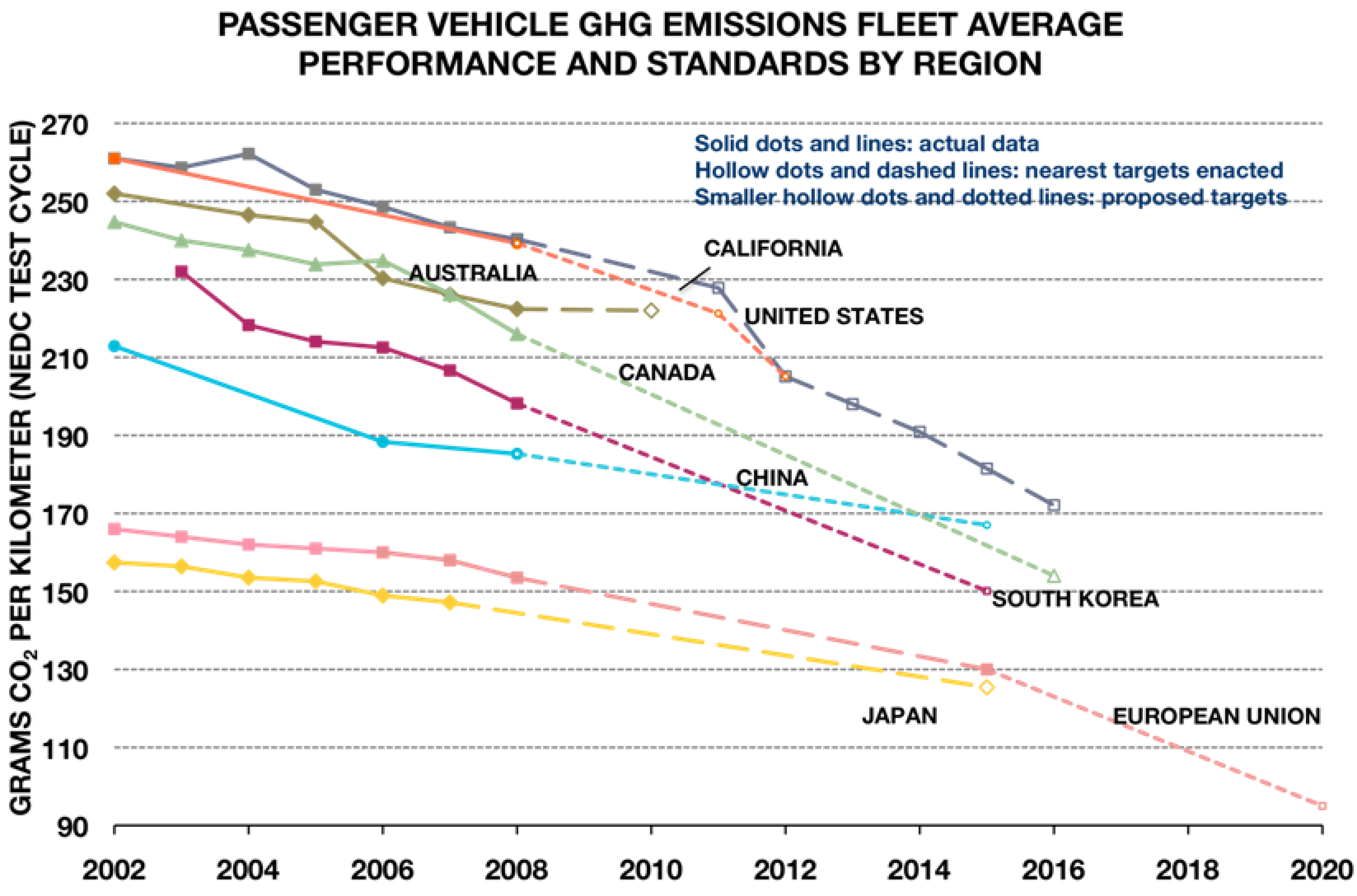
Fuel economy and fuel economy standards: They work. (>6o Bgals. saved in 2008)



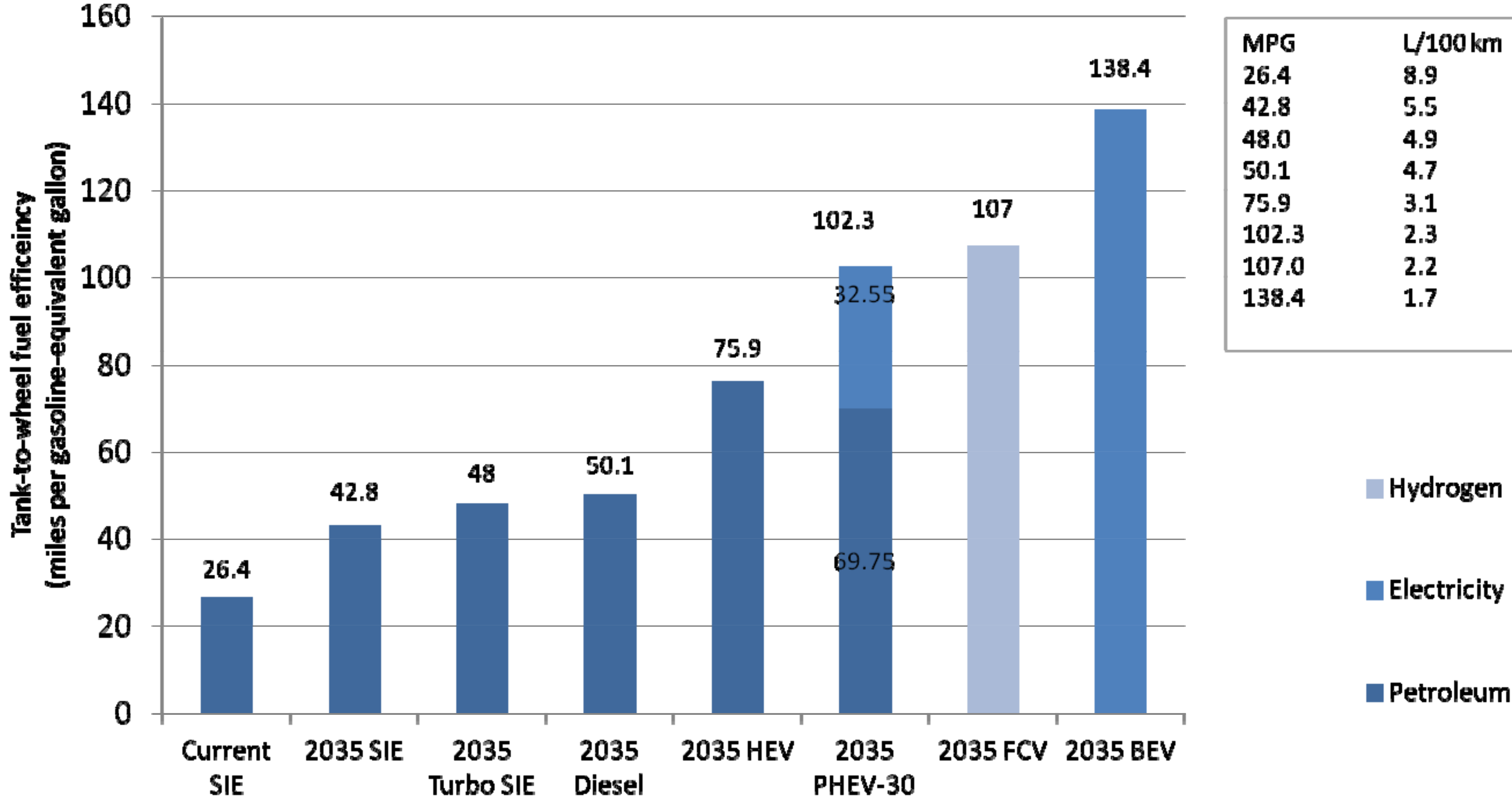
Energy efficiency paradox: Why does the market undervalue fuel economy?
Behavioral economics: the payoff is uncertain and consumers are "loss averse".



Every major auto manufacturing economy has fuel economy or GHG emissions standards.



Achieving the potential fuel economy improvements foreseen by MIT engineers by 2035 would require foregoing *further* size and power *increases*.

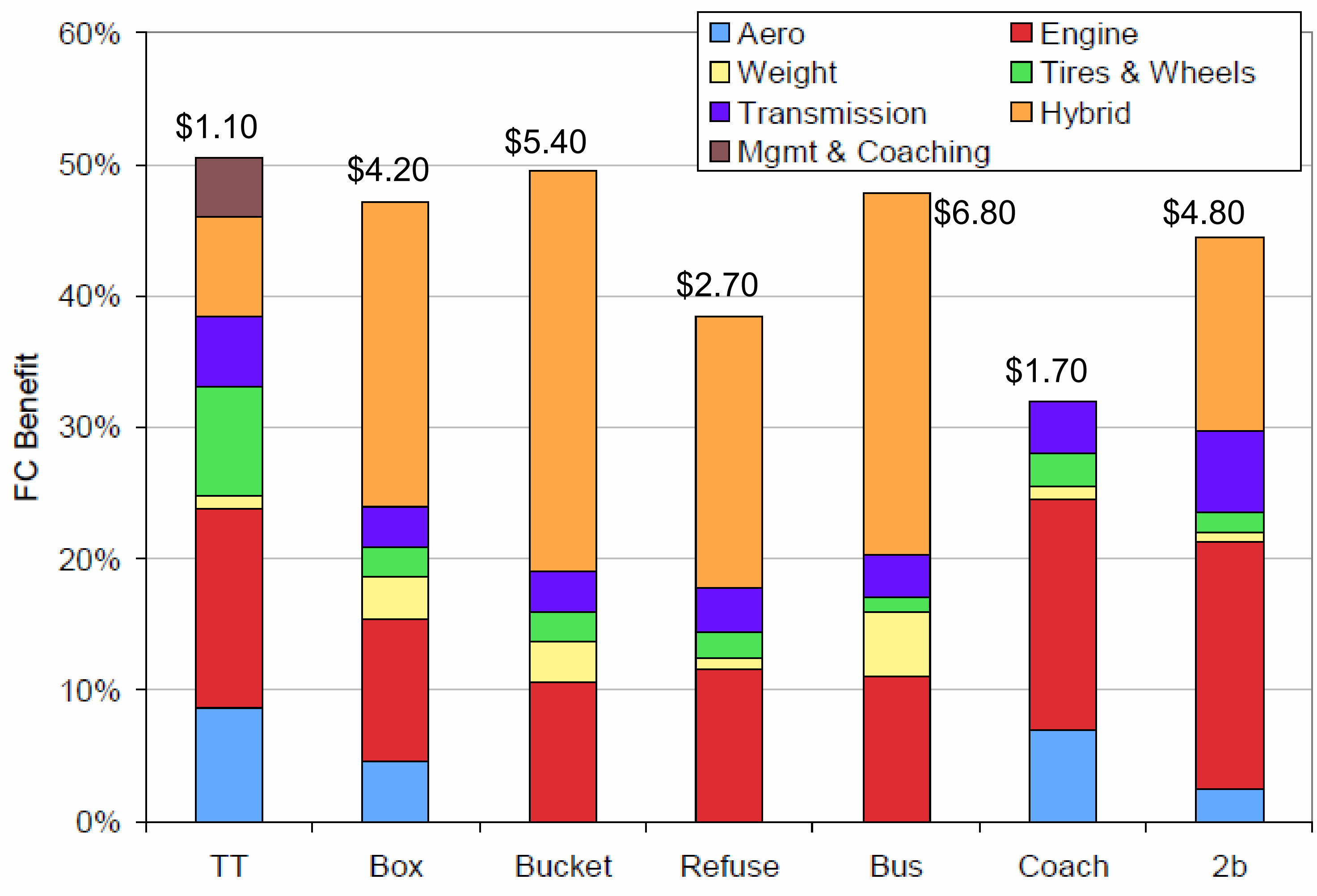


MPG	L/100 km
26.4	8.9
42.8	5.5
48.0	4.9
50.1	4.7
75.9	3.1
102.3	2.3
107.0	2.2
138.4	1.7

Bandivadekar et al., 2008. *On the Road in 2035*, MIT Laboratory for Energy and the Environment.

What about heavy trucks?

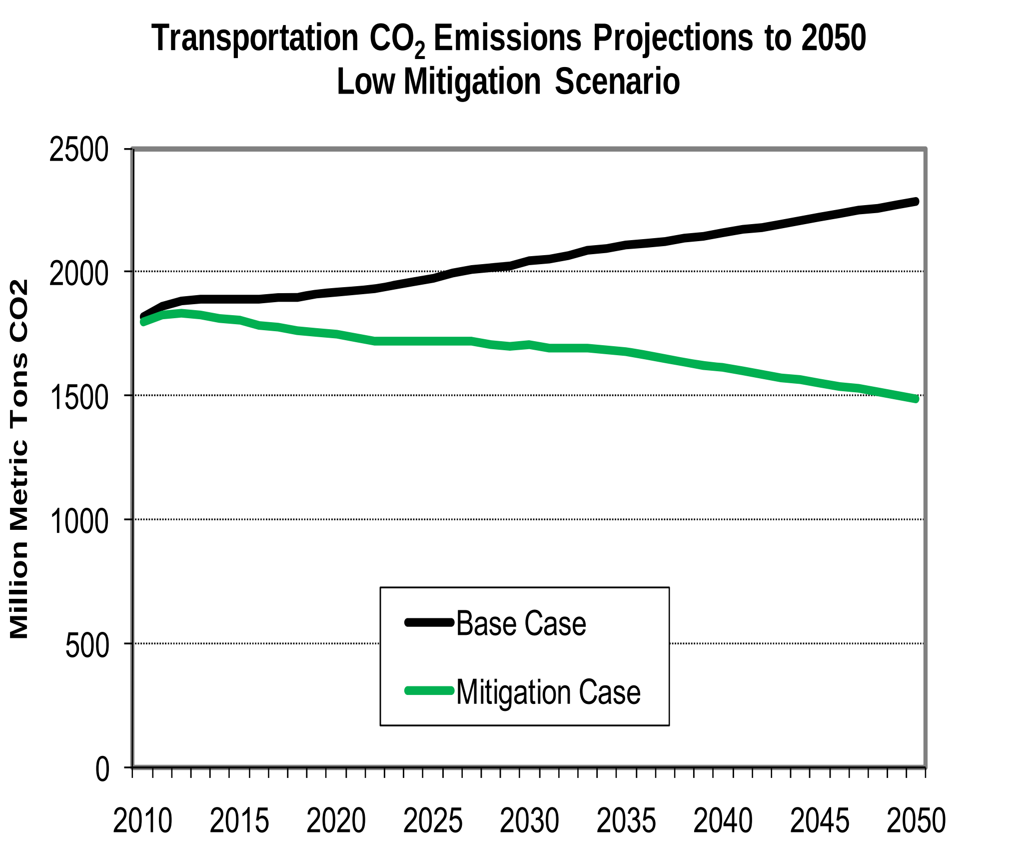
NRC, 2010, "Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles", Figure S-1. Break-even fuel prices shown above bars.

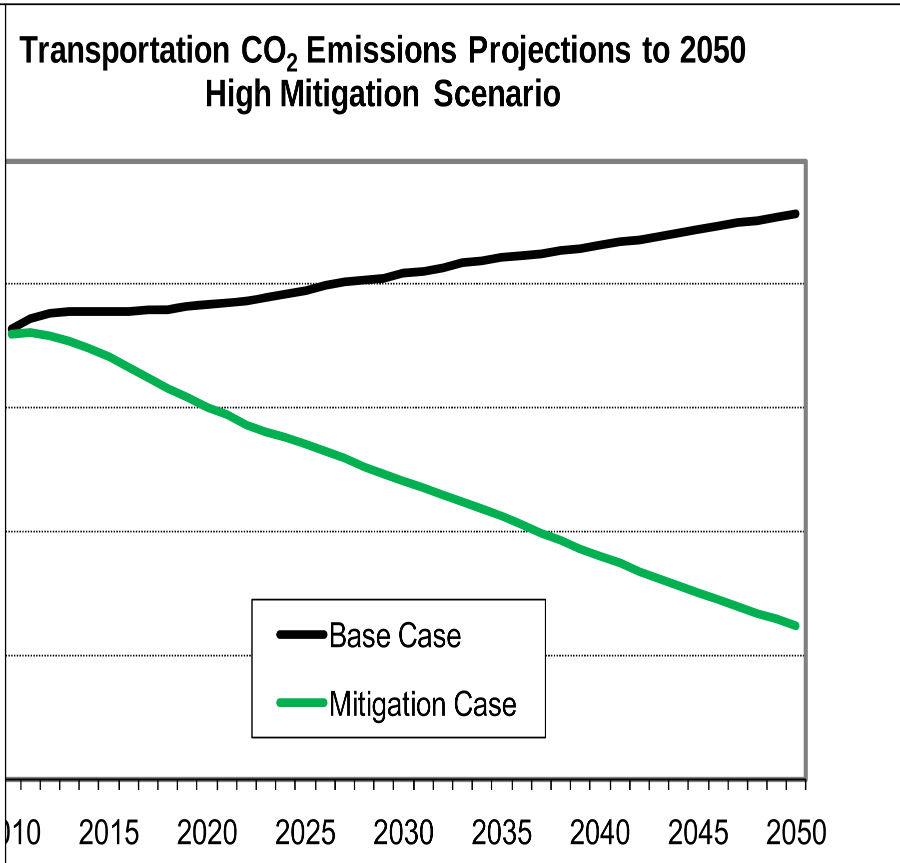


Plausible scenarios (dependent on technological progress) indicate that US transportation GHG emissions and petroleum use could be reduced by 15% to as much as 65% below 2010 levels by 2050.

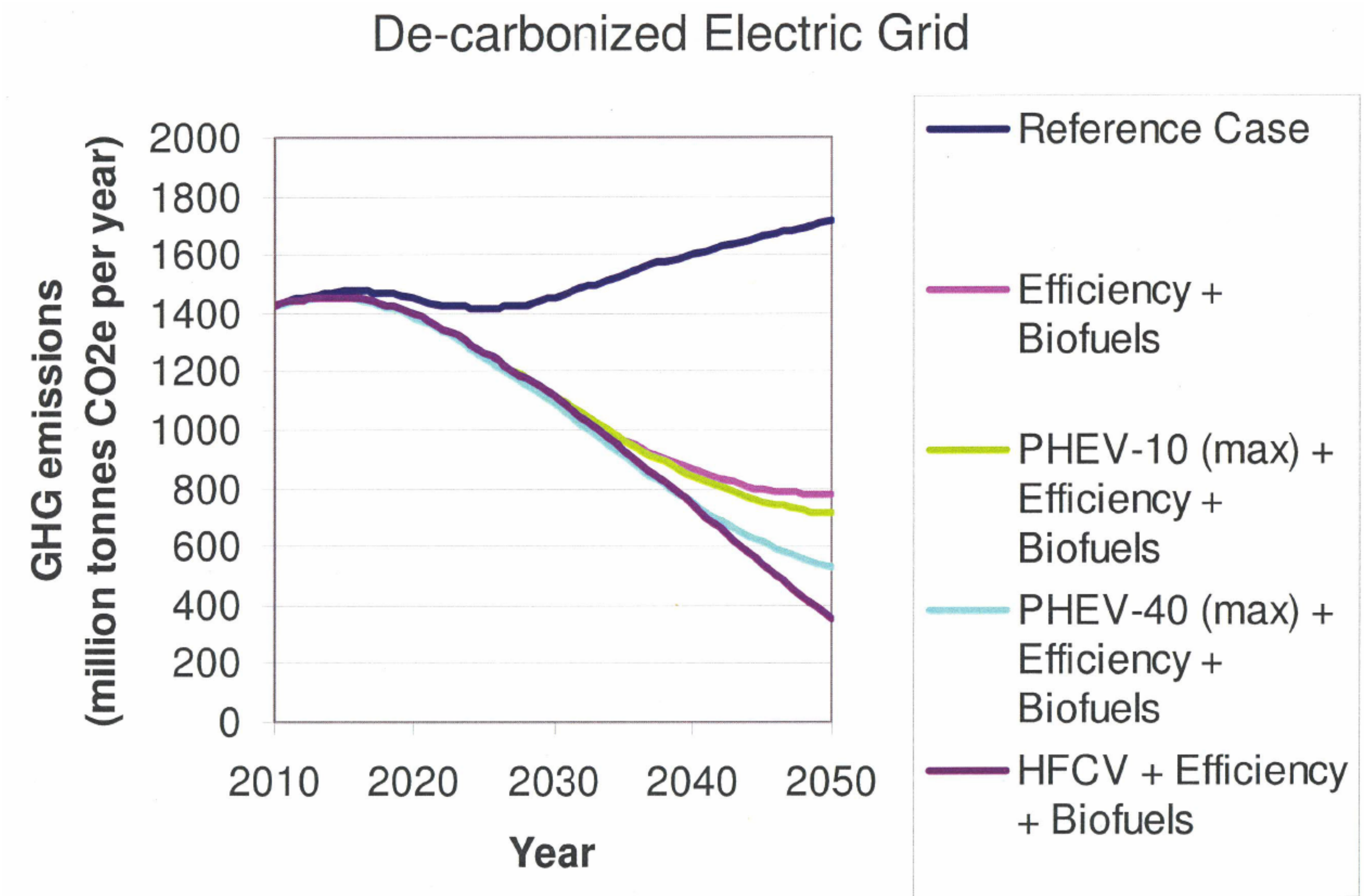
- Examples of "Low Scenario" Policies:
  - 35% additional fuel economy improvement
  - 5% reduction in fuel carbon intensity of energy
  - Carbon price (rising to $0.75/gal. in 2050)
  - Road user tax on energy indexed to efficiency
- Examples of "High Scenario" Policies
  - 80% additional increase in MPG for cars, 40% for heavy trucks
  - 45% reduction in carbon intensity of energy
  - Pay-at-the-Pump auto insurance ($1.30/gal. in 2050)
  - Feebates ($30 per g/mi in 2050)
  - Congestion pricing, intelligent vehicles and roadways, land use, etc. reduce VMT by 15% from projected level.

Versus 2010 levels, US transportation GHG emissions could be reduced by anywhere from 15% to 65% by 2050, depending on the stringency of policies and progress of technology. (Pew Ctr. 2010, *Reducing GHG Emissions from US Transportation*, forthcoming.)



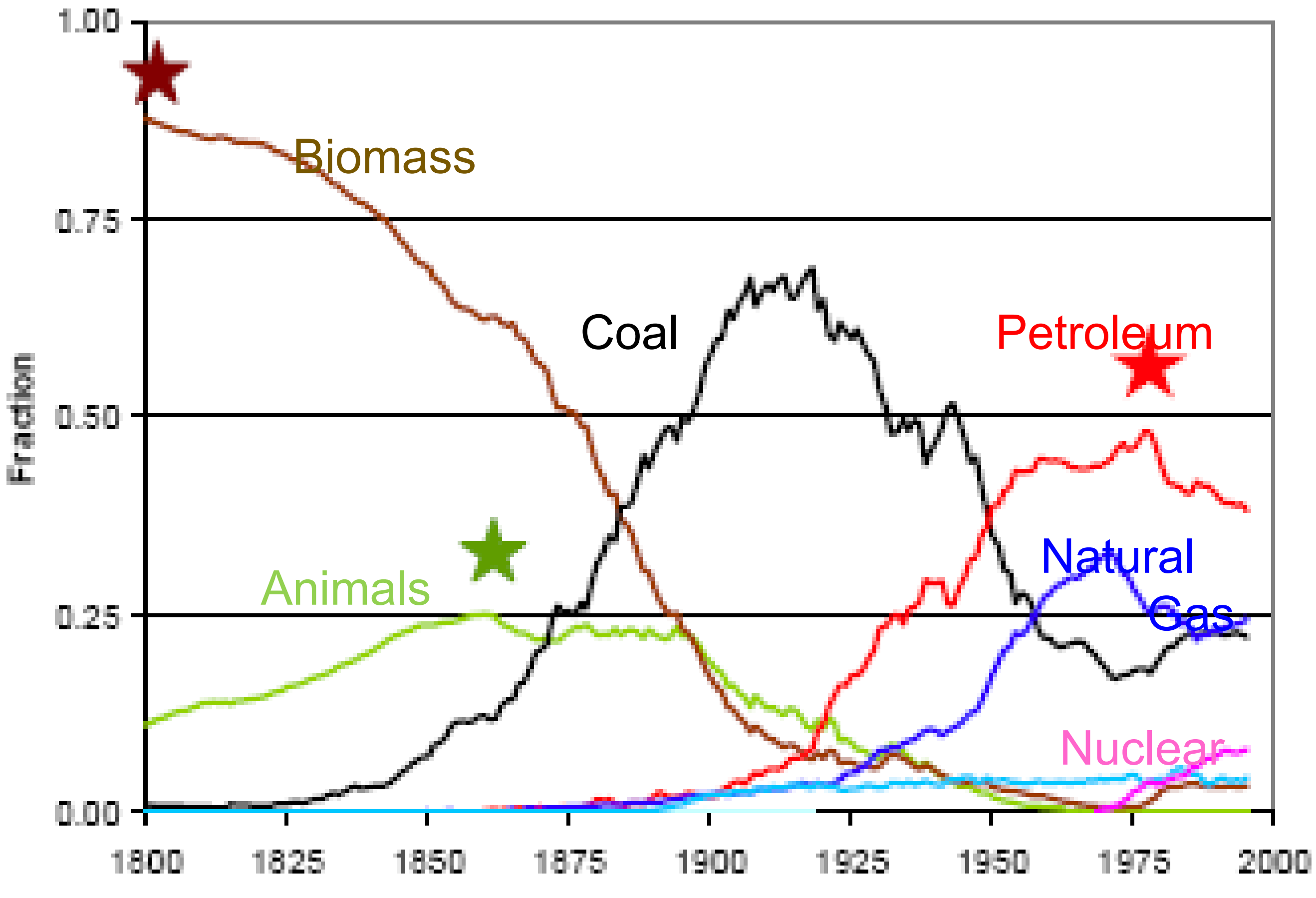


To achieve GHG reductions of 50% to 80% by 2050, electric vehicles will require a decarbonized utility sector and fuel cell vehicles will require low GHG hydrogen. The transition will take decades (2 or 3) and poses an unprecedented challenge for public policy.



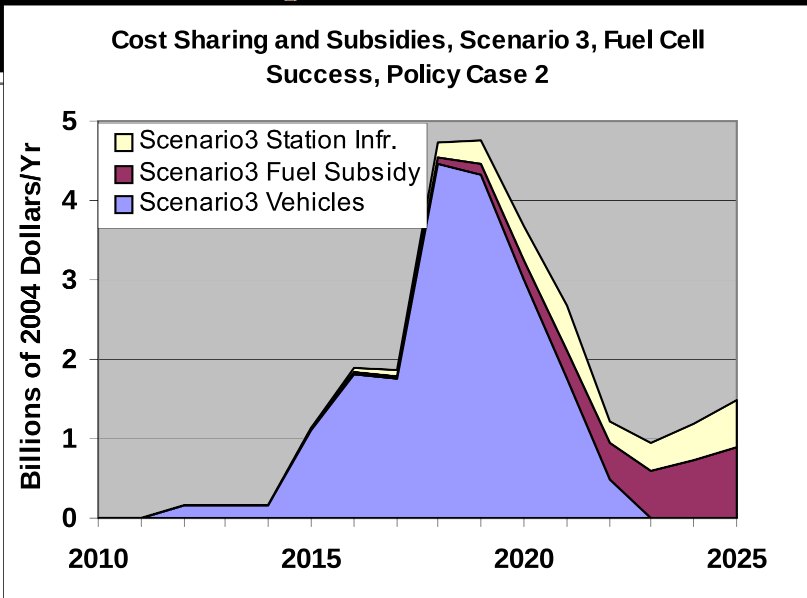
Source: NRC, 2008. *Transitions to Alternative Energy Technologies: A Focus on Hydrogen.*

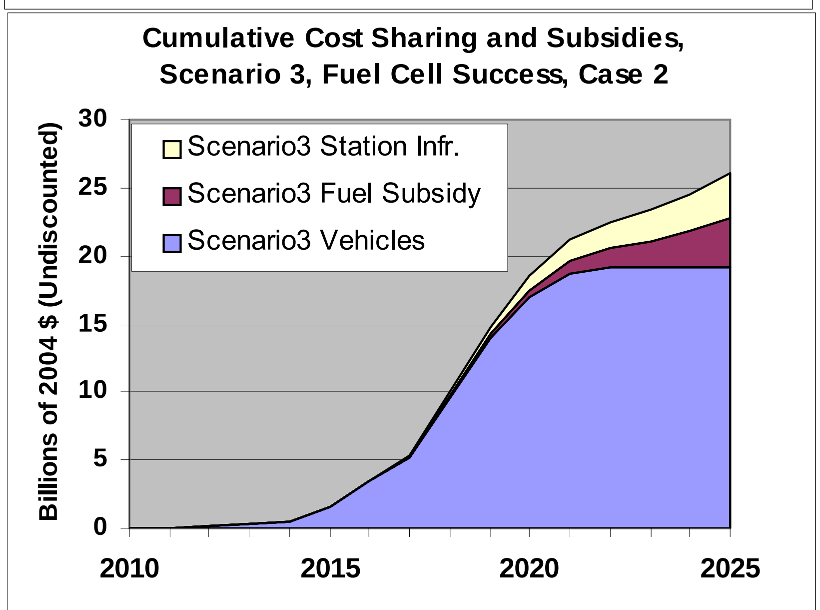
The major energy transformations of the past have been driven by technology and the market. Can a future transition be driven by climate protection, energy security and sustainability?



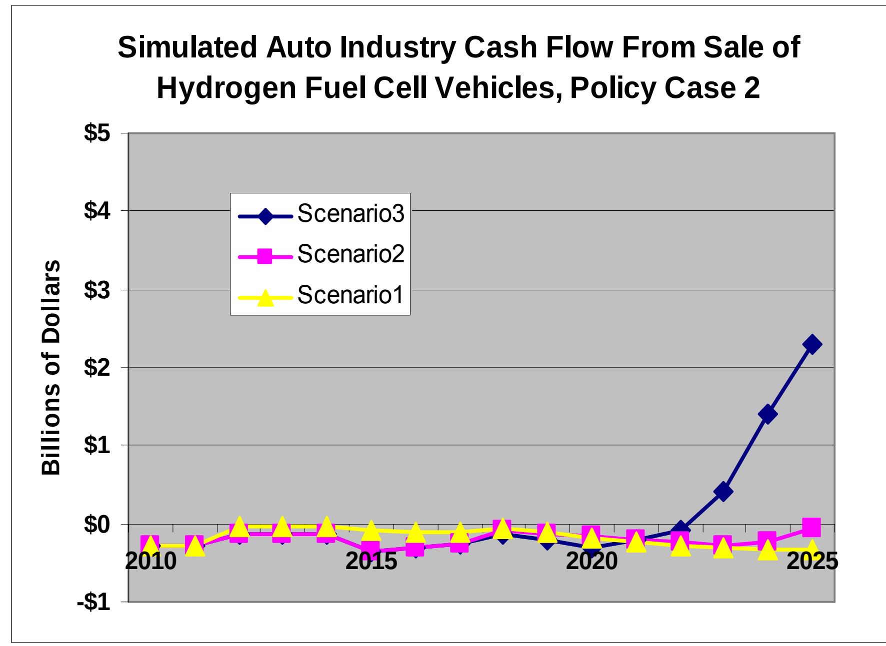
Source: A. Grubler, 2007, International Institute for Applied Systems Analysis.

It appears that the transition costs may not be large from a societal perspective. DOE's hydrogen study estimated $25-40B. NRC estimated $55B. *Both assumed technological success.*





These are not total costs. NAS estimated H2 infrastructure cost alone at $400B.



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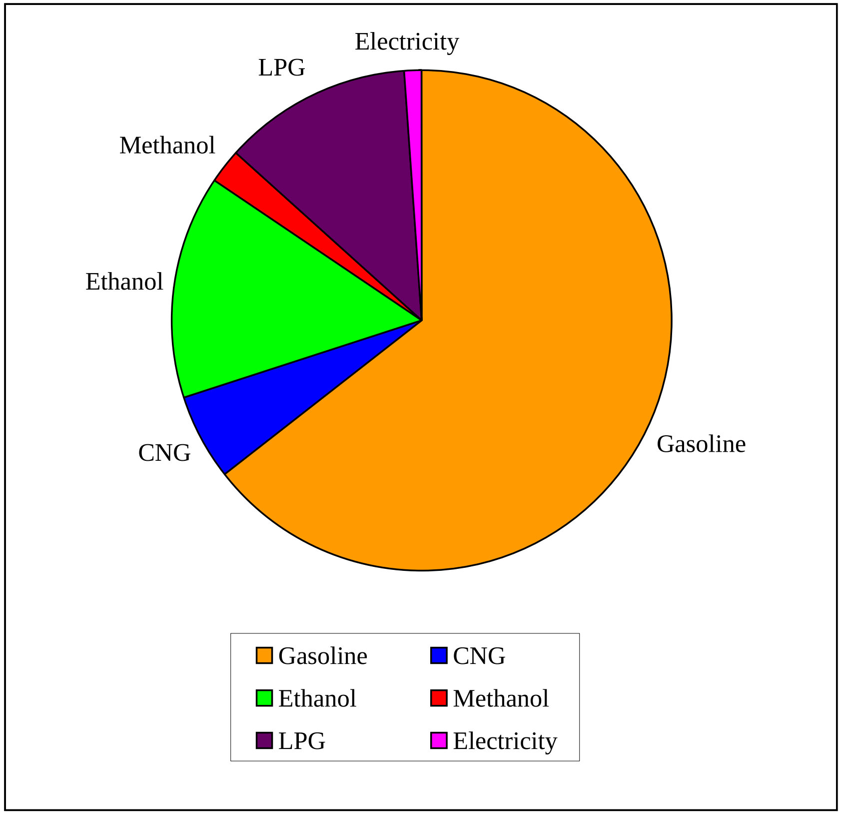
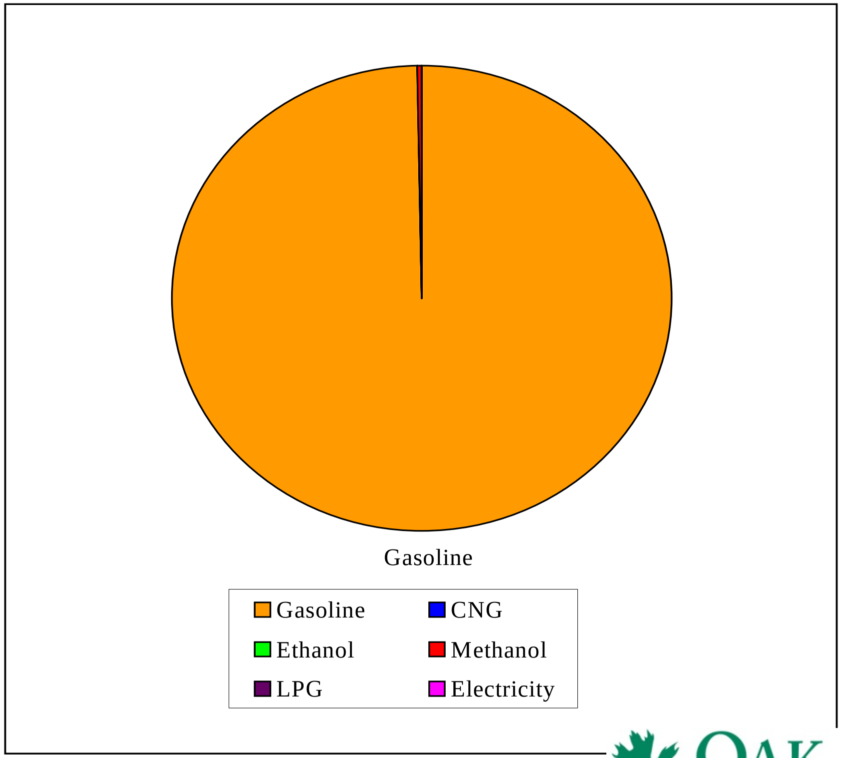
Natural market barriers can and do prevent transitions to alternative energy sources.

NO TRANSITION BARRIERS
AFTM 1997



TRANSITION BARRIERS
TAFV 2001



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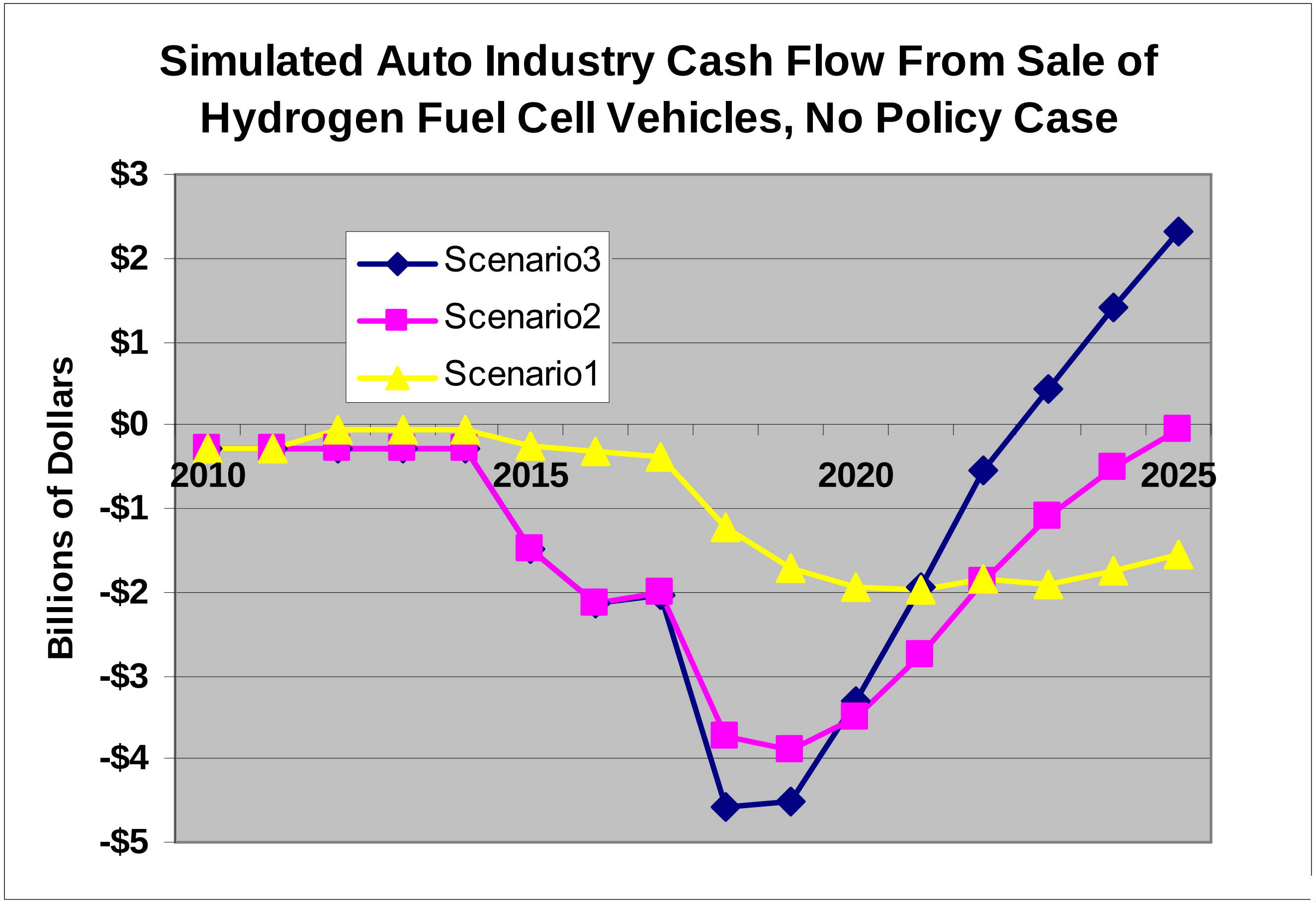
What about the private costs?: The transition's extended period of negative cash flow makes the transition's private NPV unattractive. (Pecuniary externality leads to deadweight social loss.)



Source: Greene et al., 2008. Analysis of the Transition to Hydrogen Fuel Cell Vehicles & the Potential Hydrogen Energy Infrastructure Requirements, ORNL/TM-2008/30.

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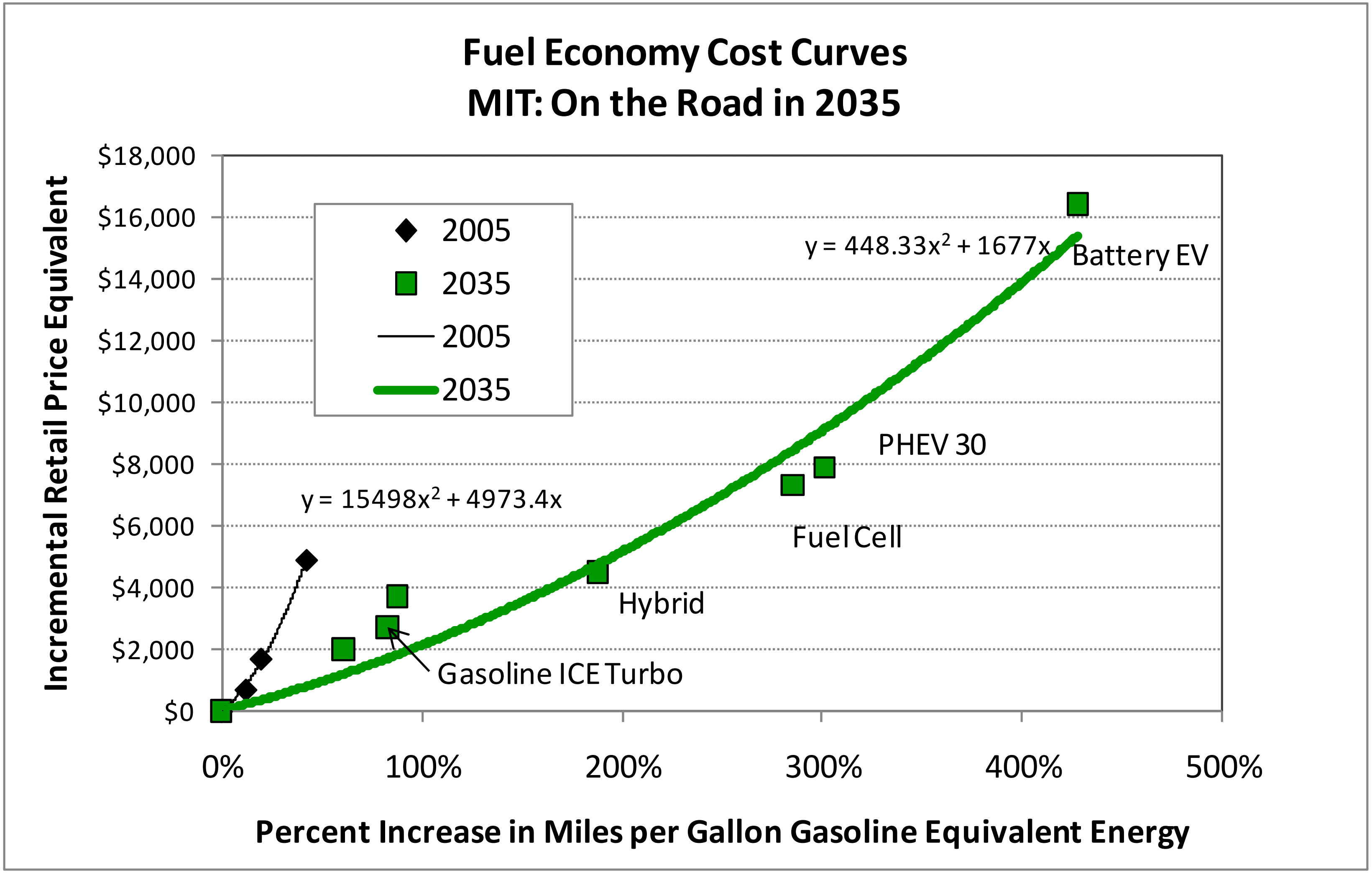
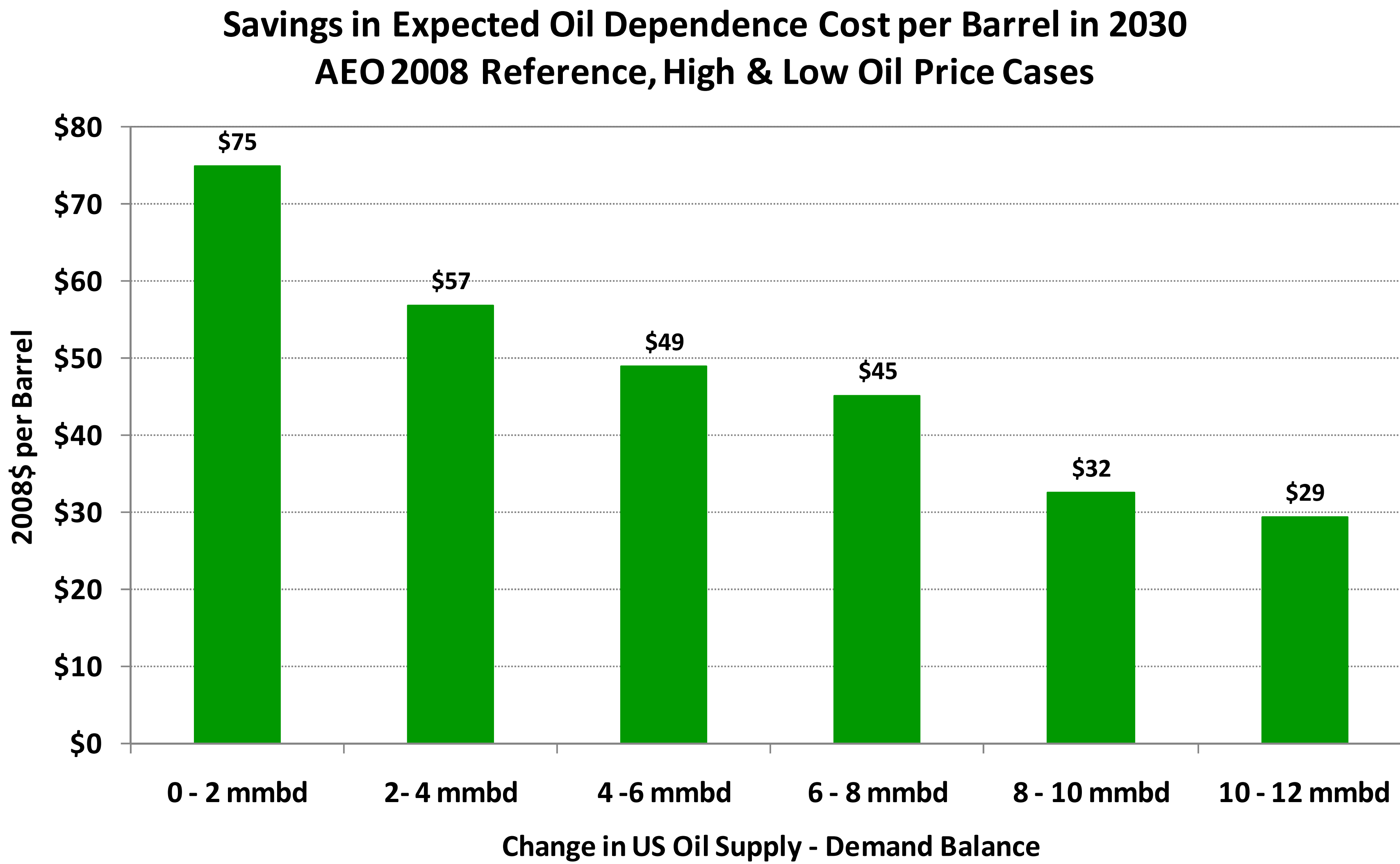
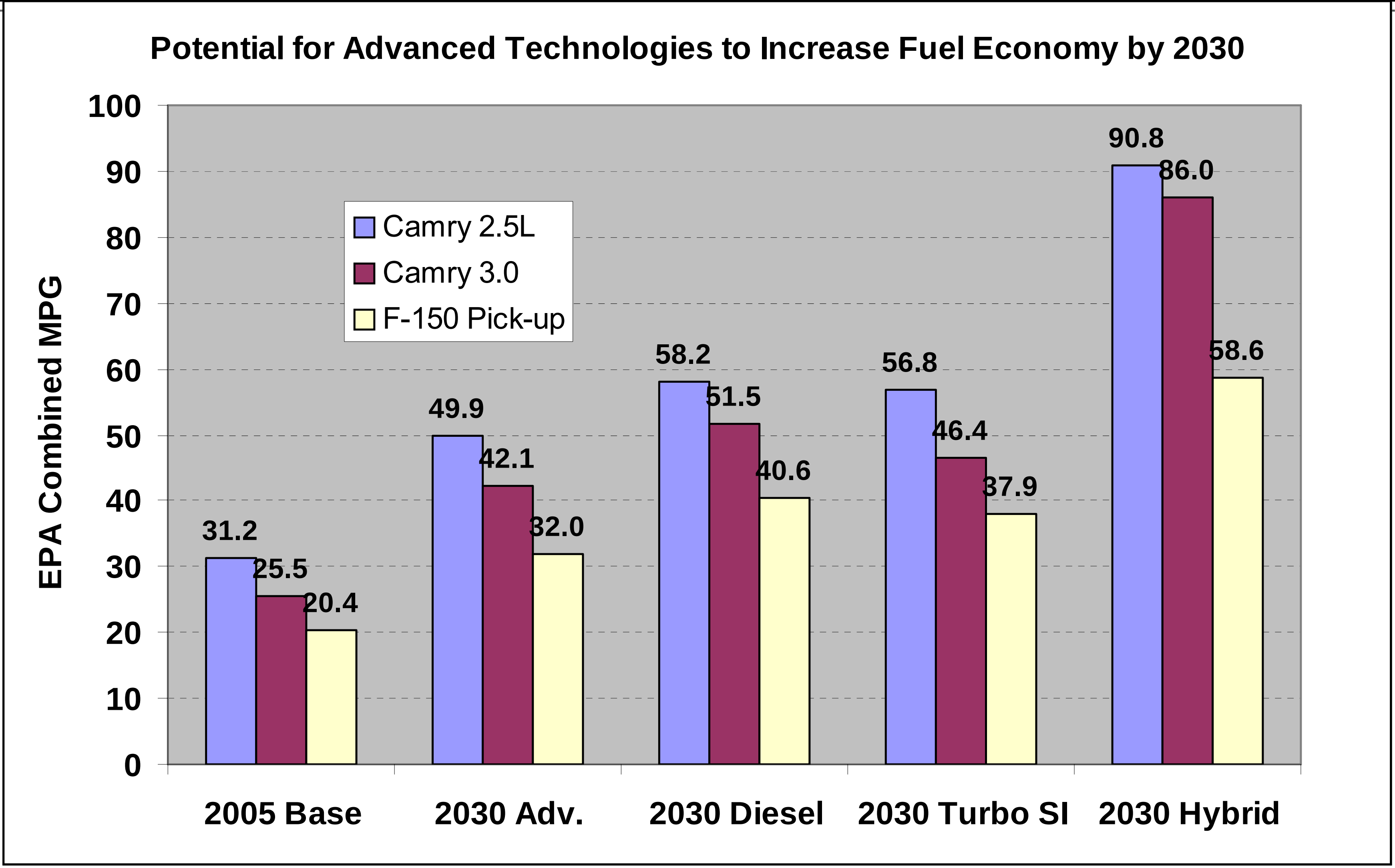
Where can we go from 2016?



What would it be worth in reduced oil dependence costs if we decreased consumption or increased domestic supply by 2,4,6,….12 million barrels per day (change in $Q_S - Q_D$)?



A 2007 MIT study predicts MPG gains of 80-85% for model year 2030 vehicles via continuous improvement of conventional technology at a rate of 2-2.5%/year.



Source: Kasseris & Heywood, SAE Technical Paper 2007-01-1605, April, 2007.

What are the "natural market barriers"?

- Need for technological advances
- Learning by doing
- Scale economies
- Resistance to novel technologies (early adopter, early majority, late majority, laggards)
- Lack of diversity of choice
- Chicken or egg?
  - Lack of fuel availability
  - Lack of vehicles to use new fuel

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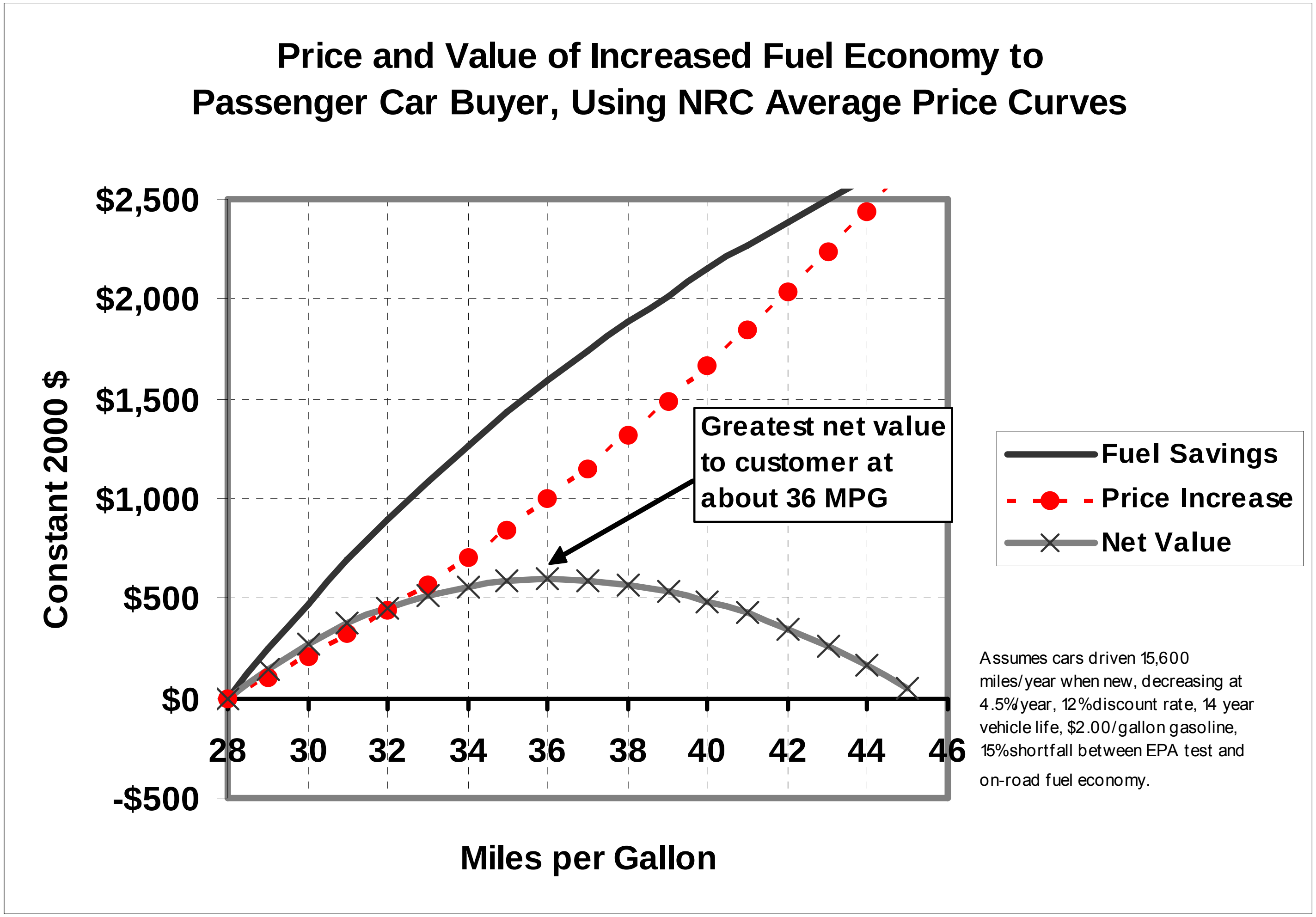
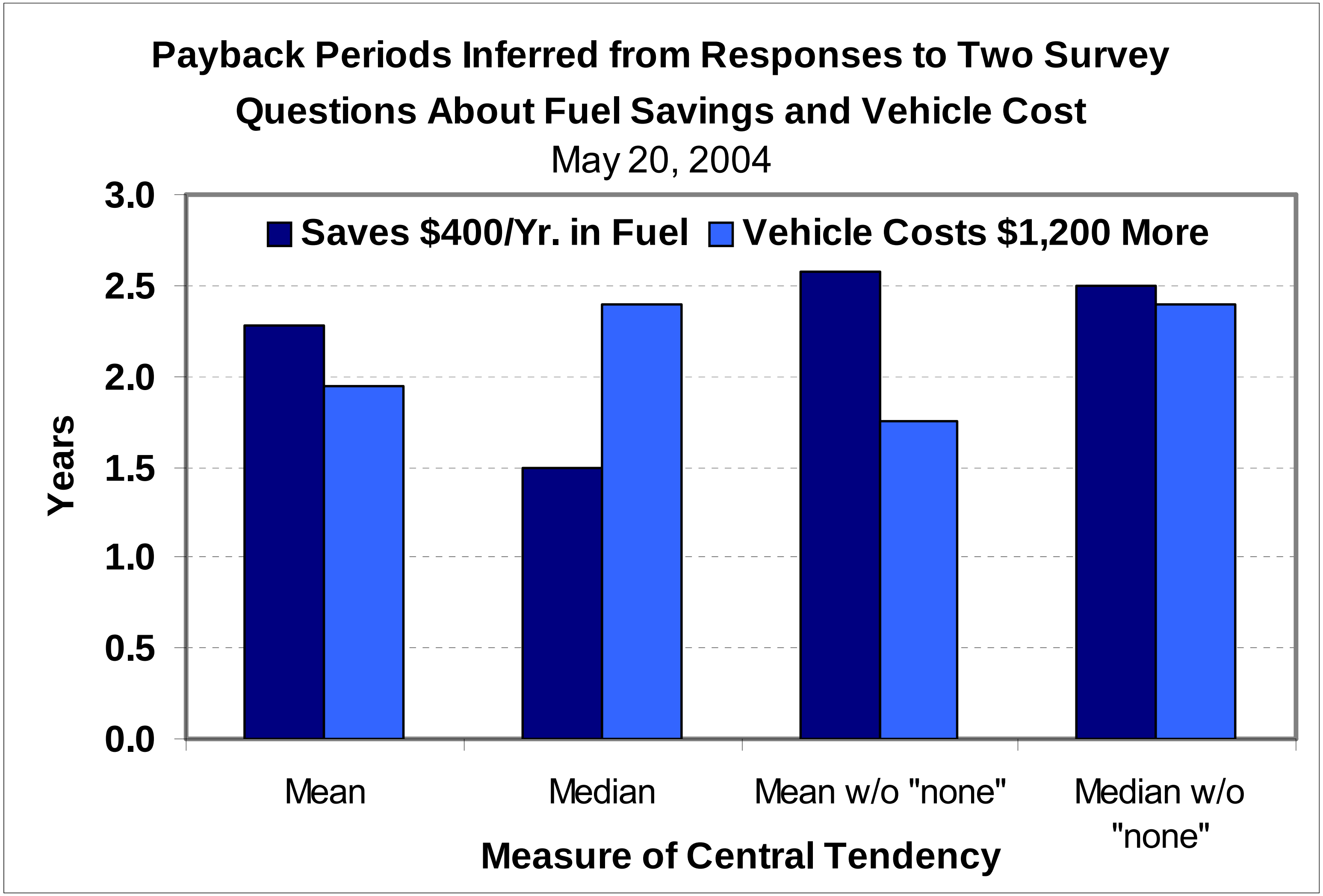
Consider the structure of the economic determination of fuel economy.

- **Consumer chooses among available range of vehicles.**
  - Fuel economy decreases with vehicle size, performance, accessories.
  - Fuel economy = cheap, small, weak.
- **Manufacturer (as consumers' agent) determines design and technological content.**
  - Fuel economy increases with more expensive, advanced technology.
  - Fuel economy = higher first cost, lower operating costs.
  - ALL fuel economy improvement in the U.S. over the past 30 years attributable to this process.

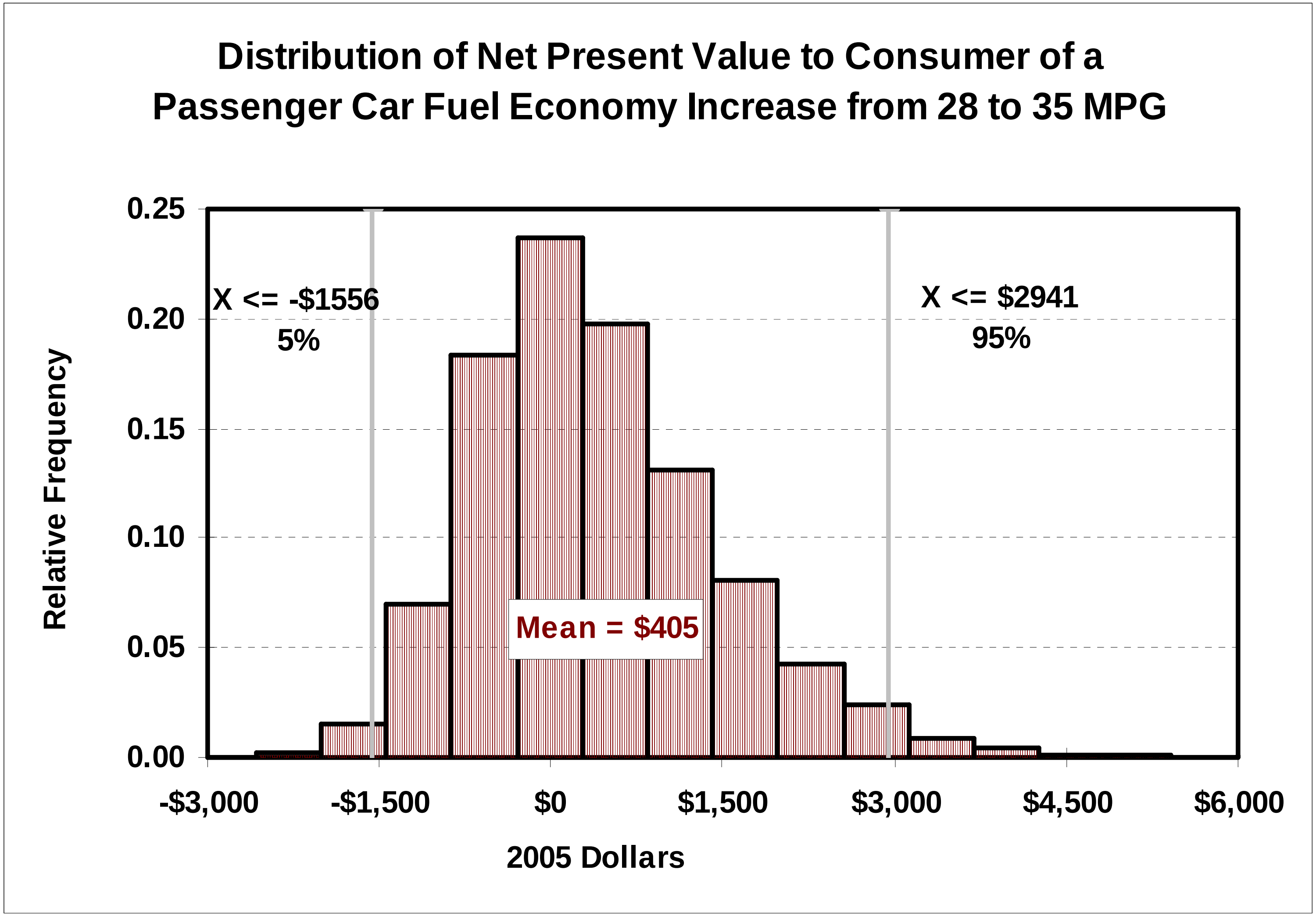
Absent uncertainty, the net present value of improved fuel economy is the difference between the present value of future fuel savings and the price increase. (US NAS, 2002)



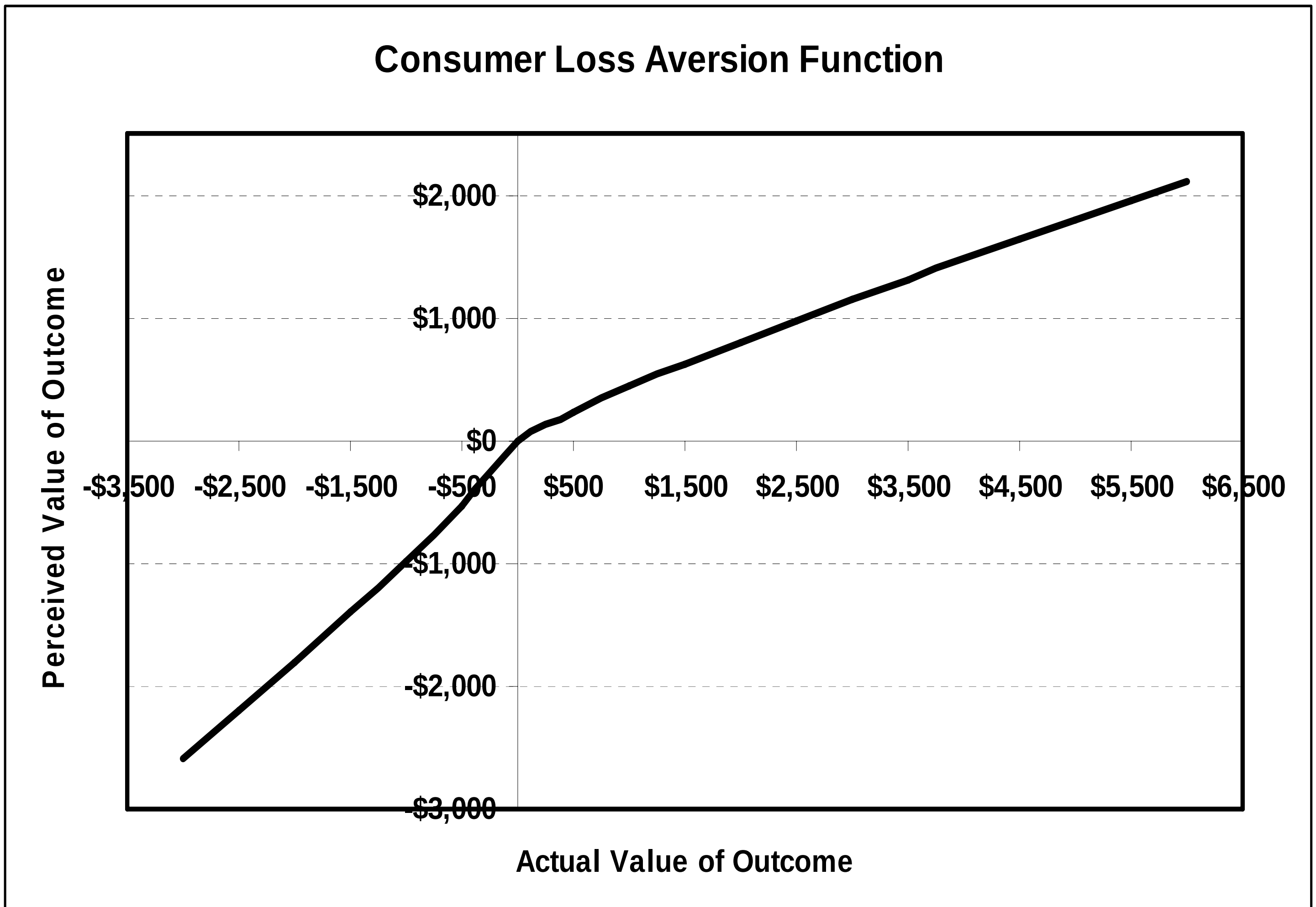
Asked about fuel economy payback, consumers responded with short payback periods, just as carmakers expected. But few actually make financial calculations as Turrentine & Kurani (*Energy Policy 2007*) demonstrated.



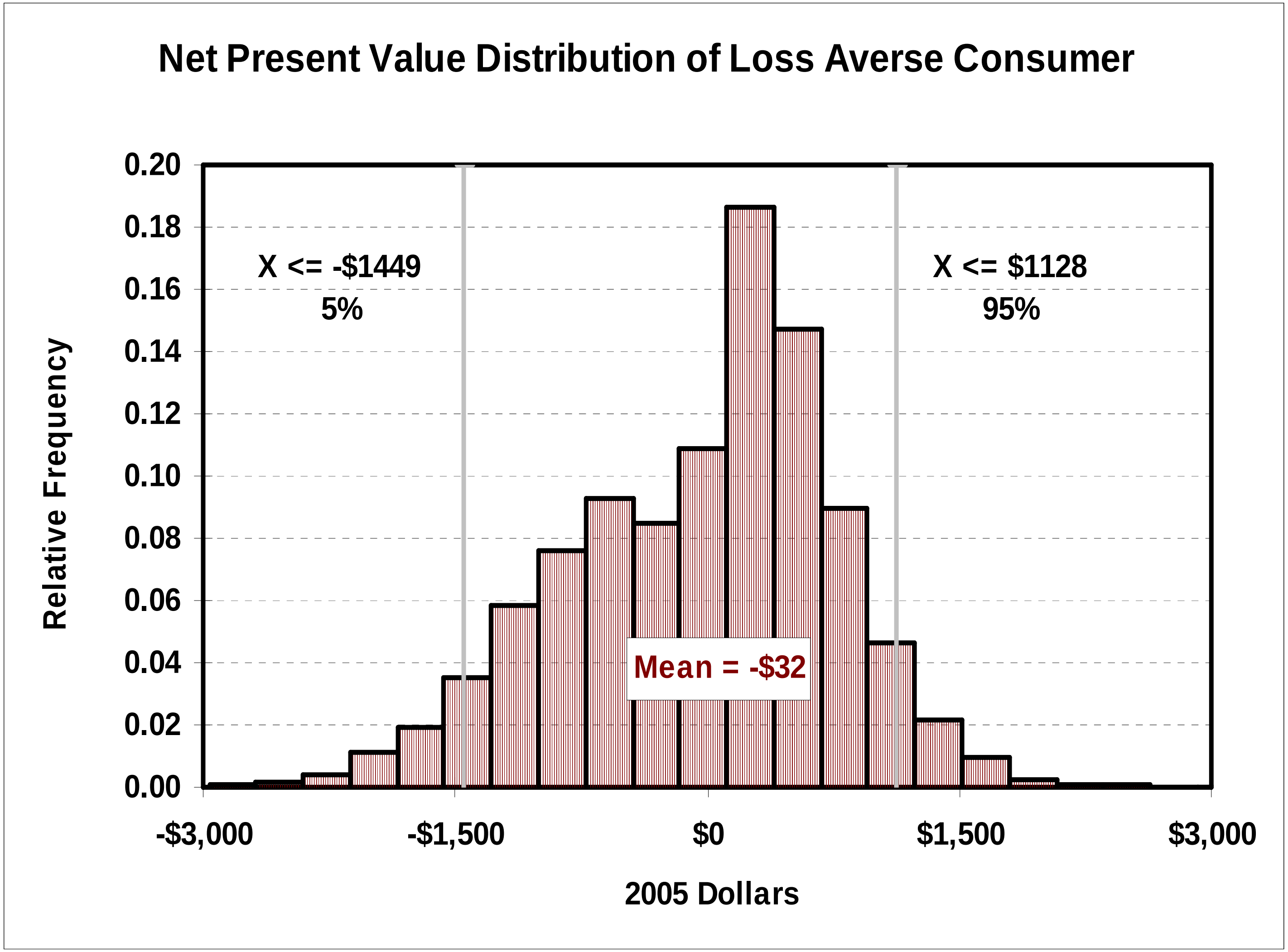
Quantifying uncertainties about fuel prices, realized fuel economy, vehicle use and vehicle life produces a probability distribution of Net Present Value.



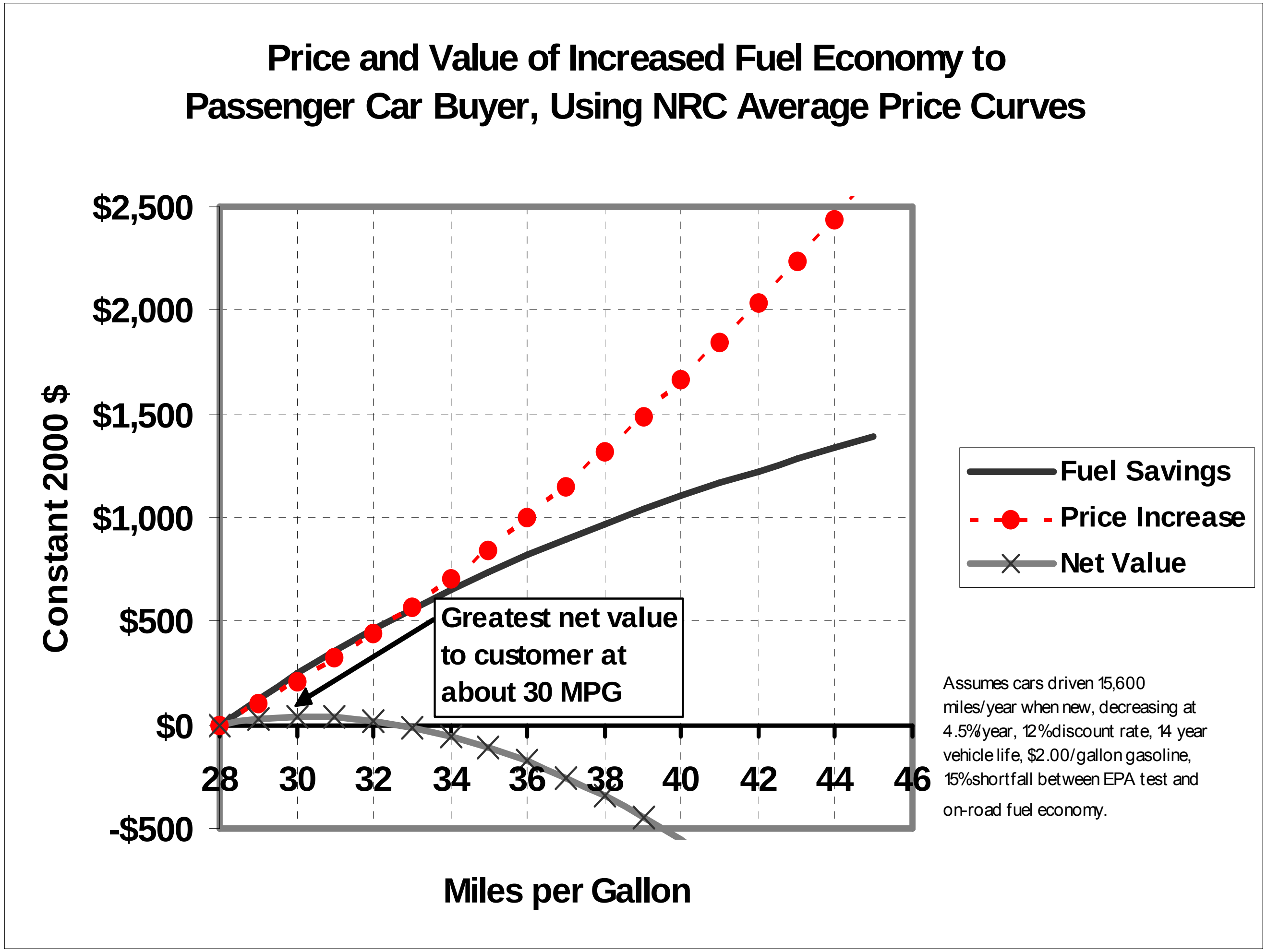
According to prospect theory, typical consumers magnify potential losses relative to gains and exaggerate the probability of loss (Tversky & Kahnemann, 1992).
"A bird in the hand is worth two in the bush."



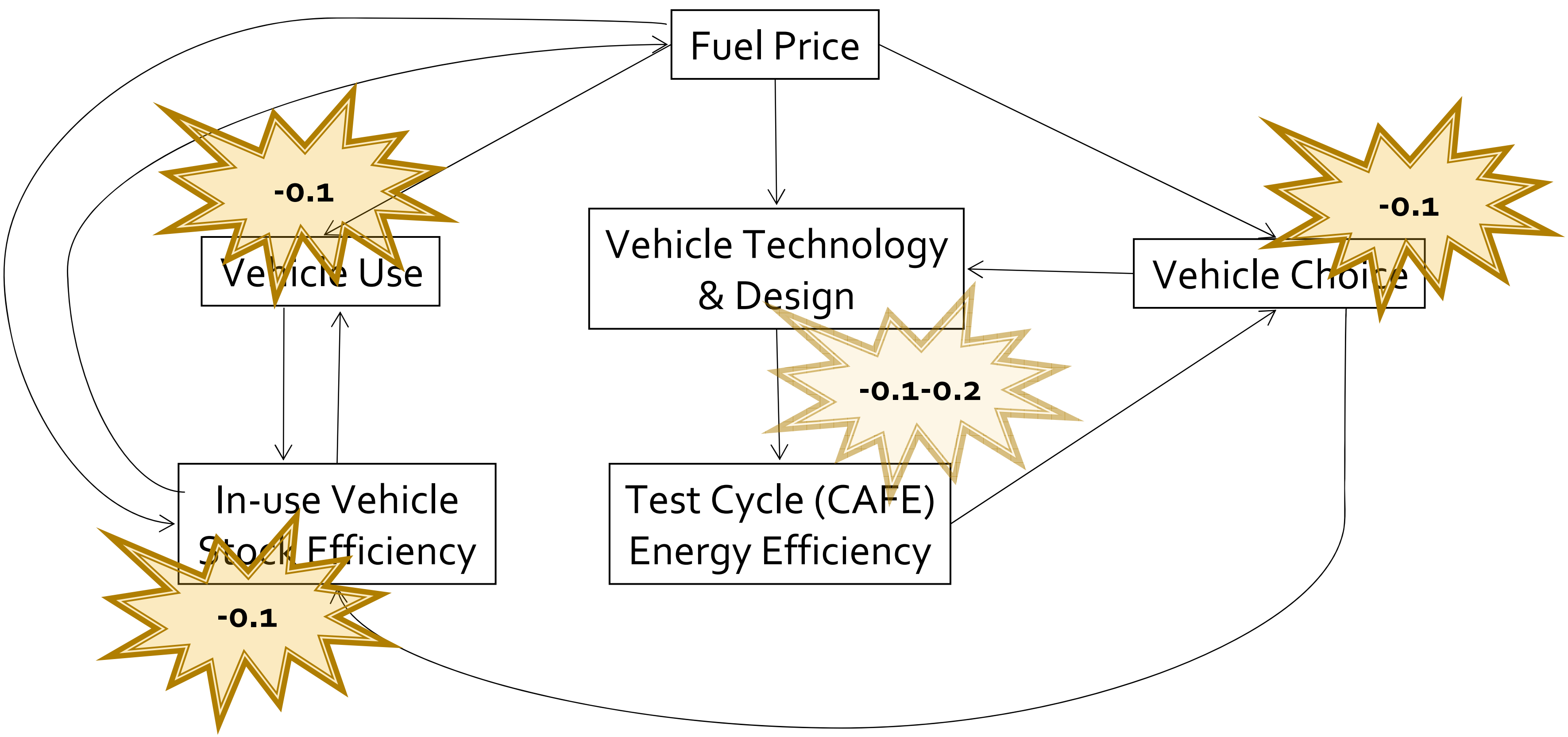
Integrating the loss aversion function with the probability distribution of NPV causes the benefit to disappear. There's no "there", there.



Uncertainty/loss aversion bias is also consistent with manufacturers' belief that consumers will pay for only 2-4 years of future fuel savings.



Even with fuel economy or emissions standards, the energy tax should reduce GHG emissions three times as much as a VMT tax.



In 2005 the heads of 11 National Academies endorsed the IPCC's statements on global climate change.

- "Climate change is real"

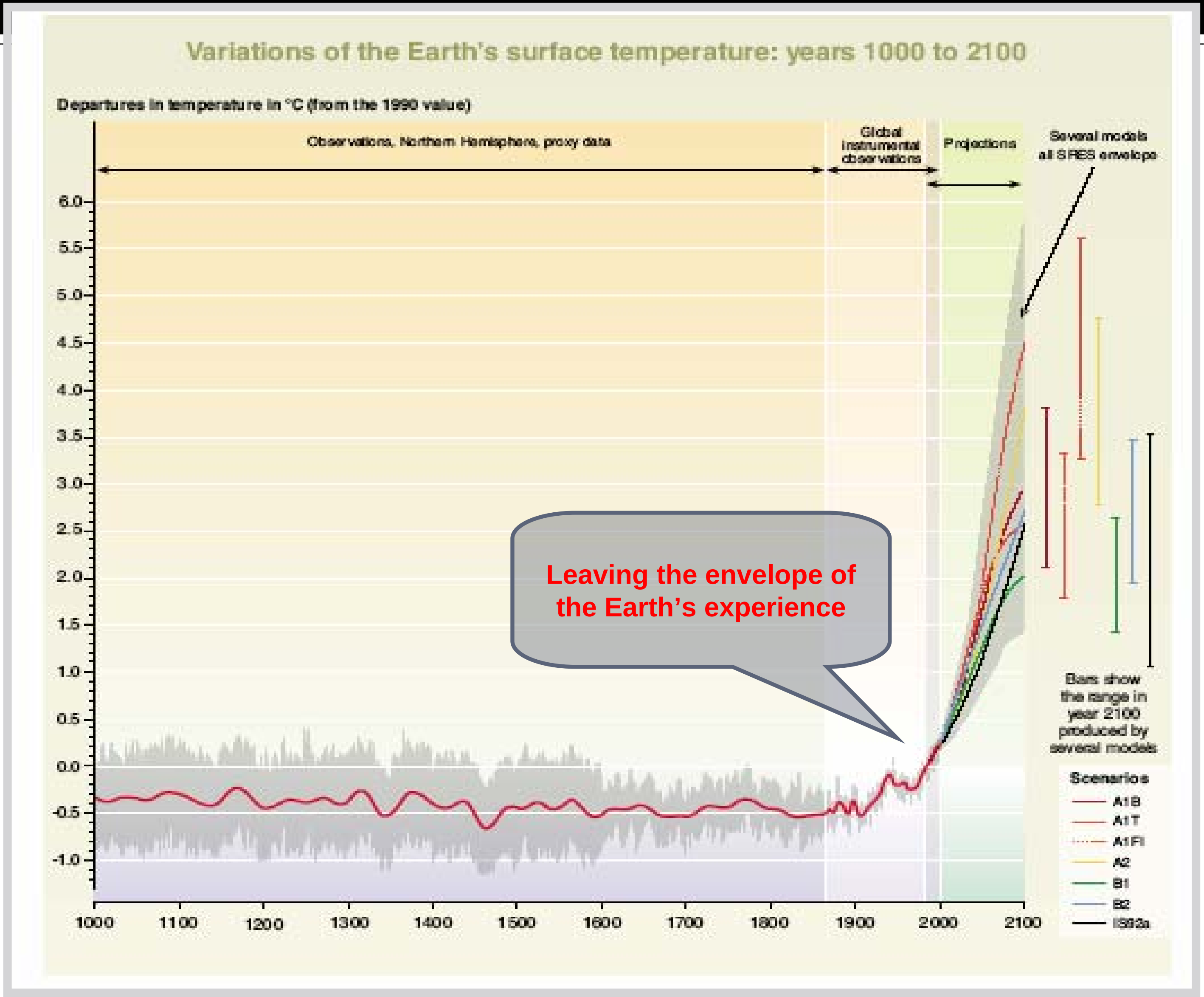
"There will always be uncertainty in understanding a system as complex as the world's climate. However there is now strong evidence that significant global warming is occurring. The evidence comes from direct measurements of rising surface air temperatures and subsurface ocean temperatures and from phenomena such as increases in average global sea levels, retreating glaciers, and changes to many physical and biological systems. It is likely that most of the warming in recent decades can be attributed to human activities (IPCC 2001). This warming has already led to changes in the Earth's climate."

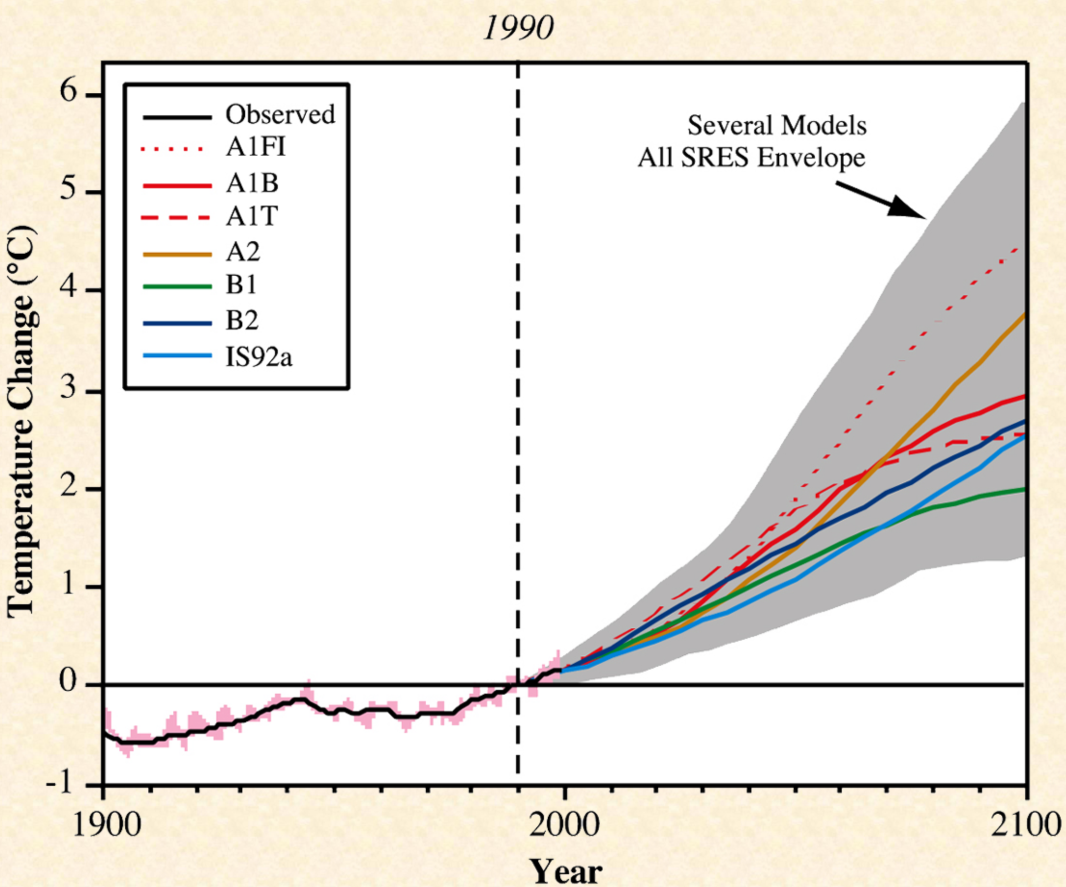
Joint statement of the National Academies of Sciences of Brazil, Canada, China, France, Germany, India, Italy, Japan, Russia, United Kingdom and United States of America (a.k.a. G8+5), 2005.

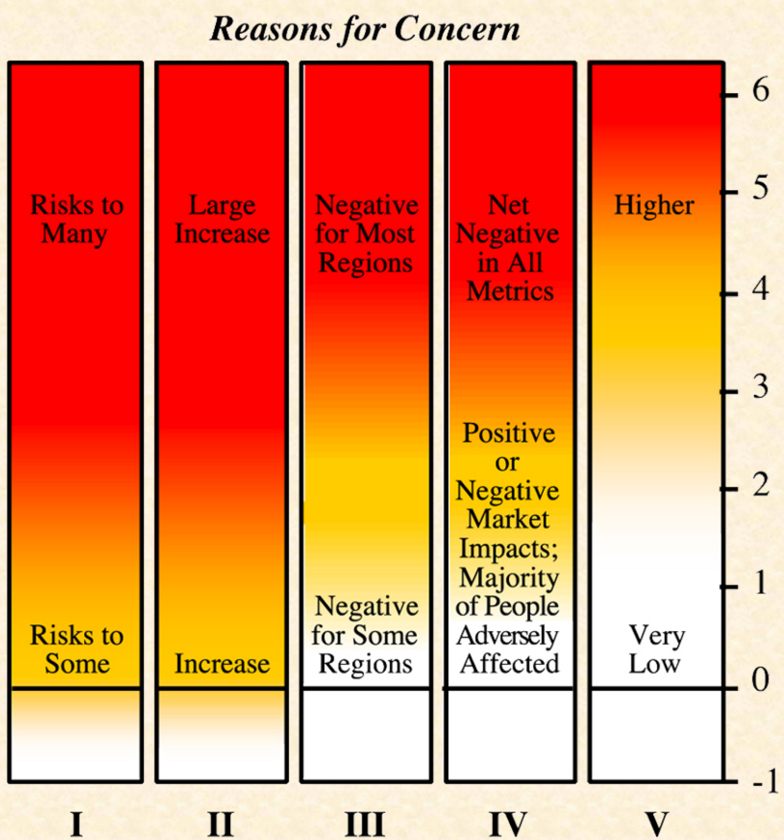
The American Association for the Advancement of Science has spoken unequivocally on the subject.

- “The scientific evidence is clear: global climate change caused by human activities is occurring now, and it is a growing threat to society. Accumulating data from across the globe reveal a wide array of effects: rapidly melting glaciers, destabilization of major ice sheets, increases in extreme weather, rising sea level, shifts in species ranges, and more. The pace of change and the evidence of harm have increased markedly over the last five years. The time to control greenhouse gas emissions is now.”
- Board of Directors, American Association for the Advancement of Science, December 9, 2006.

Unless our climate models are very wrong, we are about to boldly go where no human has gone before.



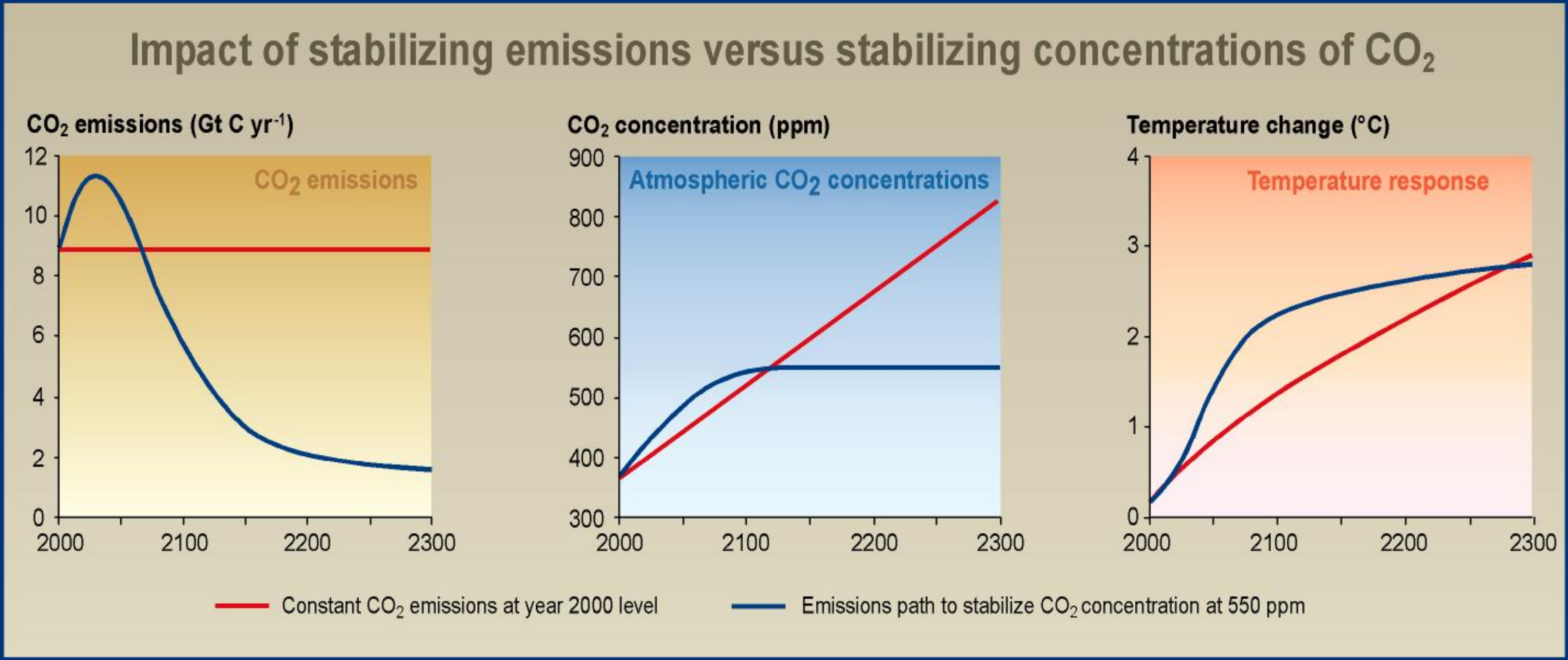




I	Risks to Unique and Threatened Systems
II	Risks from Extreme Climate Events
III	Distribution of Impacts
IV	Aggregate Impacts
V	Risks from Future Large-Scale Discontinuities

Most likely, we won't like it there. Can we avoid dangerous climate change?

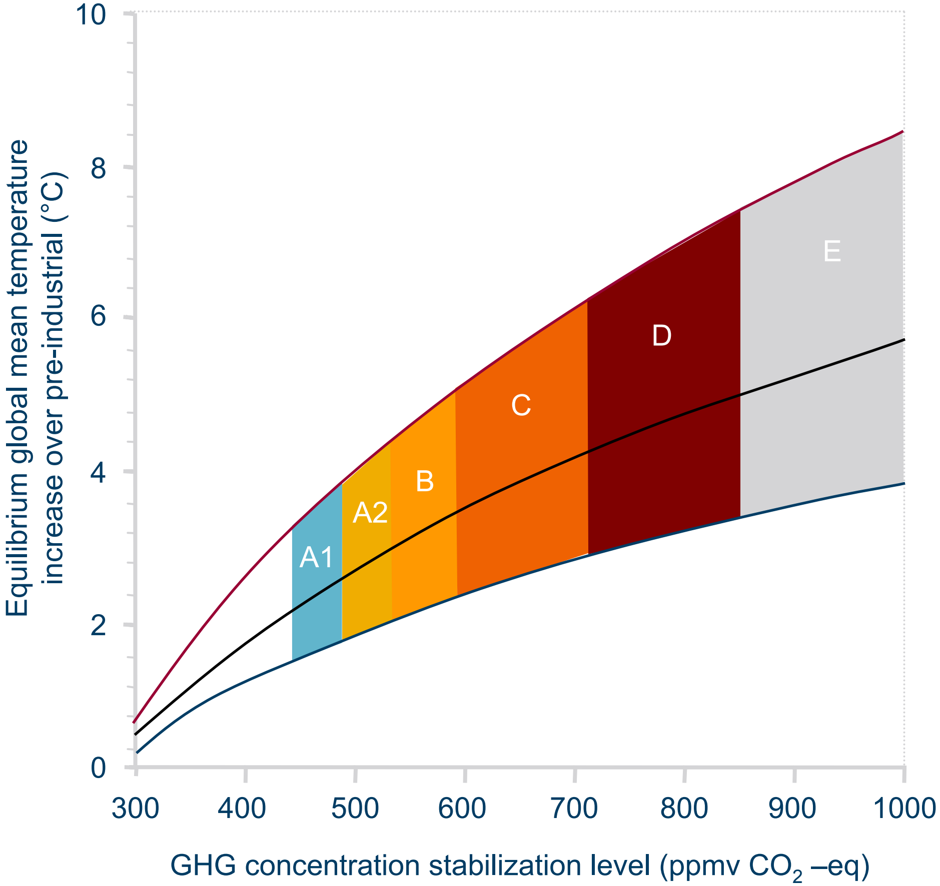
Stabilizing emissions rates won't stabilize greenhouse gas concentrations and stabilizing atmospheric concentrations won't stabilize temperatures right away.



SYR - FIGURE 5-2

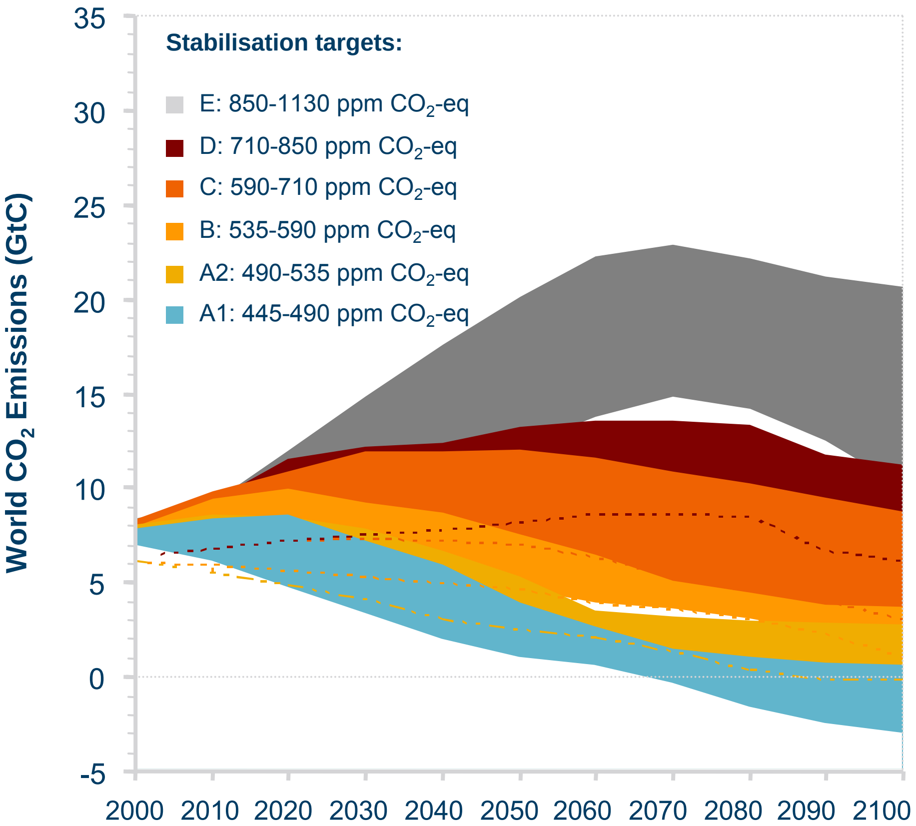
Stabilising global mean temperature requires a stabilisation of greenhouse gas concentrations in the atmosphere.

The lower the aspired temperature increase, the lower the concentration stabilisation level



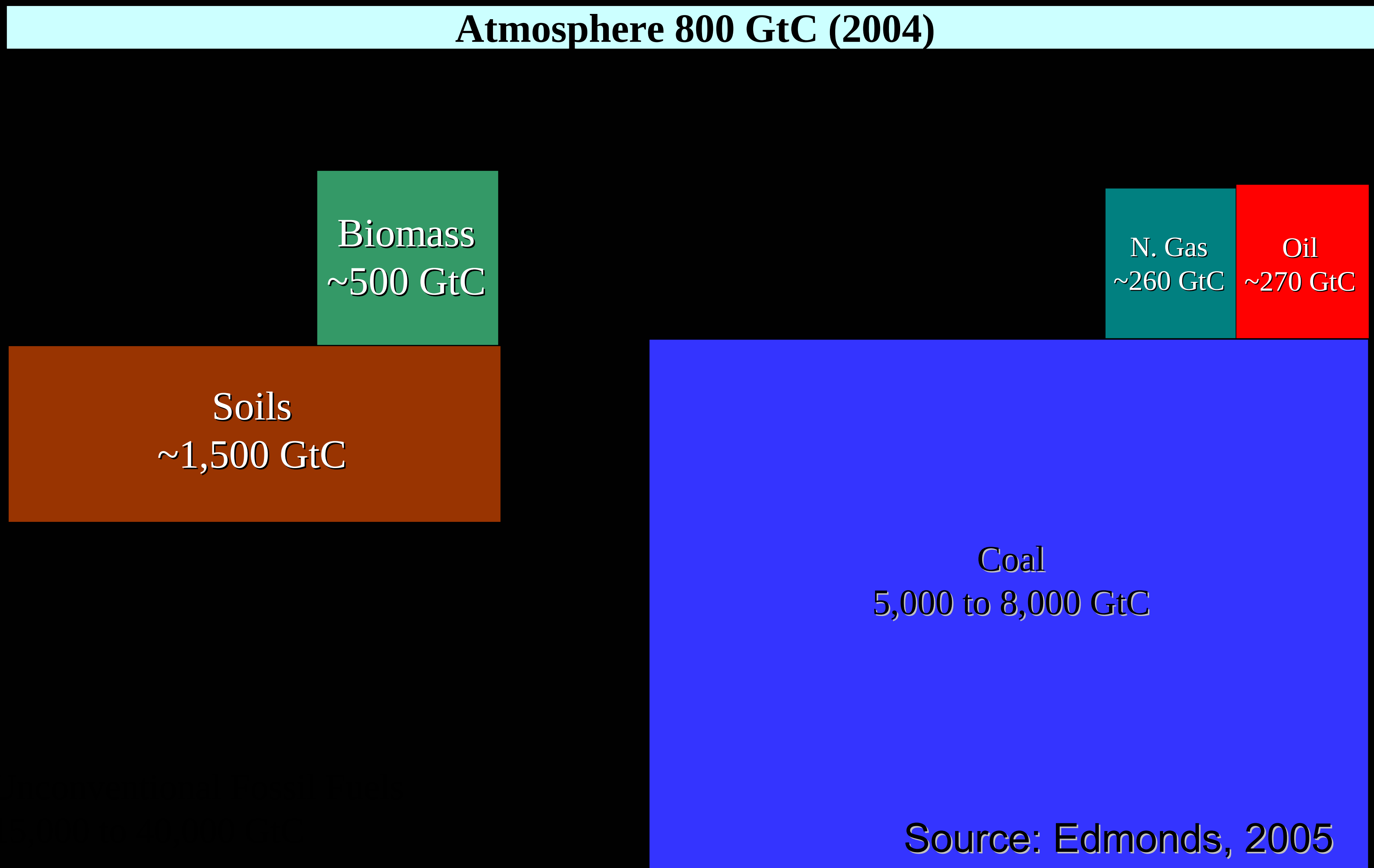
The lower the stabilisation level, the earlier global CO_2 emissions have to peak.

- The lower the target stabilisation level limit, the earlier global emissions have to peak.
- Limiting increase to 3.2 – 4°C requires emissions to peak within the next 55 years.
- Limiting increase to 2.8 – 3.2°C requires global emissions to peak within 25 years.
- Limiting global mean temperature increases to 2 – 2.4°C above pre-industrial levels requires global emissions to peak within 15 years and then fall to about 50 to 85% of current levels by 2050.

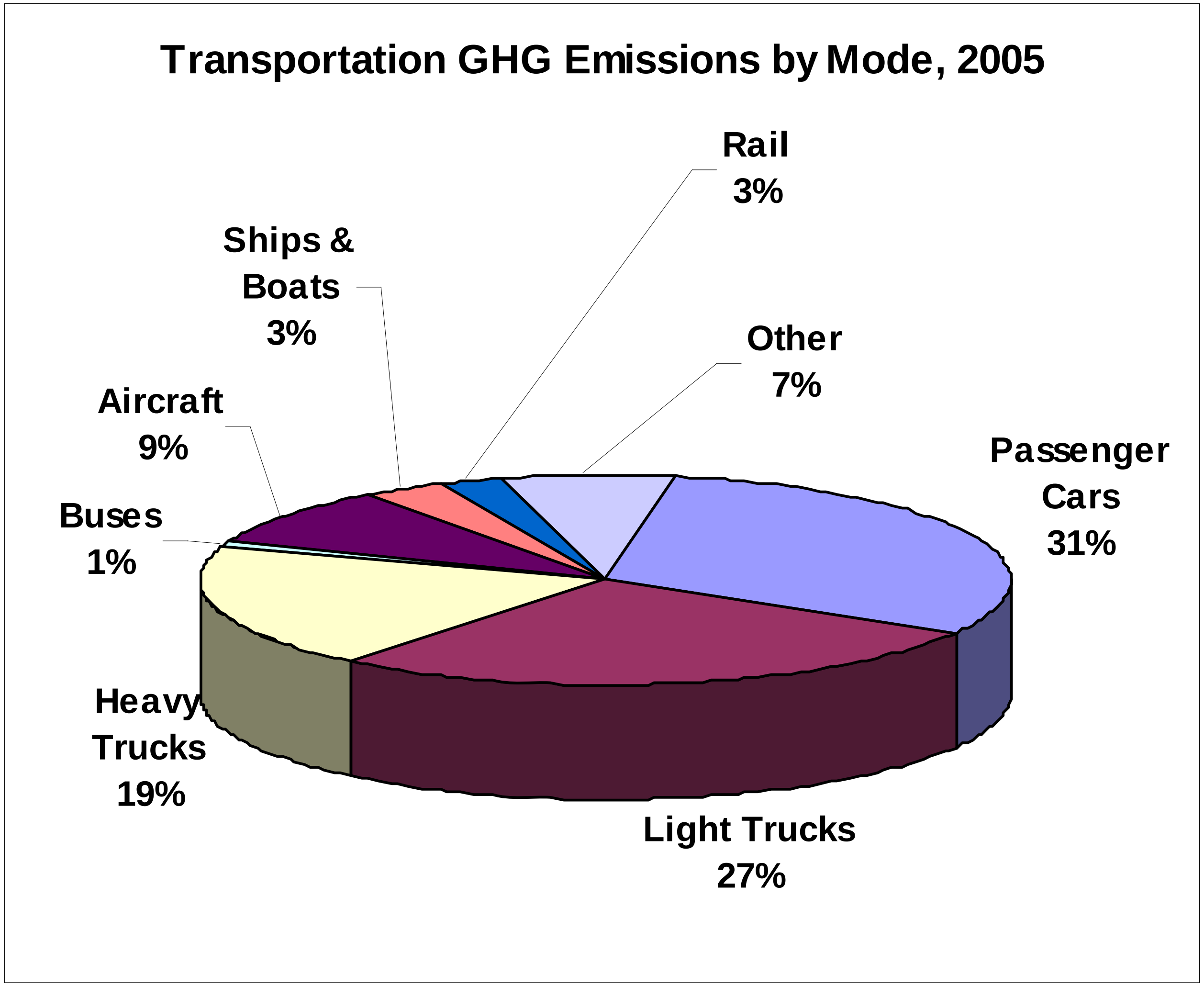


Multigas and CO_2 only studies combined

Carbon Reservoirs



Highway vehicles, especially passenger cars and light trucks, account for most (78%) transportation C emissions.



Source: USEPA, 2007, U.S. GHG Inventory, table 2-17.