Transportation and Energy: National and Global Challenges

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Transportation is work.

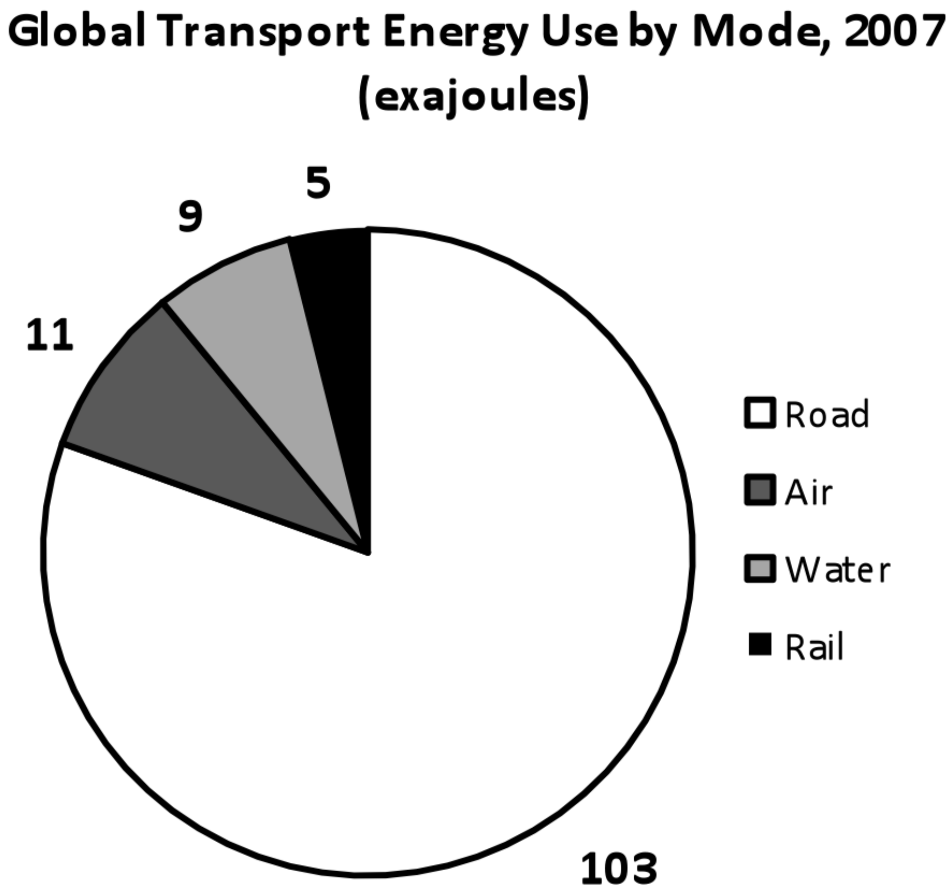
Work = Force·Distance = Joule = Energy

Activity·Share·Intensity·Fuel-efficiency = ASIF
(Lee Schipper)

The U.S. and world transport systems face serious problems that can only be solved with the help of public policy.

- GHG mitigation
- Energy security (Oil Dependence)
- Sustainable Energy
  - Insuring energy resources that permit future generations to achieve a level of well being at least as good as our own.
  - Graedel, T.E. and E. van der Voet, 2010. *Linkages of Sustainability*, “Energy”, chs. 18-22, MIT Press, Cambridge, MA.

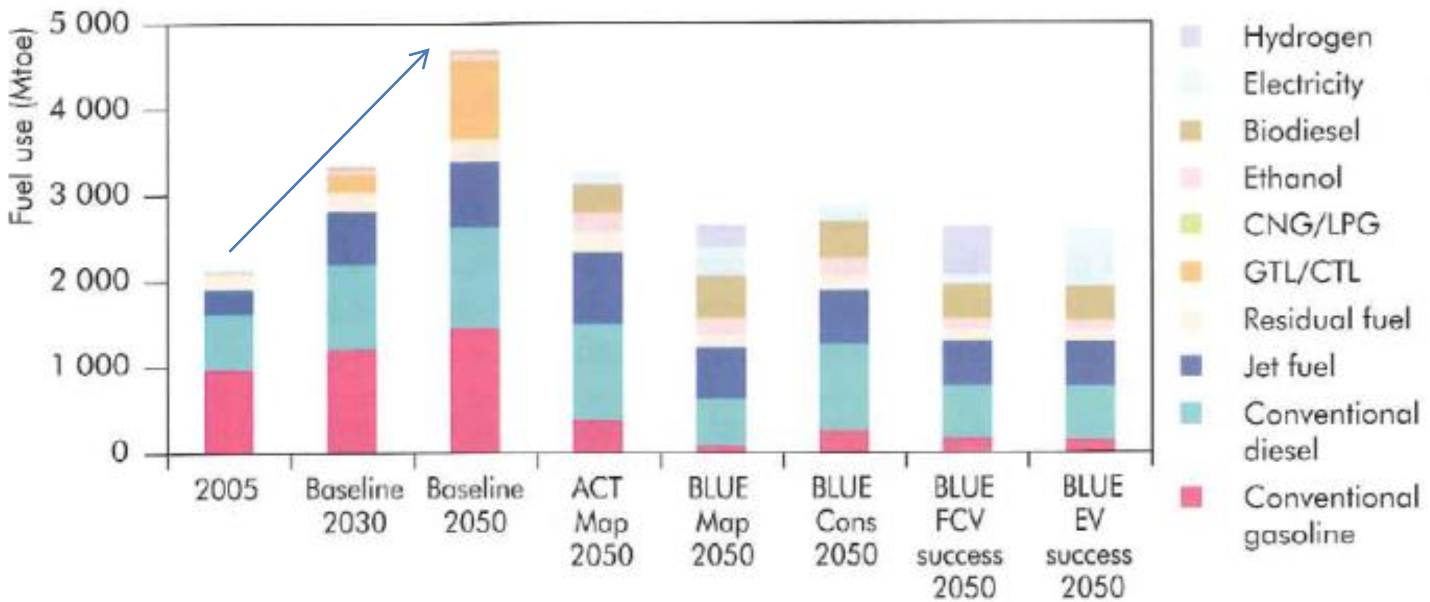
Petroleum provides 95% of the energy for global transport, which accounts for 27% of global final energy use.



IEA, Energy Technology Perspectives 2010.

What few projections there are of transport energy use to 2050 expect a doubling or more.

Figure 2.21 ▶ Transport energy use in the Baseline, ACT Map and BLUE Map scenarios, 2005-2050

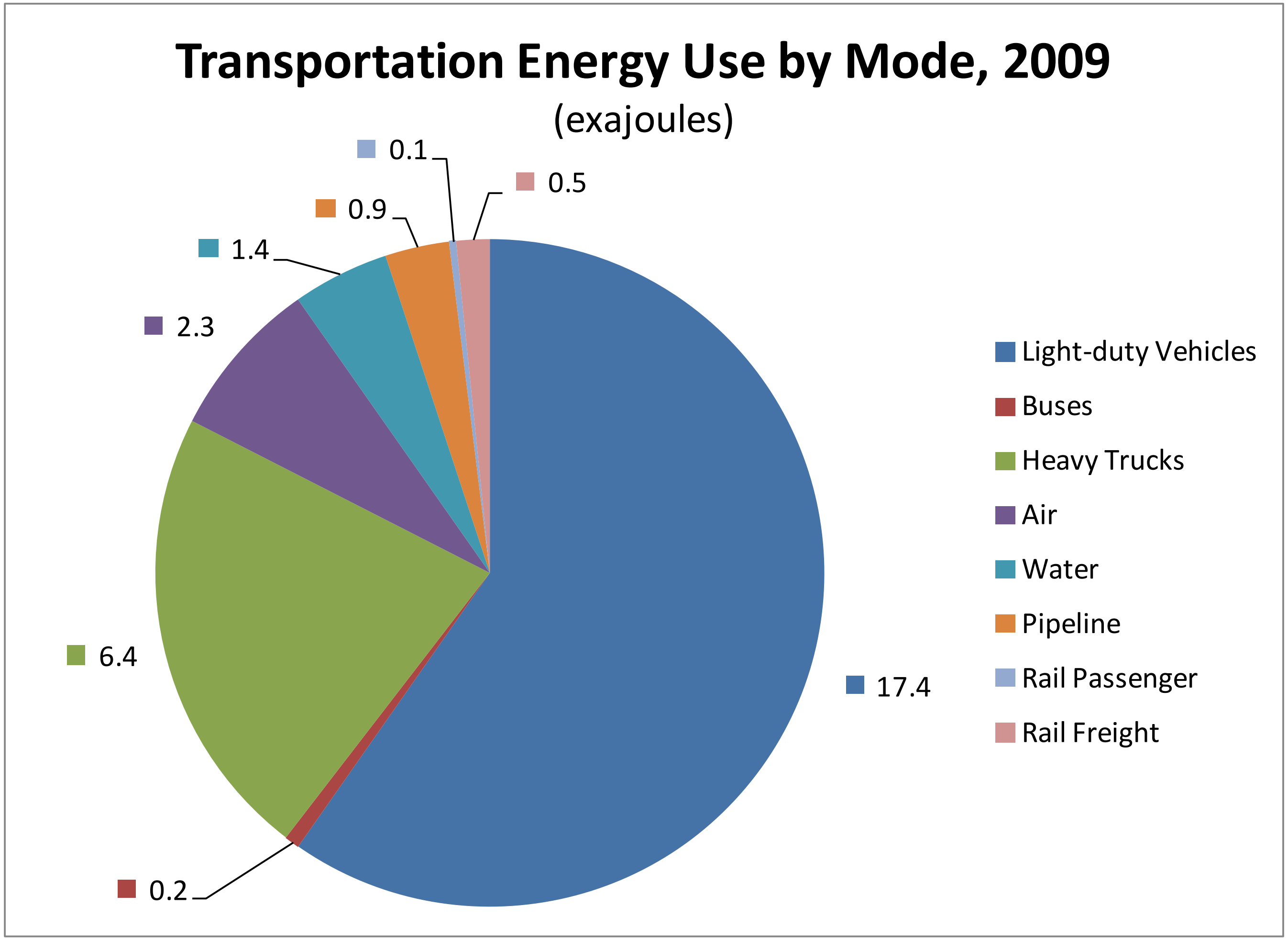


Key point

Demand for oil products in 2050 is 37% above the 2005 level in the ACT Map scenario, and 5% above to 38% below the 2005 level in the BLUE cases.

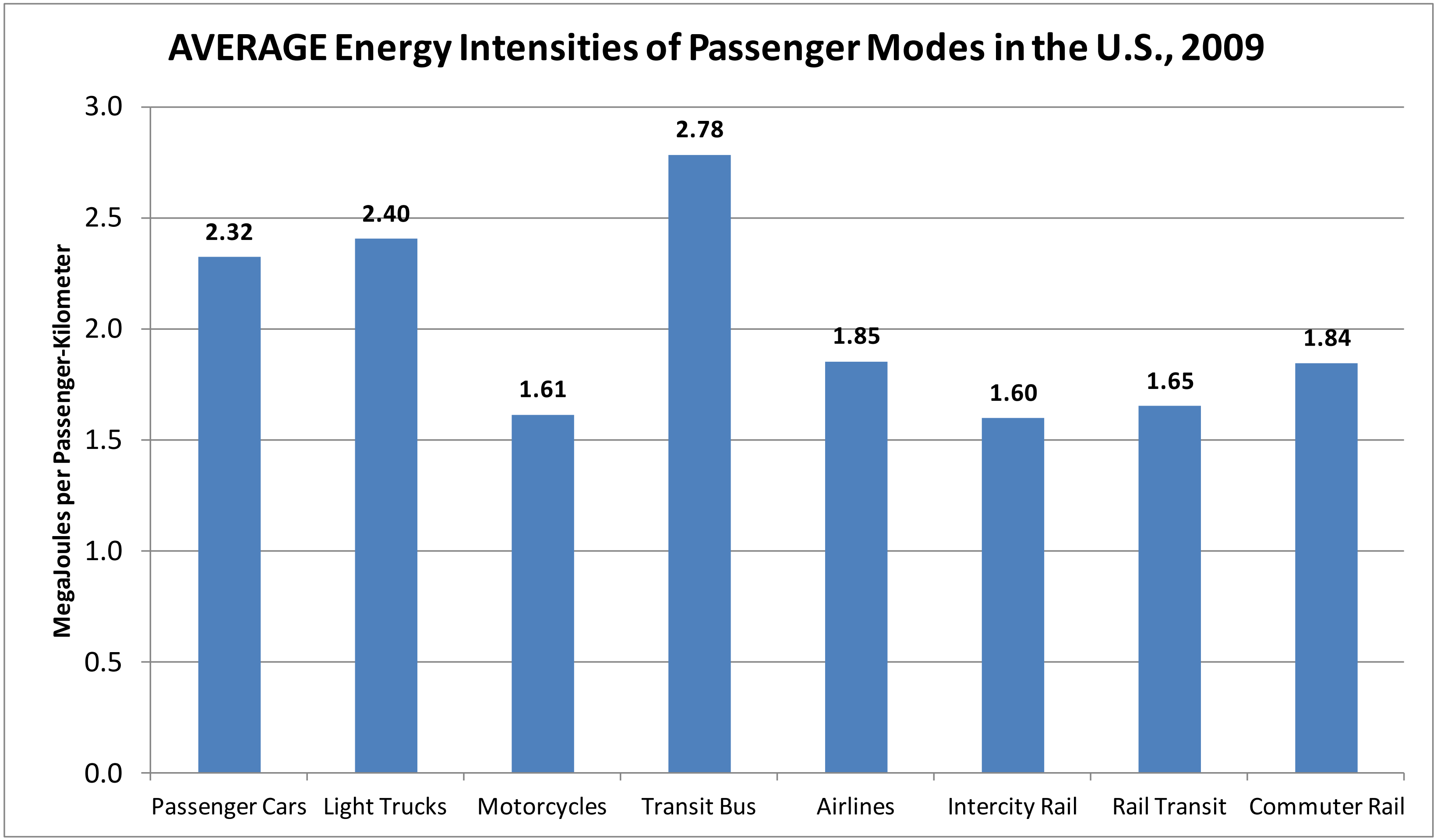
International Energy Agency, 2008. Energy Technology Perspectives, Figure 2.21.

Highway vehicles also predominate in U.S. transport: Light-duty vehicles account for 60%, heavy-duty trucks 22%. All bus energy use plus all passenger rail equals 0.3%.



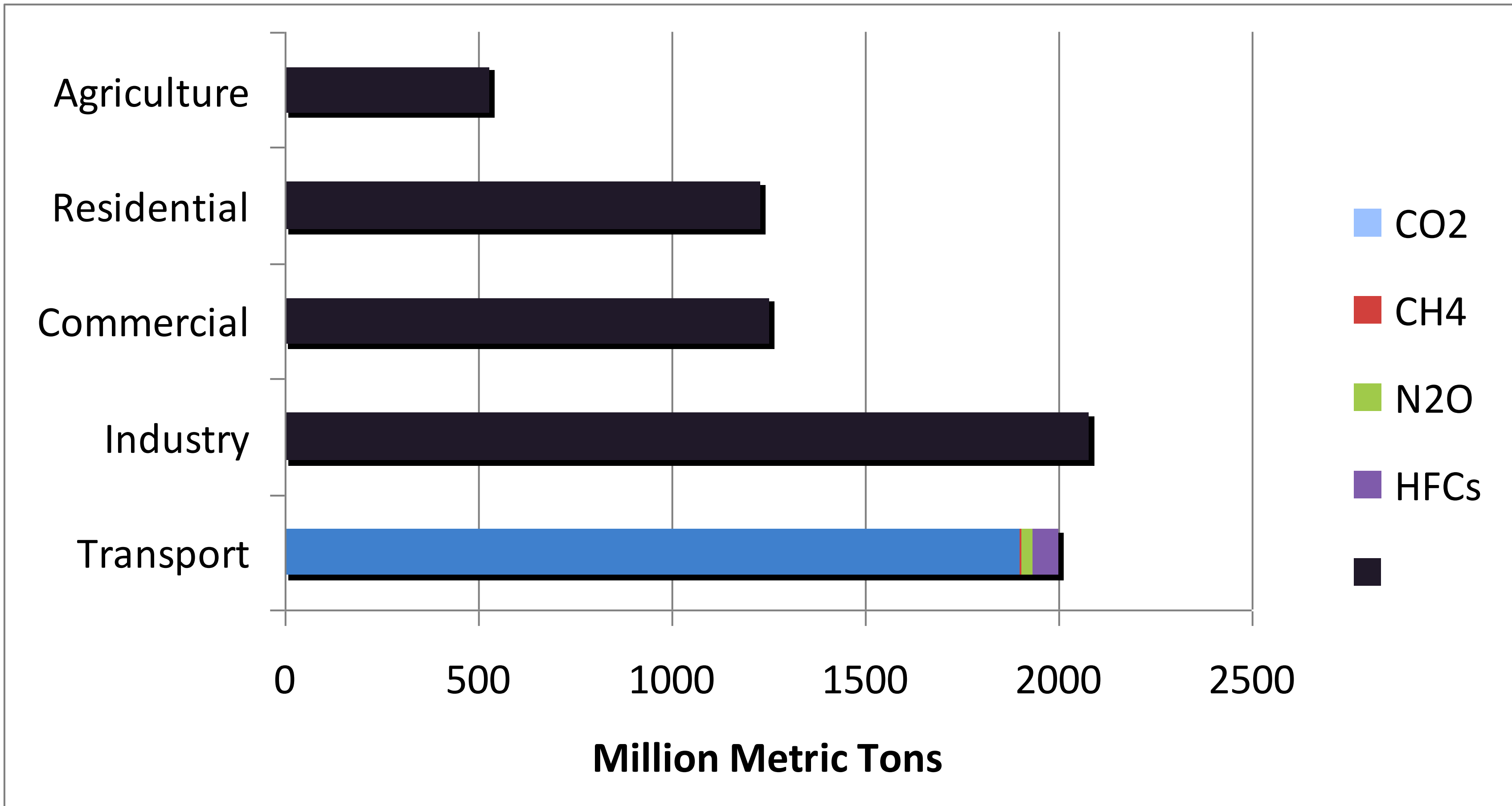
Davis, S.C., S.W. Diegel and R.G. Boundy, 2011, Transportation Energy Data Book Ed. 30, Tables 2.6 7 2.13.

Average energy intensities ***can*** be misleading. Marginal changes could be better or worse. Still, double, triple or quadruple transit ridership and the effect on transportation energy is small.



Davis et al., 2011. Transportation Energy Data Book, Ed. 30, table 2.12

The U.S. transportation system emits more CO_2 than any country in the world except China. CO_2 comprises nearly all of transportation's GHG emissions.



According to the NAS, to limit the global average temperature rise to 2˚C (avoid dangerous climate change) implies the U.S. limits its C emissions to 170 $GtCO_2$ eq.

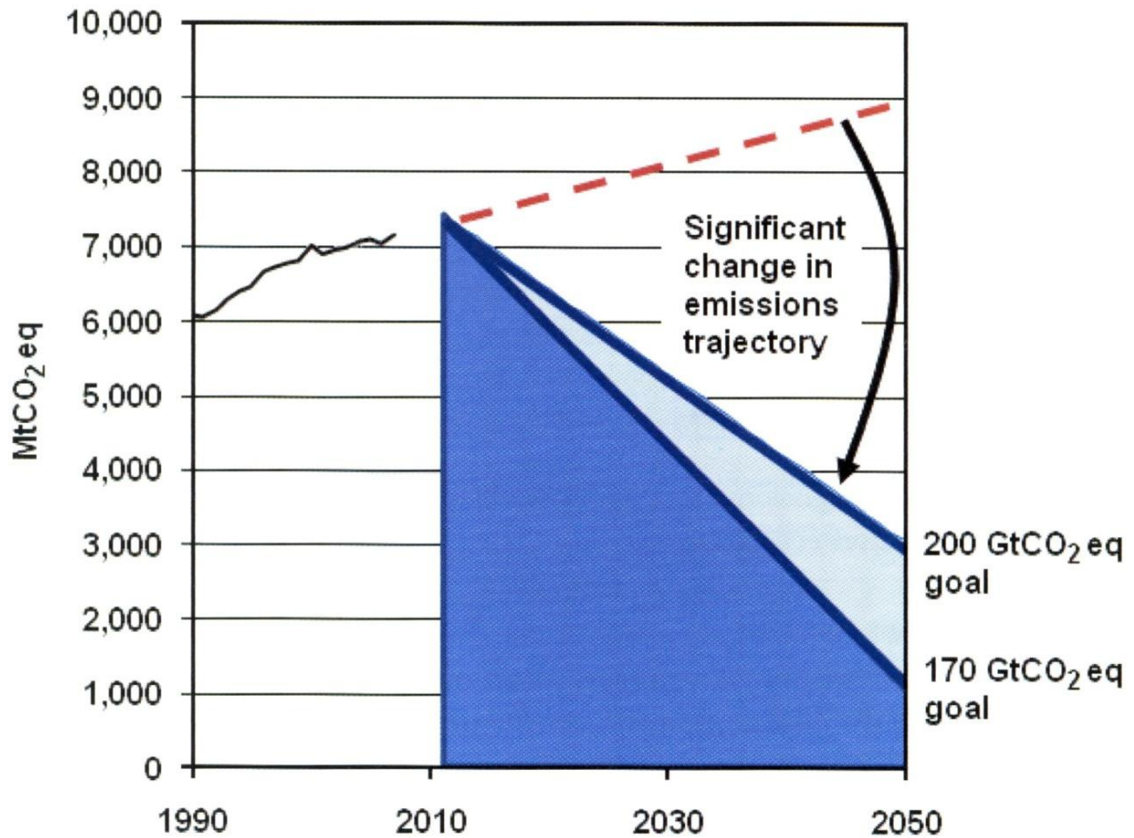
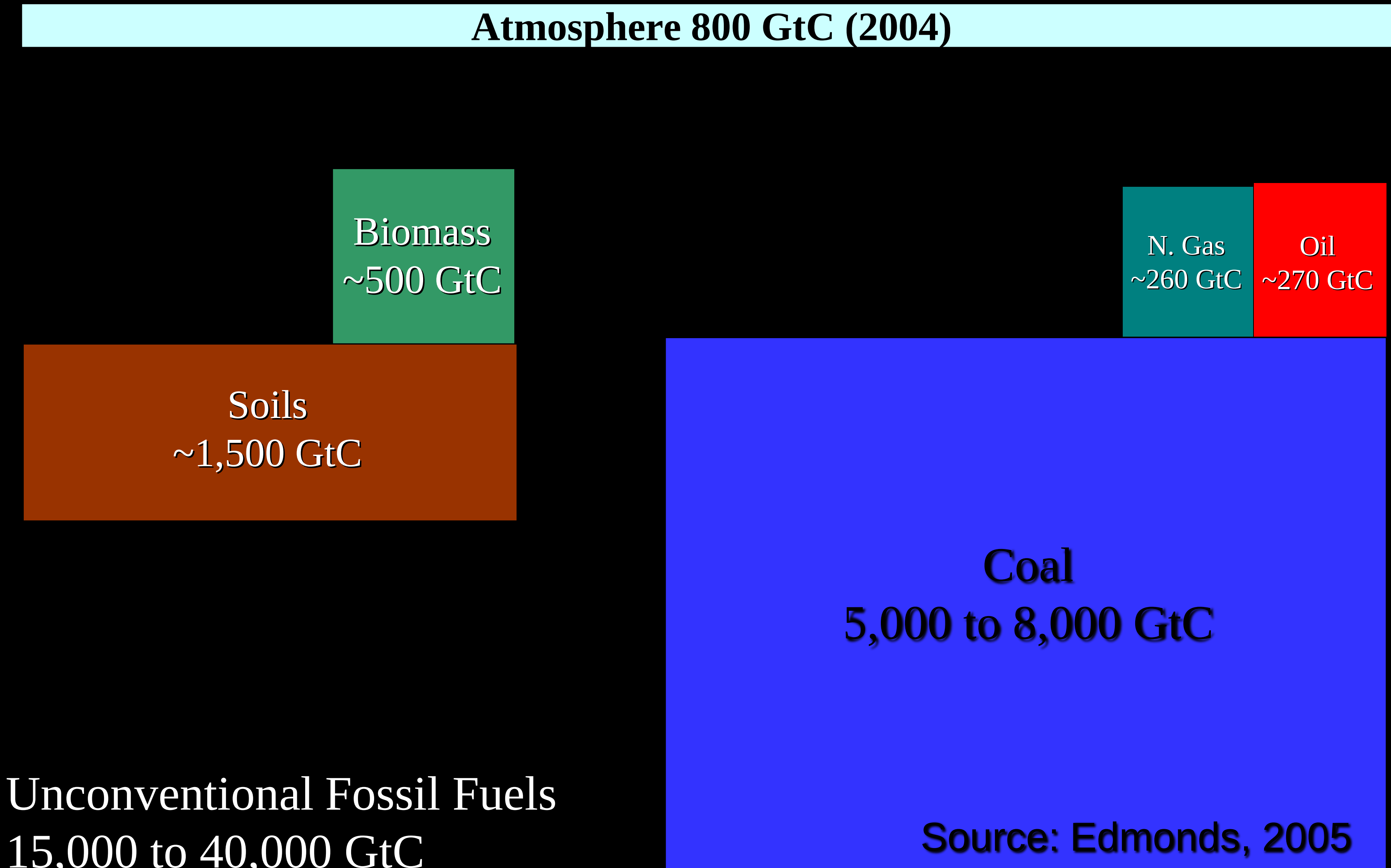
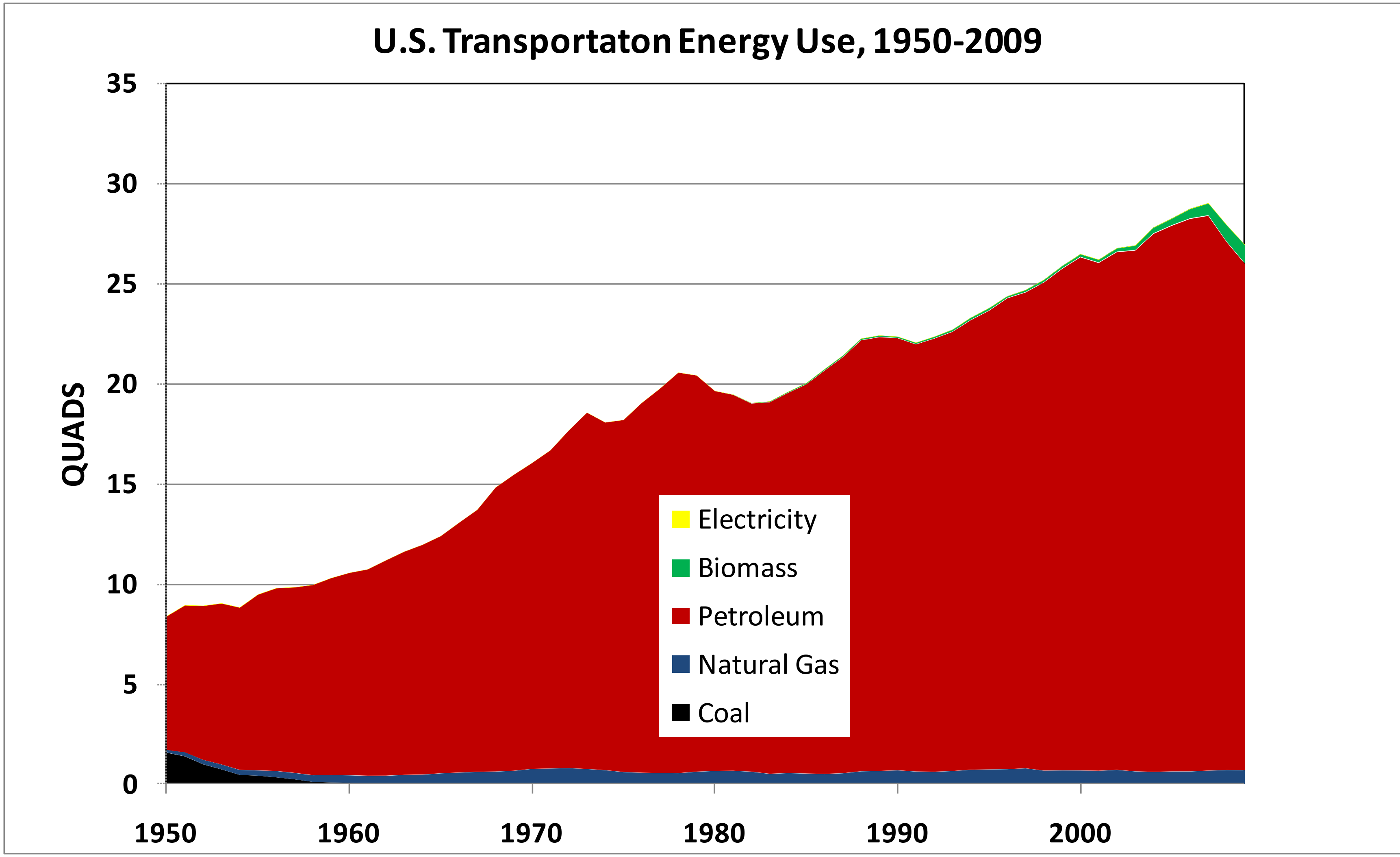


FIGURE 2.10 Illustration of the representative U.S. cumulative GHG emissions budget targets: 170 and 200 Gt CO_2-eq (for Kyoto gases) (Gt, gigatons, or billion tons; Mt, megatons, or million tons). The exact value of the reference budget is uncertain, but nonetheless illustrates a clear need for a major departure from business as usual.

Carbon Reservoirs

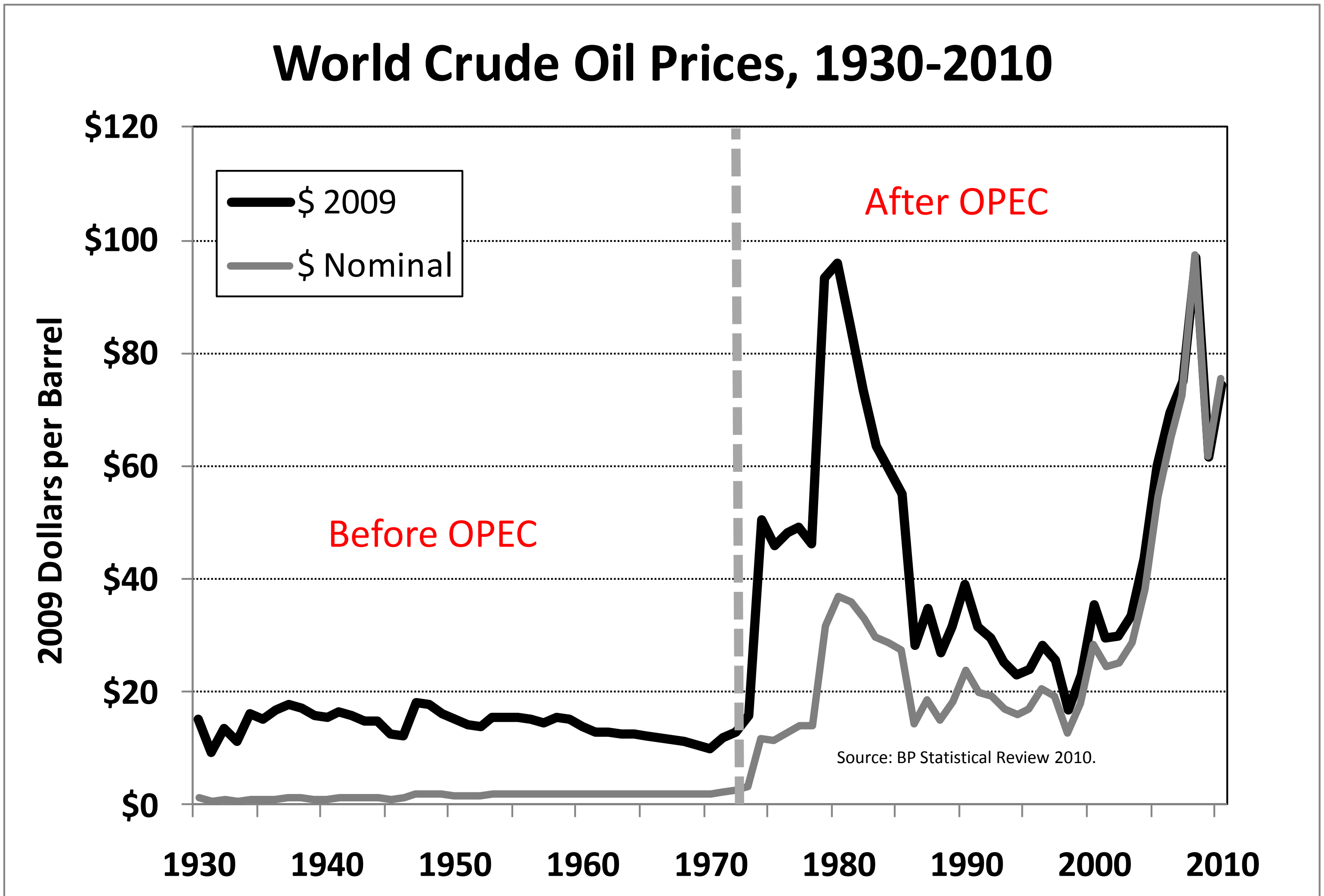


It's about petroleum. Our transportation sector consumes petroleum at the rate of 6,300 gallons per second.

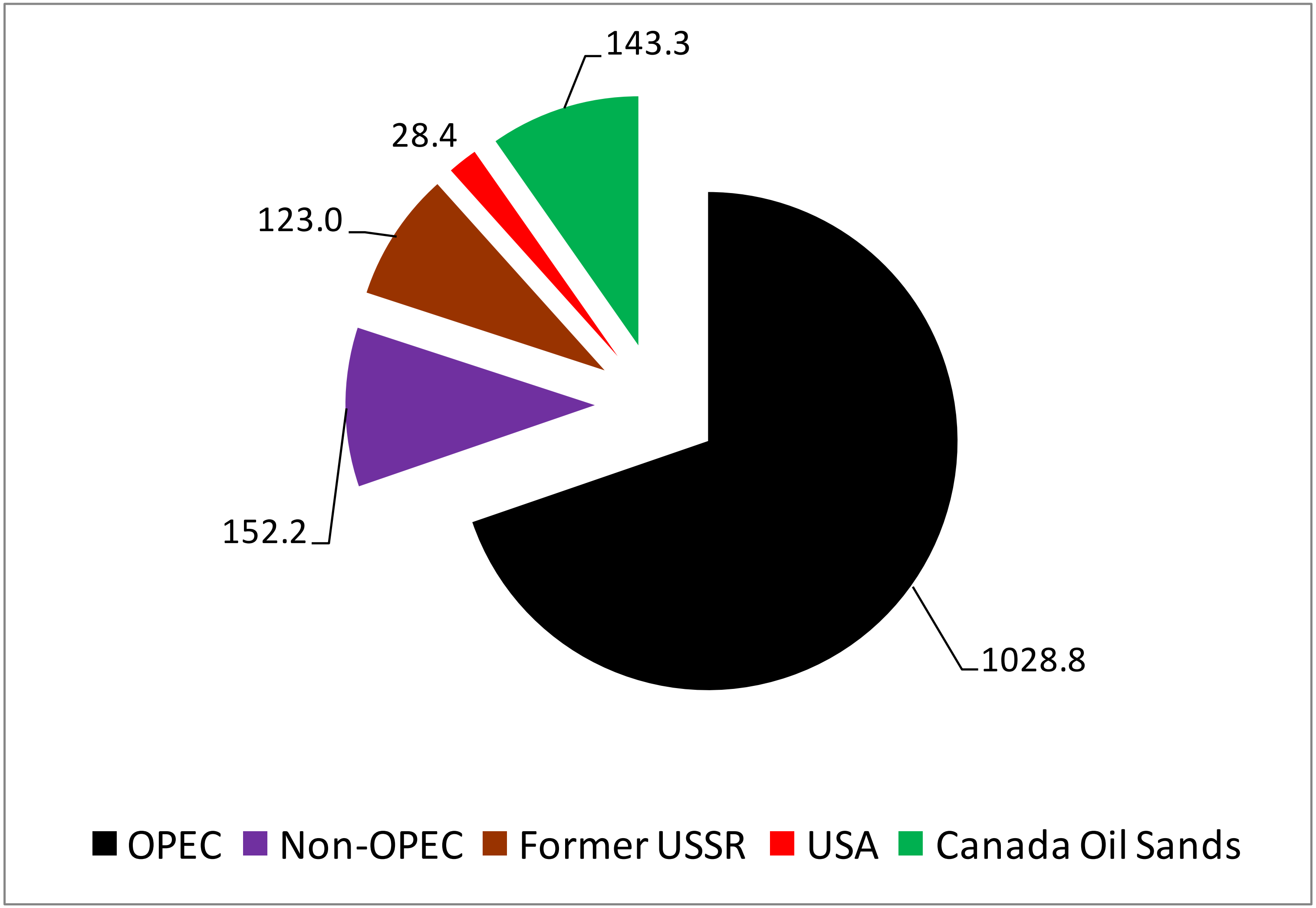


"The real problem we face over oil dates from after 1970: a strong but clumsy monopoly of mostly Middle Eastern exporters operating as OPEC." Prof. M. Adelman, MIT, 2004.

RANDOM WALK? (Hamilton, 2009 *Energy Journal*, 30(2), 179-206).



OPEC members own 70% of the world's proven oil reserves and more than half of ultimate resources of conventional oil. National oil companies own more than 80%.



Source: BP Statistical Review of World Energy 2010, "Oil: Proved Reserves".

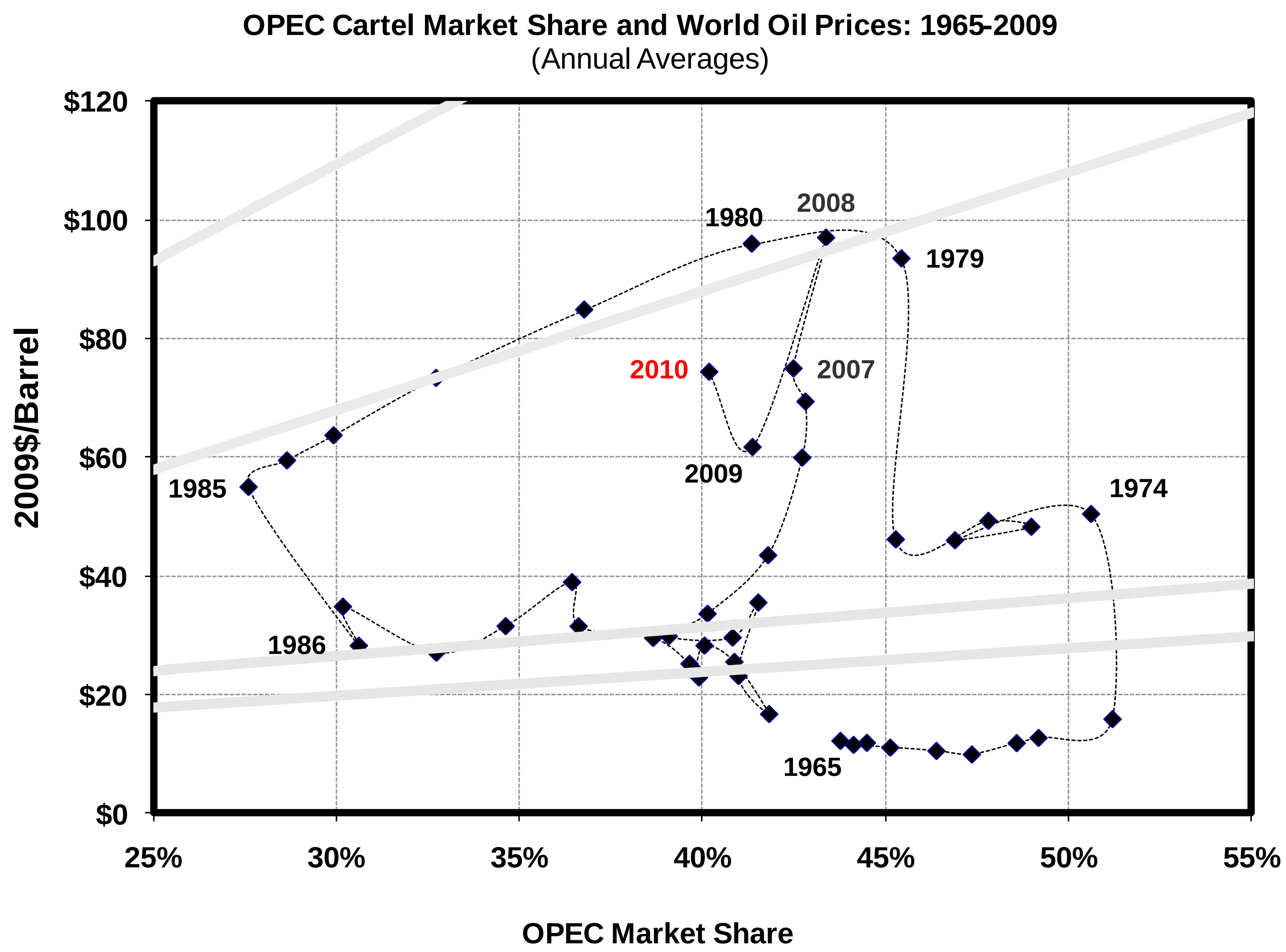
The economic theory to understand the behavior of the OPEC oil cartel was developed more than half a century ago by Heinrich von Stackelberg.

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

β = price elasticity of world oil demand (β < 0)
S = OPEC share of world oil market (0 < S < 1)
μ= non-OPEC supply response (-1 < **μ** < 0)
Elasticity = % change in quantity / % change in price = d ln(y)/d ln(x)

Short- and long-run elasticities differ by an order of magnitude!

The “random walk” of oil prices since 1974 takes place within the partial monopoly framework.



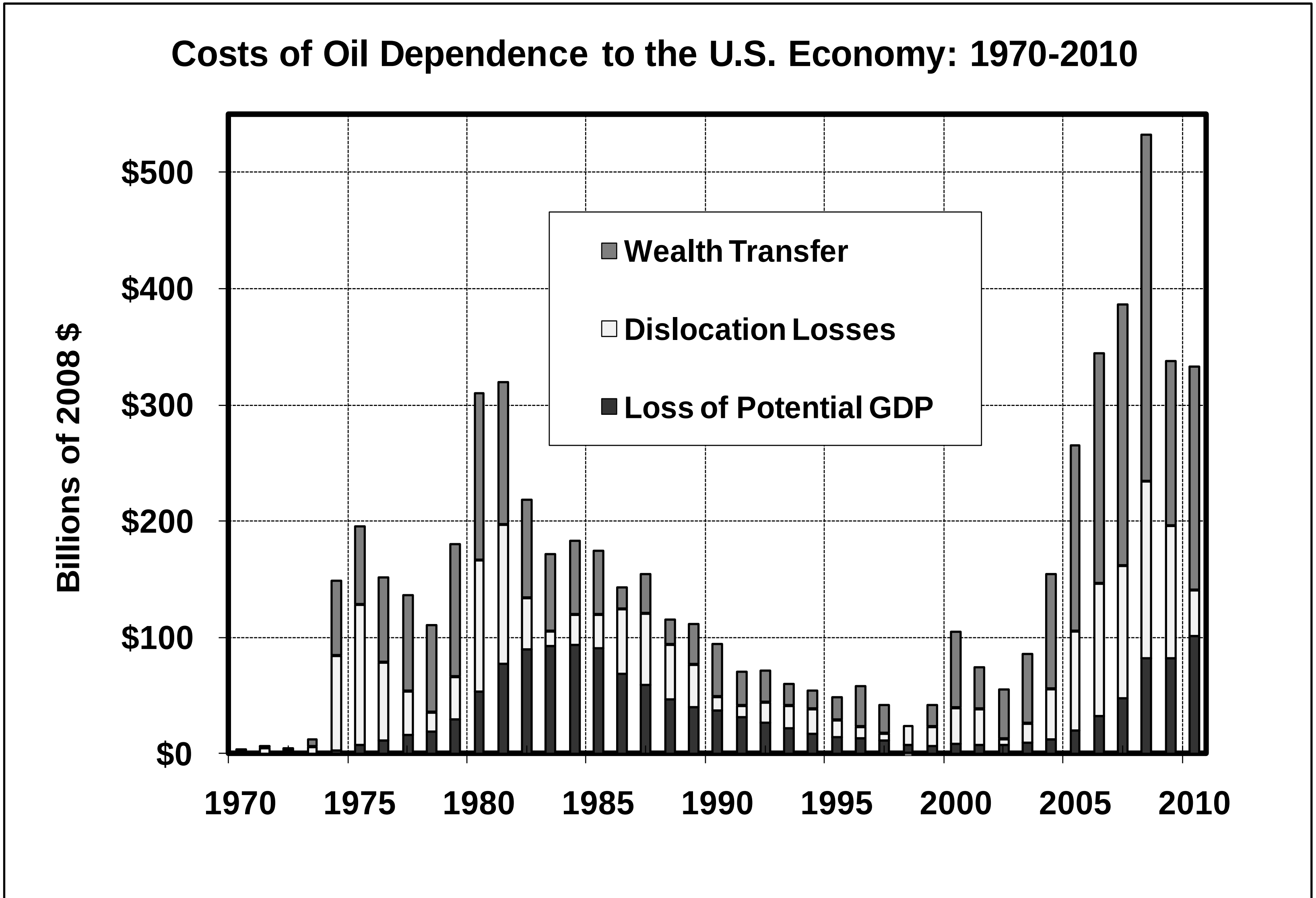
Source: 1965-2009 BP Statistical Review 2010. Oil Production - barrels and Oil - crude oil prices since 1861.

What is oil dependence?

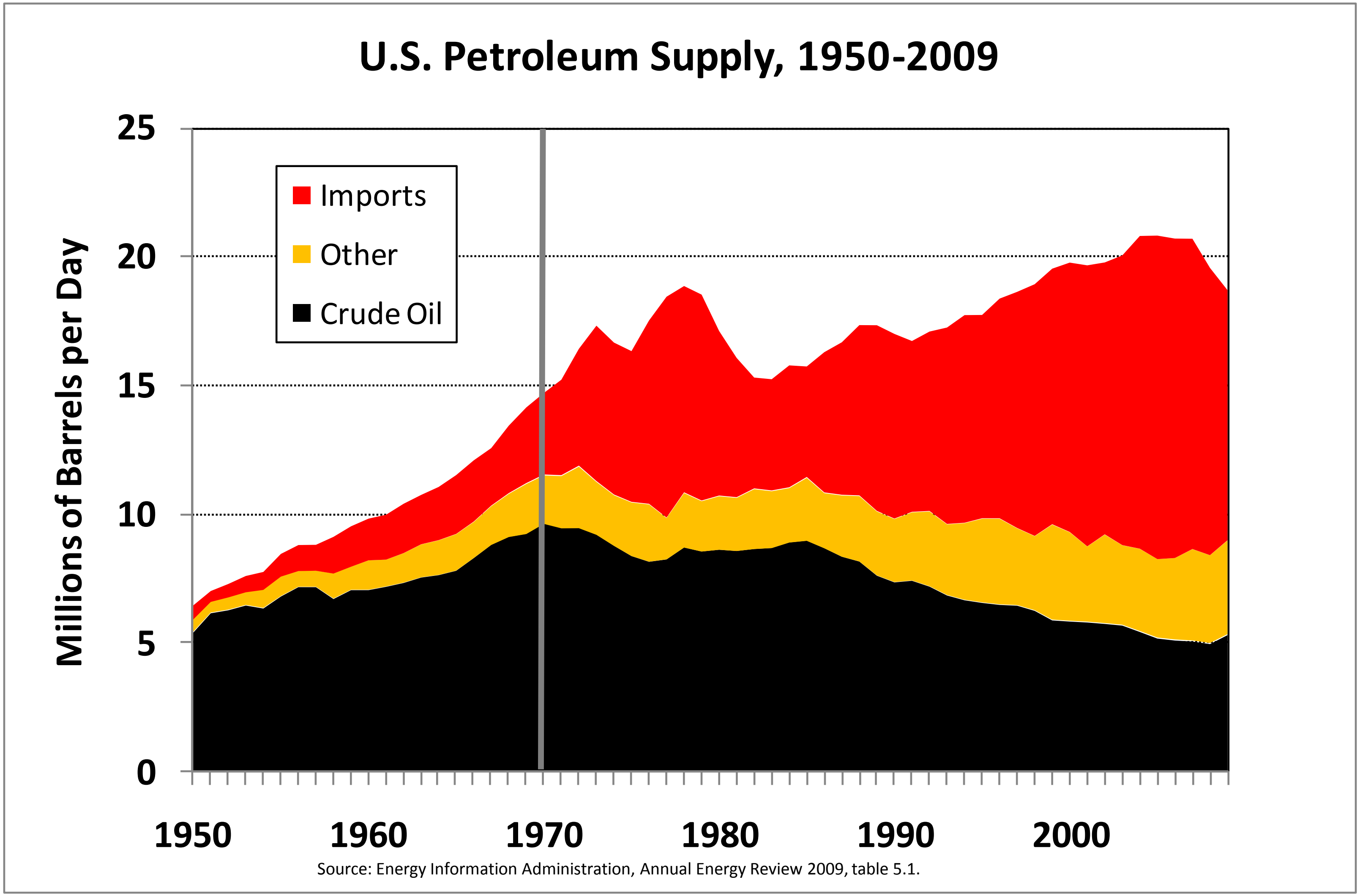
Oil dependence is primarily an economic problem with major national security implications caused by,

- use of **market power** by oil producing states,
- importance of oil to the economy and,
- lack of economical substitutes for oil.
- Oil dependence is NOT an externality.

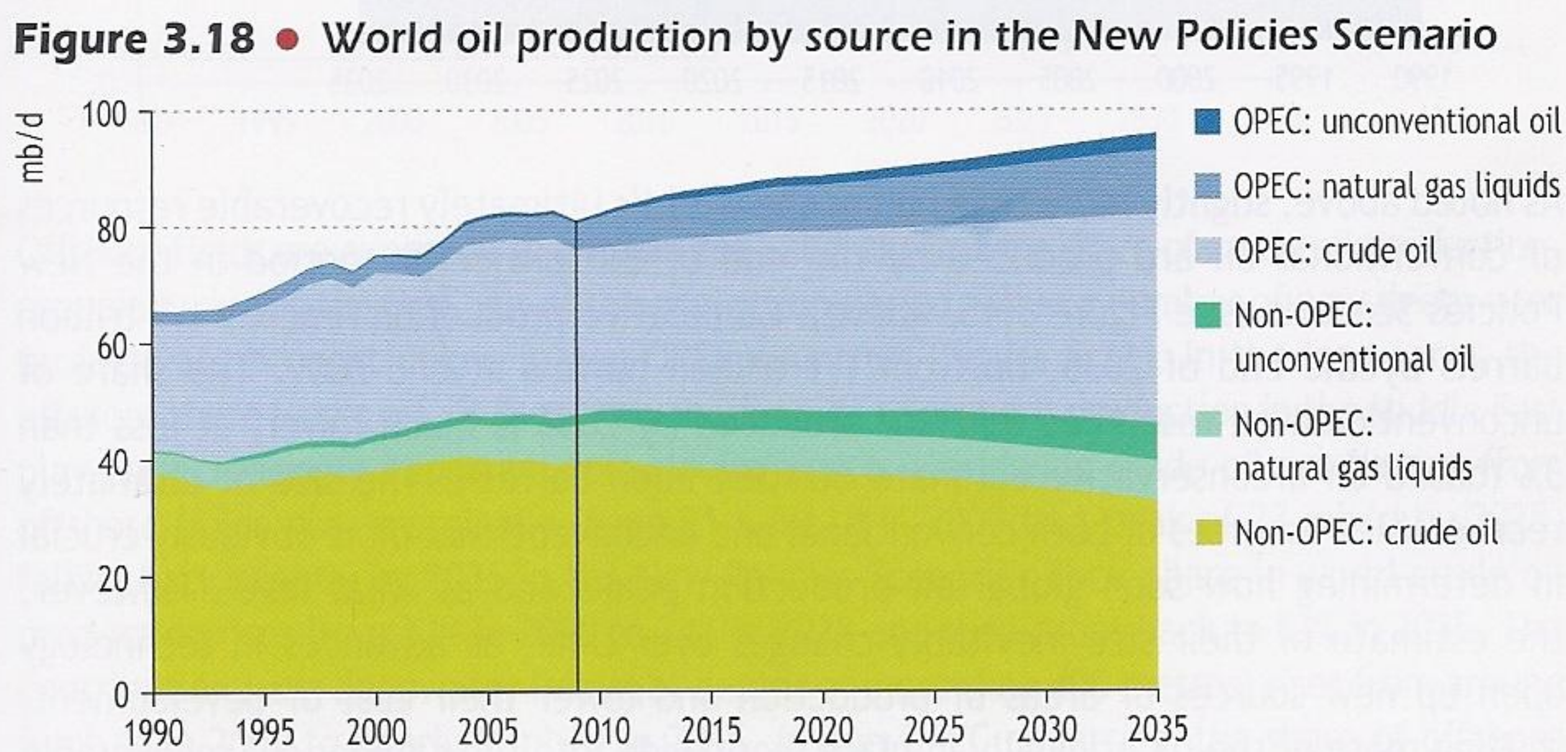
Oil dependence cost the US more than $500 billion in 2008.
Oil independence doesn't mean using no oil or importing no oil.



The cartel's market power was strengthened by growing world demand, its increasing market share and…the peaking of US crude oil production in 1970.

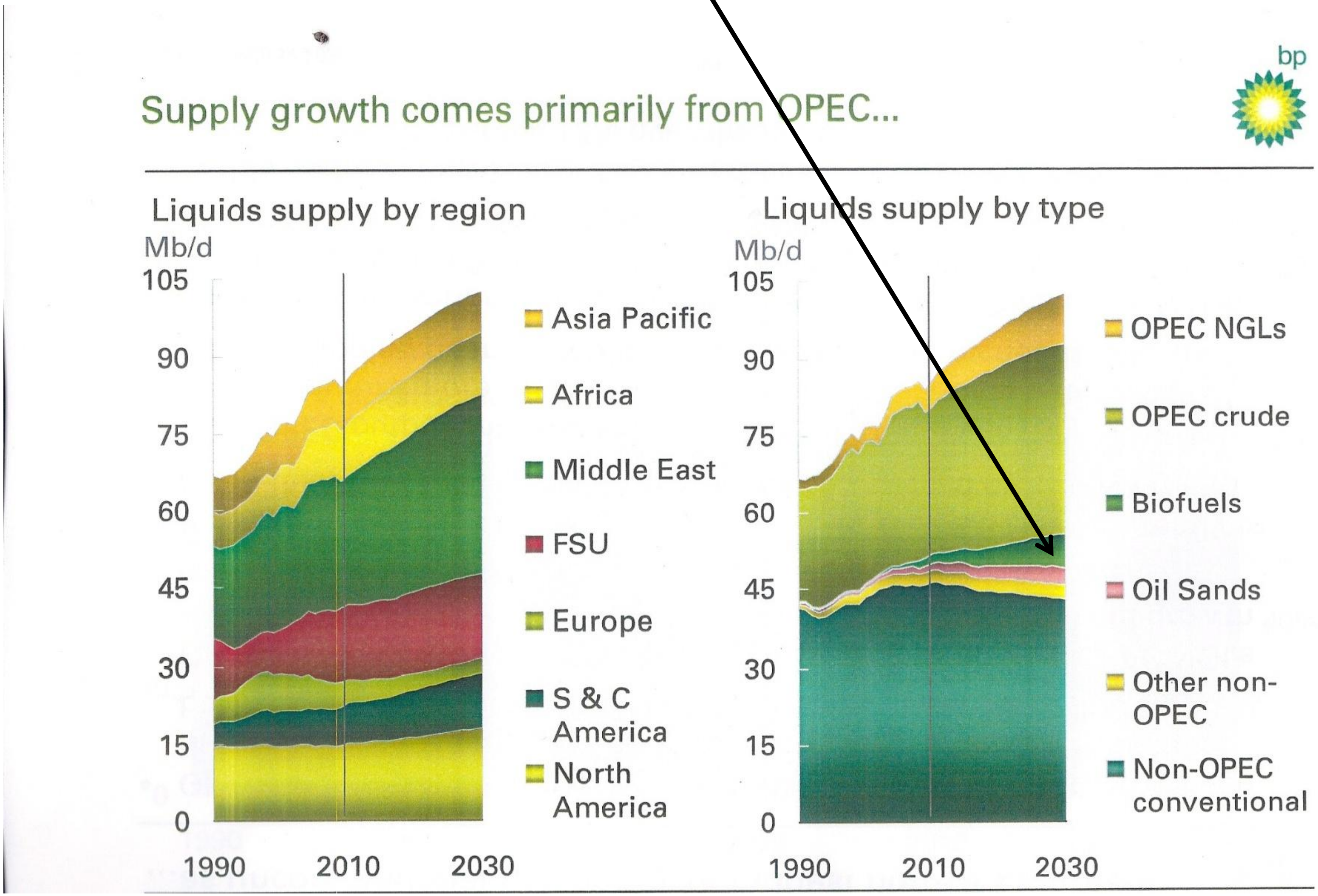


The International Energy Agency foresees a plateau in non-OPEC conventional and unconventional oil production from now to 2030.



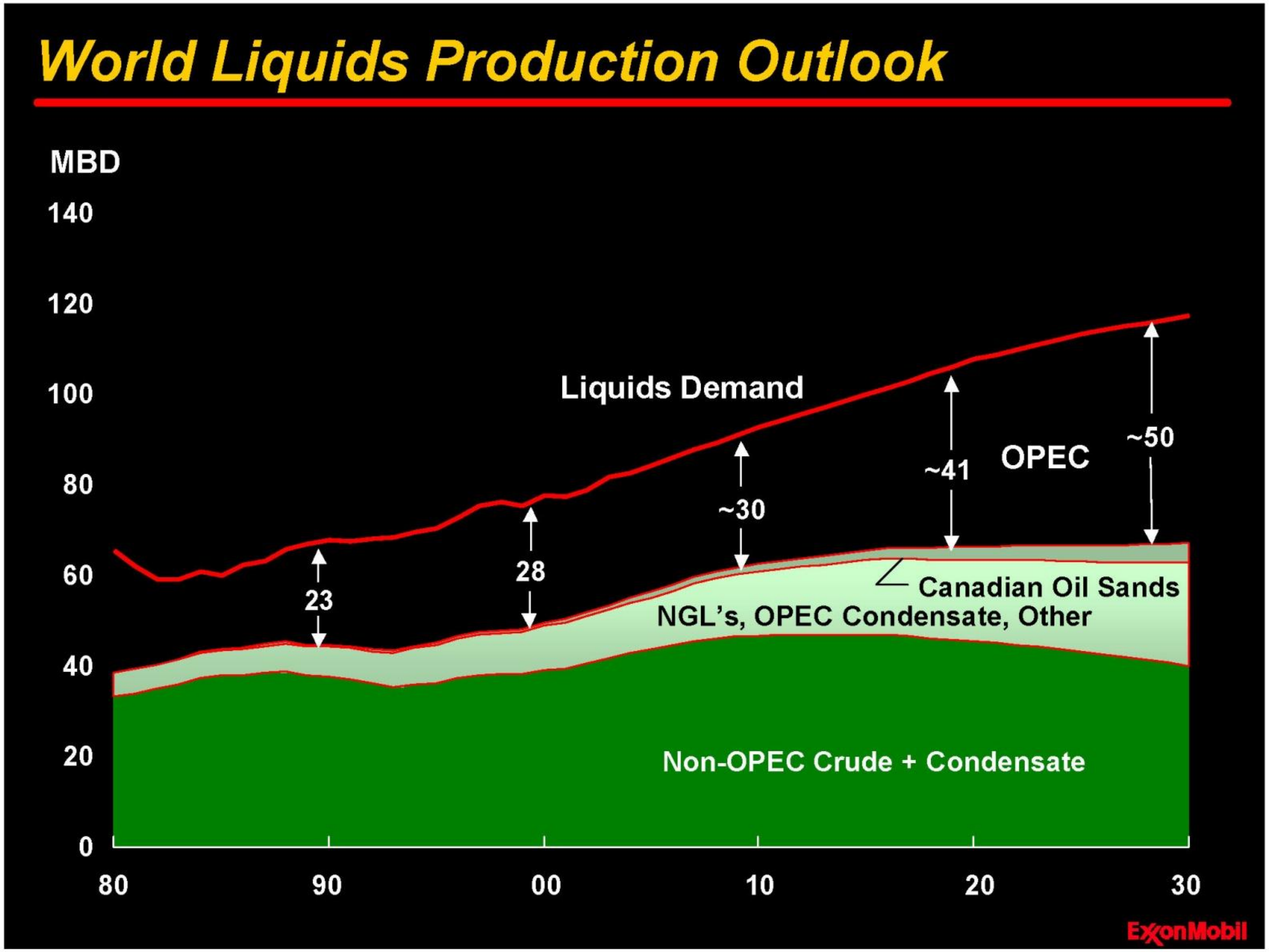
Source: International Energy Agency, *World Energy Outlook 2010*, OECD, Paris.

Even including oil sands, BP sees non-OPEC production flat or declining after 2010.

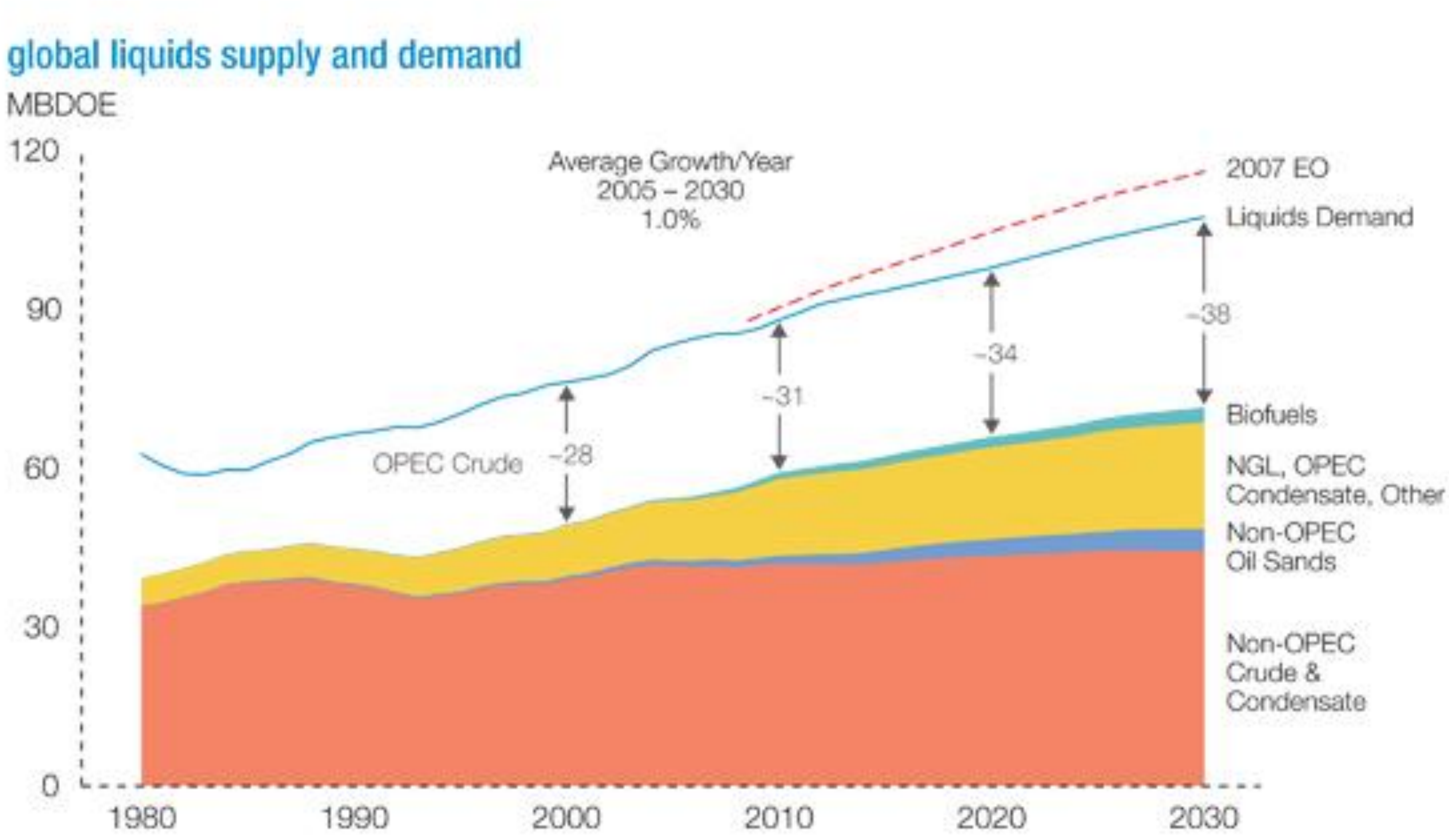


Source: BP Energy Outlook 2030, London, January 2011.

Projections made before the run-up in oil prices expected peaking of non-OPEC supply with OPEC filling the gap.

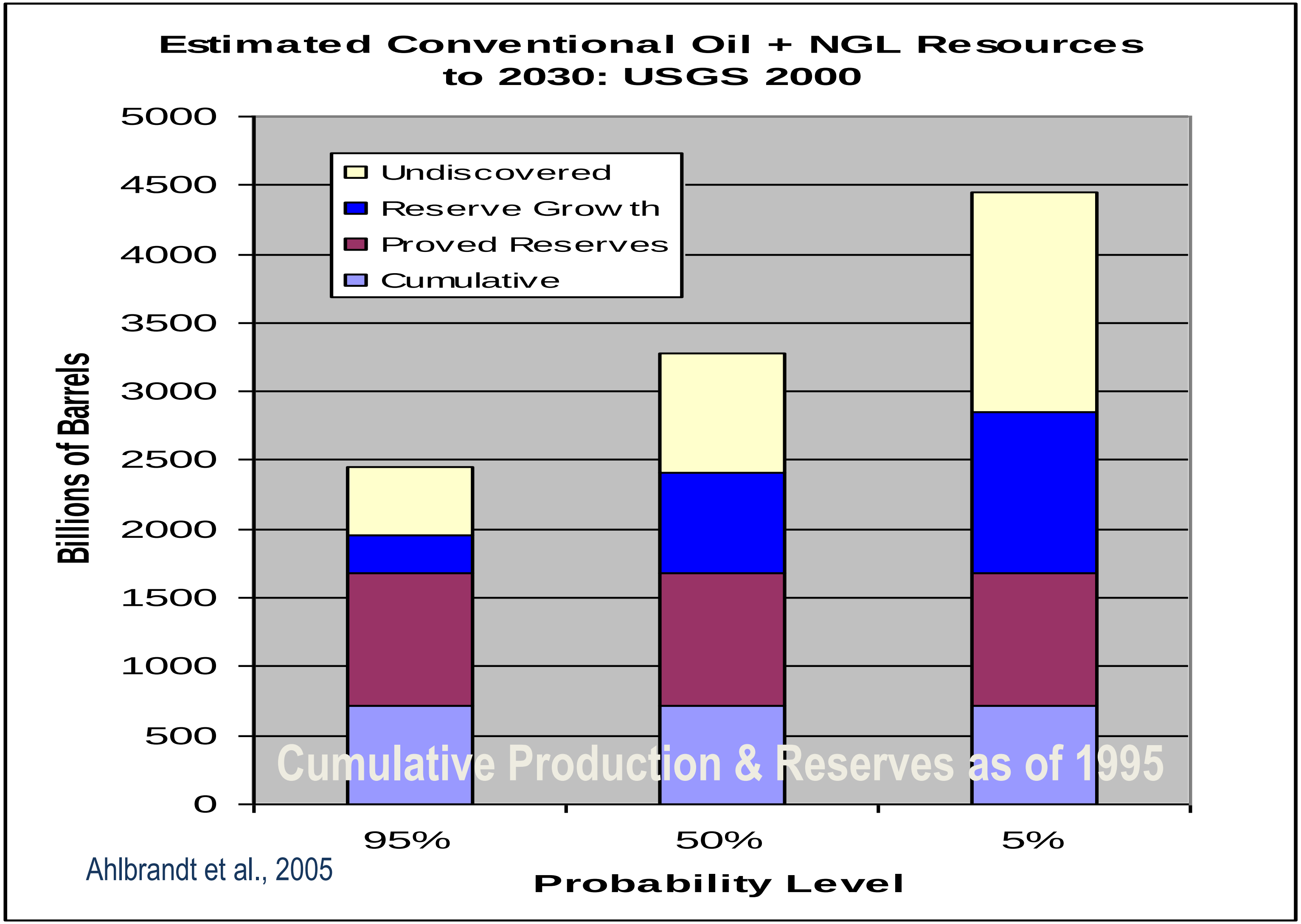


ExxonMobil's 2009 & 2010 energy outlooks, considering recent high oil prices, were not much more optimistic about non-OPEC crude oil supply.

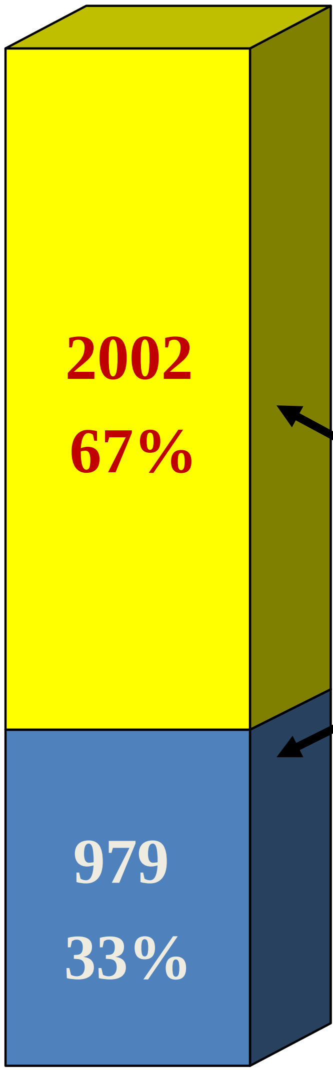


Source: ExxonMobil, The outlook for energy: a view to 2030, January 14, 2009.
http://www.exxonmobil.com/Corporate/energy_outlook.aspx

But do we know how much oil there is?
US Geological Survey Estimates reflect 2 trillion barrels of uncertainty about how much exists and can be produced.



The RATE of world oil use is large relative to any of the USGS' estimates.



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 between 1995 and 2005.

* From USGS 2000, USGS 1995, and MMS 1996

The path of least resistance is producing liquid fuels from unconventional fossil resources at prices the world has shown it is willing to pay.

But, production is more capital intensive, and…

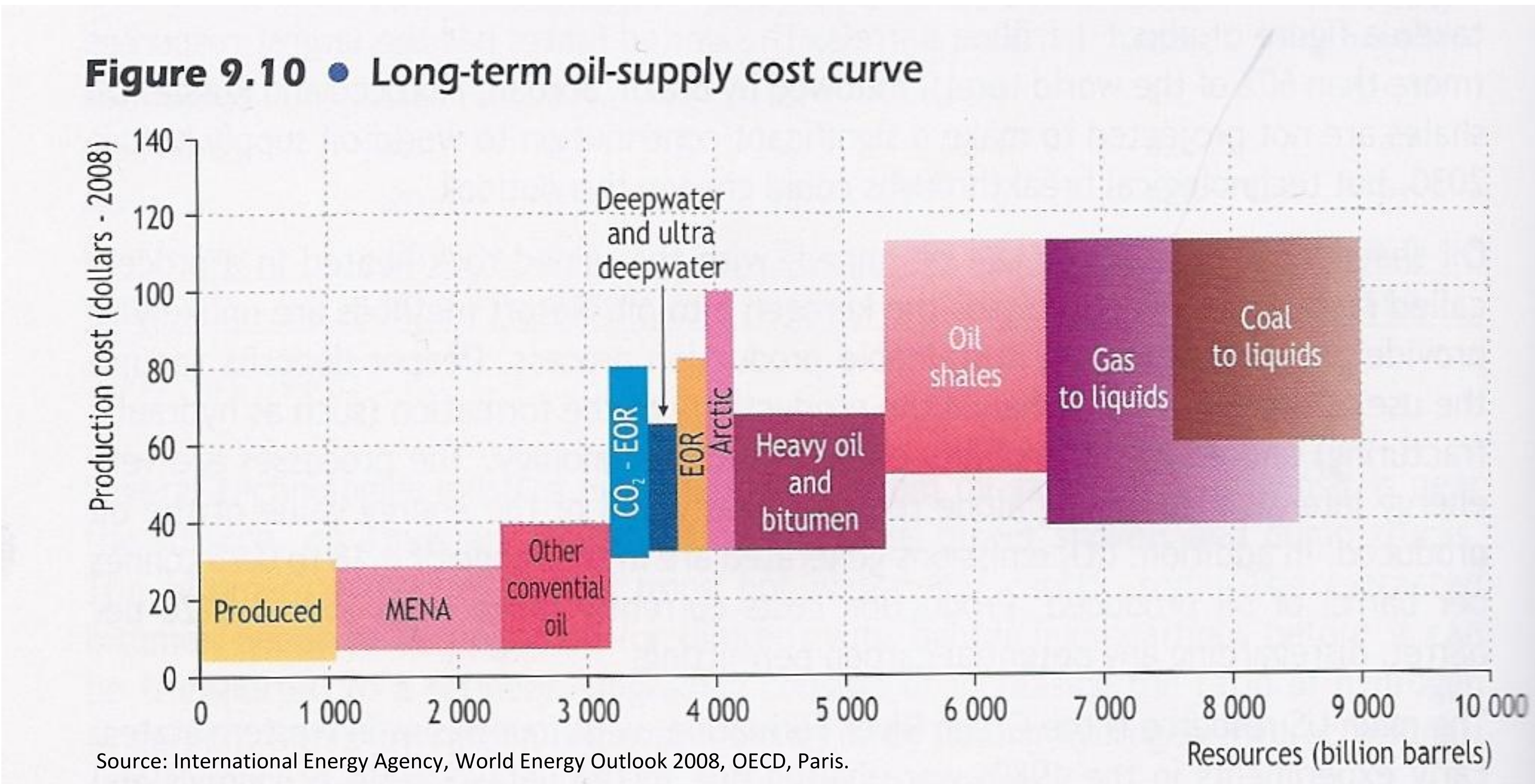
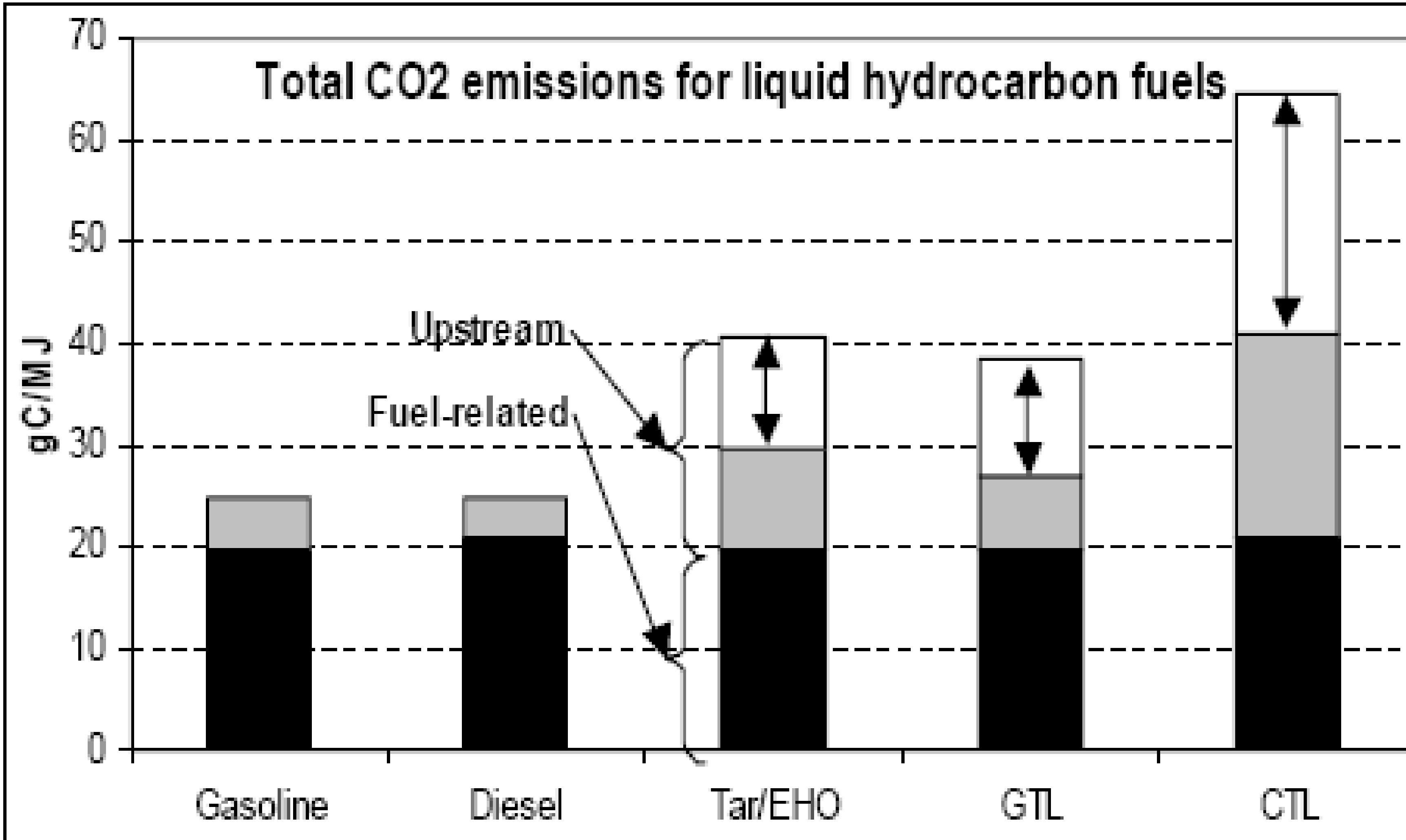


Figure 9.10 • Long-term oil-supply cost curve

Source: International Energy Agency, World Energy Outlook 2008, OECD, Paris.

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



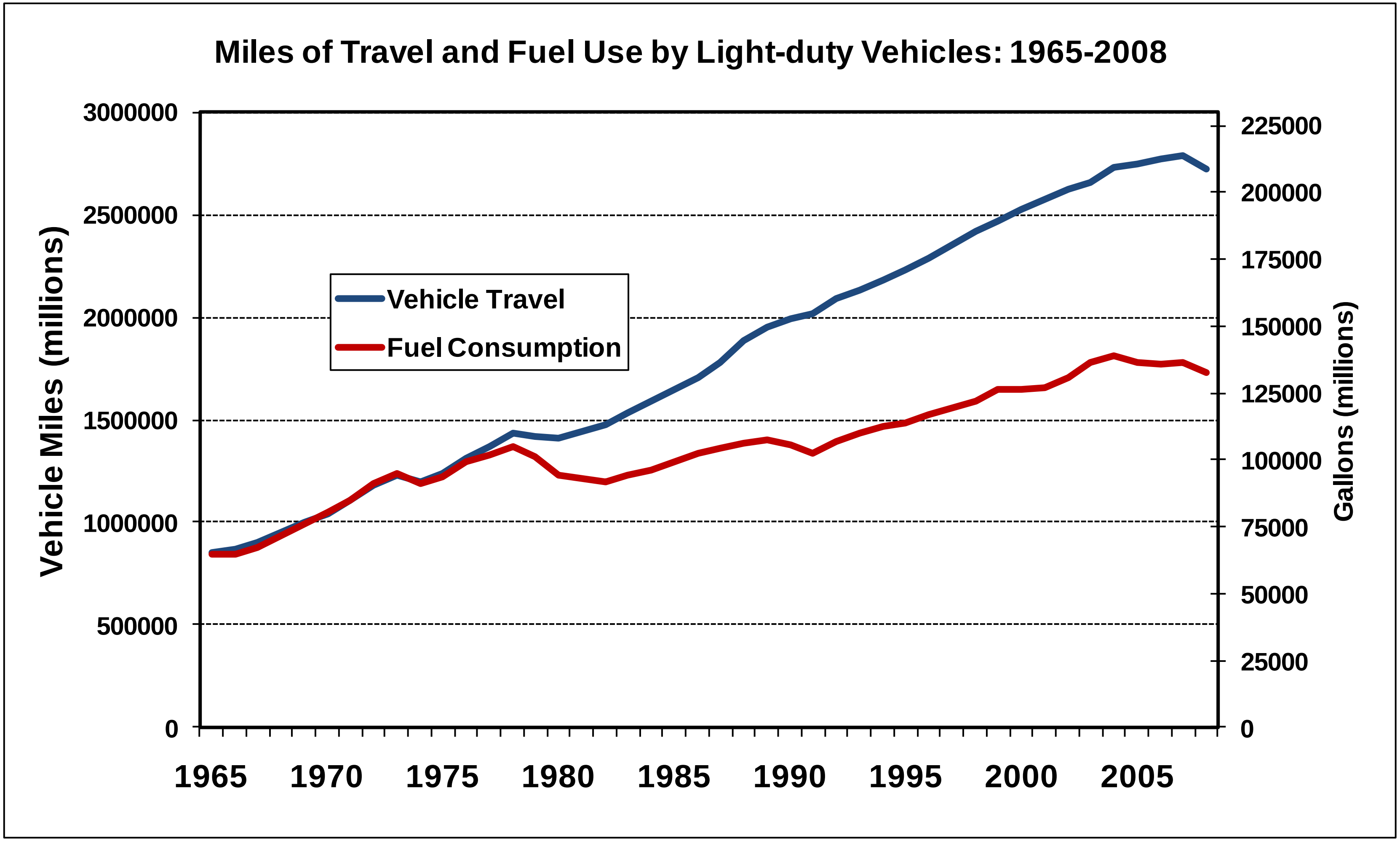
Source: Farrell, 2006.

In the near term improving energy efficiency is the most promising strategy.

The CAFE standards decoupled VMT and energy use.

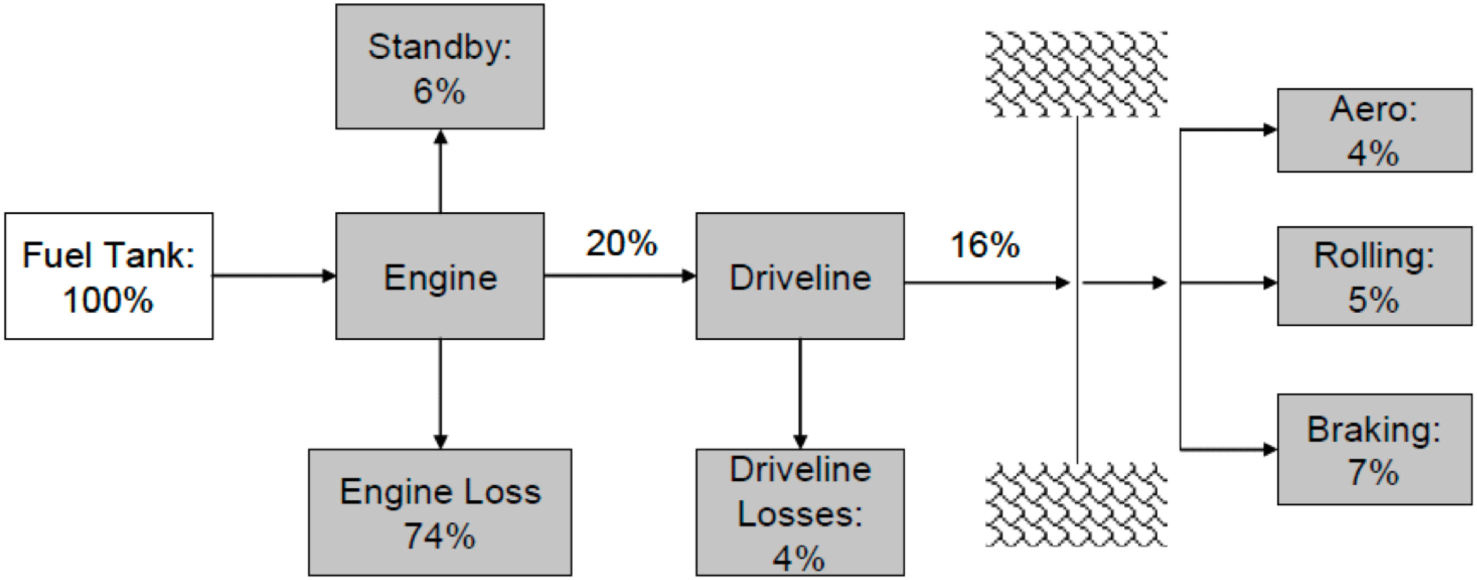
(>60 Bgals. saved in 2008)

And the public ***likes*** the standards.



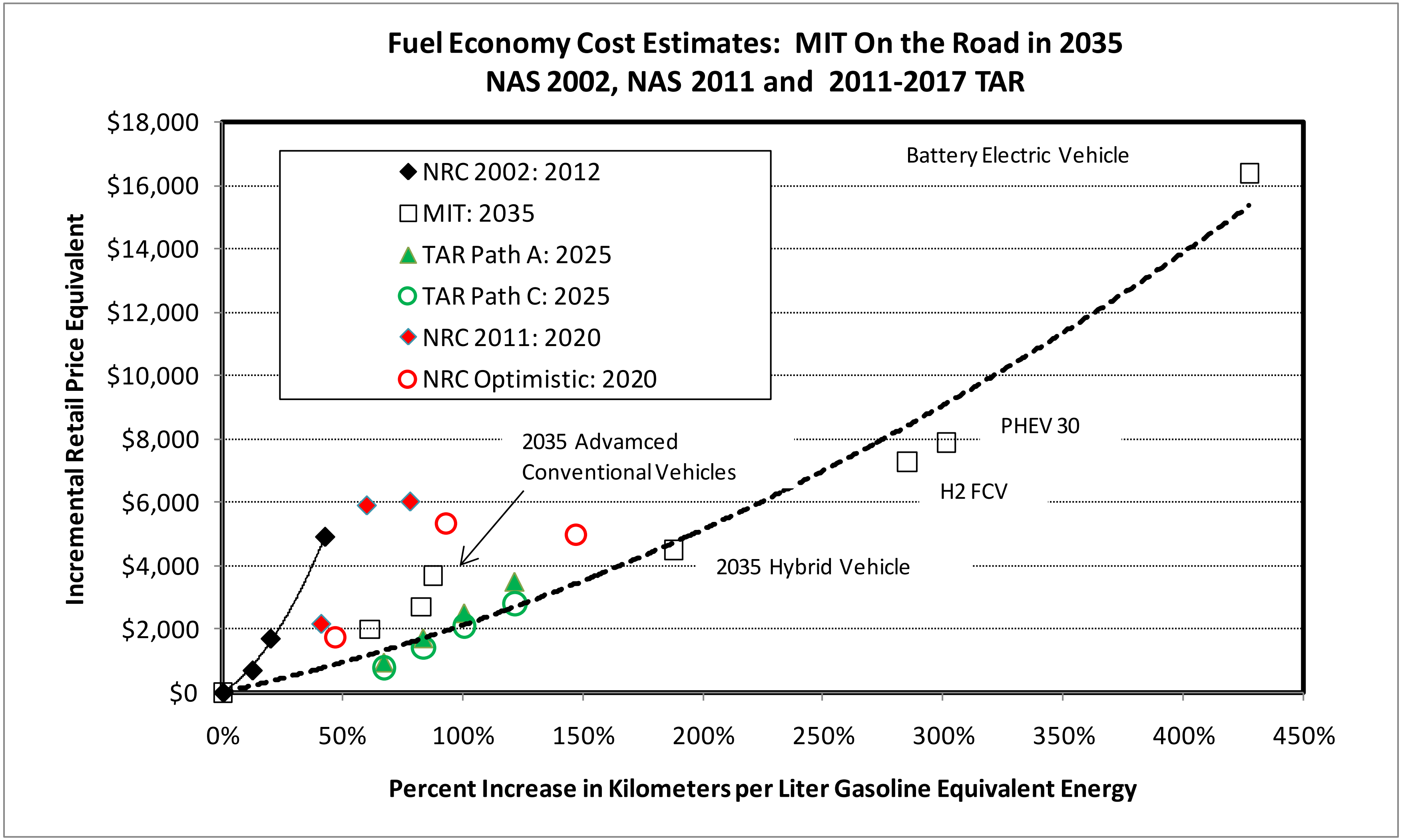
The overall energy efficiency of U.S. passenger vehicles is ≈ 1%.
Fuel to wheels ~16%, "payload" ~1/16th of total mass.

Though this is an extreme example, it is reasonable to infer potential for major improvement.

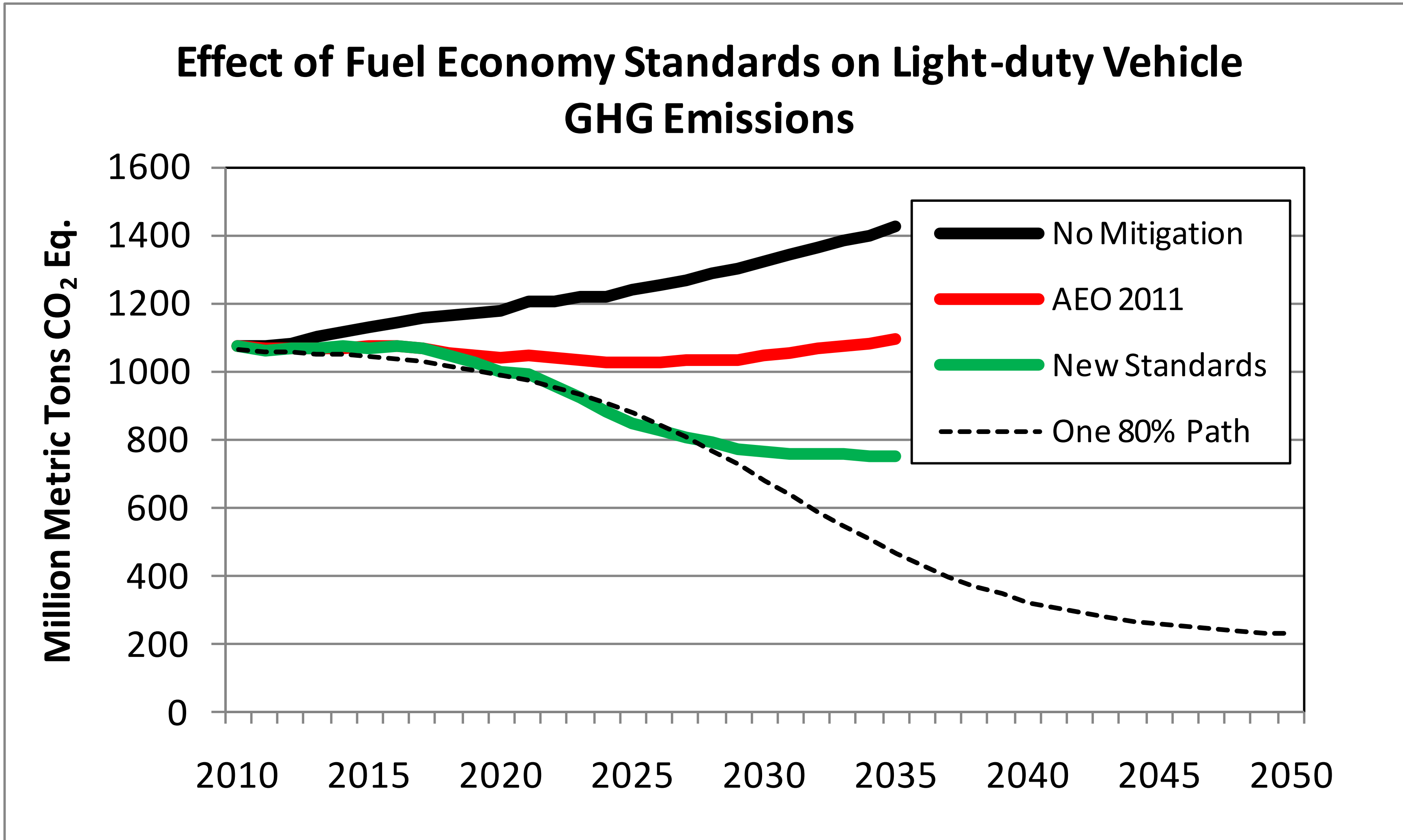


Bandivedekar et al., 2008, "On the Road in 2035", MIT Sloane Automotive Res. Lab.

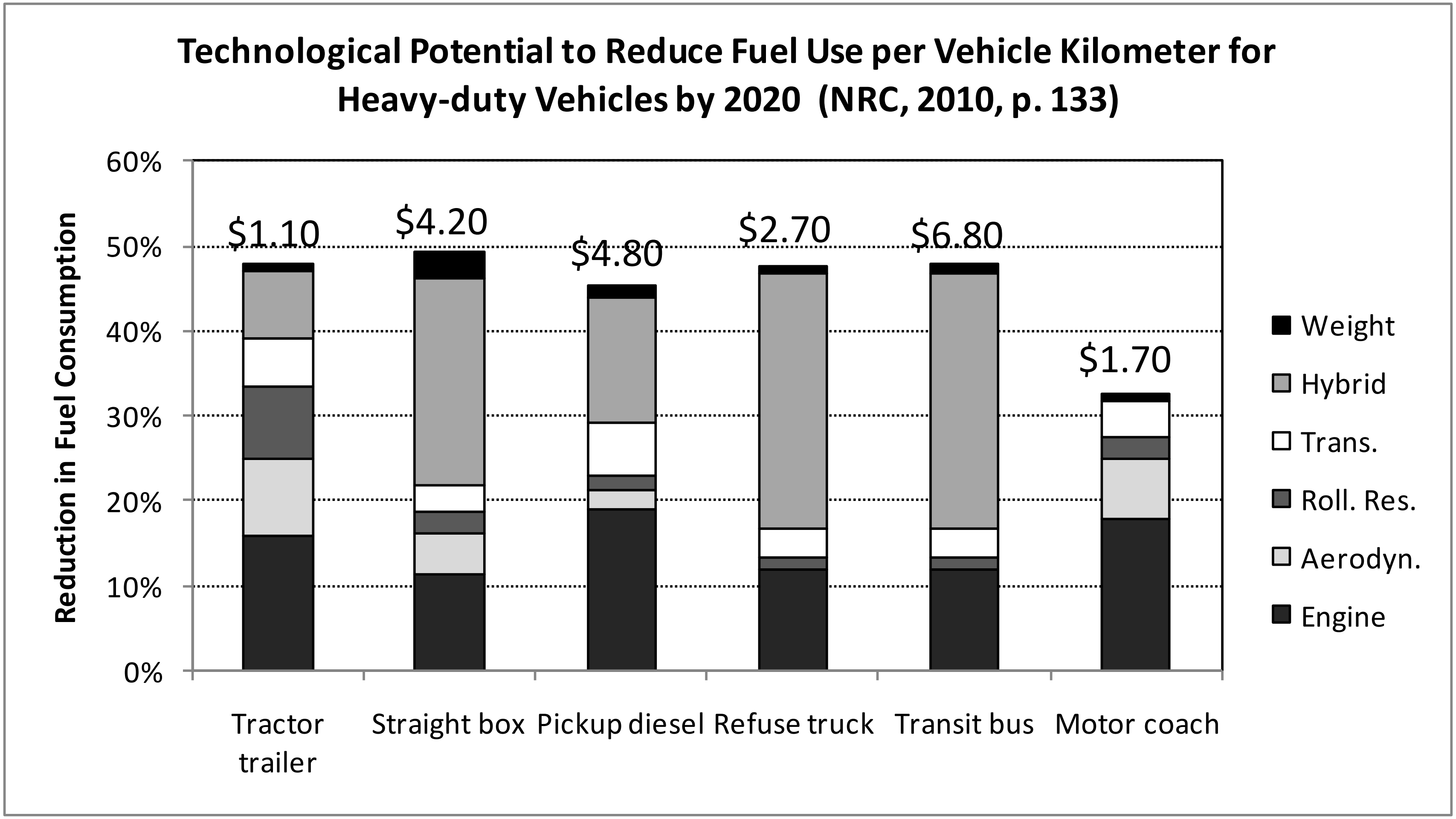
Proposed fuel economy standards require more than a doubling of miles per gallon by 2025. Can it be done cost-effectively?



The proposed 2017-2025 US standards will put light-duty vehicles on a path toward oil independence and an 80% reduction in CO_2 emissions.



The EU, the US and China are also implementing efficiency standards for heavy-duty vehicles. (US: 9-23% reduction in fuel consumption)



Other modes also have substantial potential to reduce fuel consumption cost-effectively.

- Air transport uses 10% of transport energy.
  - Next Gen aircraft -40% fuel burn vs. 2005 by 2020: IATA
  - “wing-body” “double-bubble”: -50 to -70% by 2035
- Water transport is 7% of transport energy use
  - -60% by 2050: IEA (includes speed reduction)
  - -15% to -30 by 2020 at $<\$100/\text{tCO}_2$: IMO
- Rail Transport uses only 4% of transport energy
  - -18% to 24% near term: IEA, USDOT
  - -50% by 2050: Argonne Nat’l Lab.

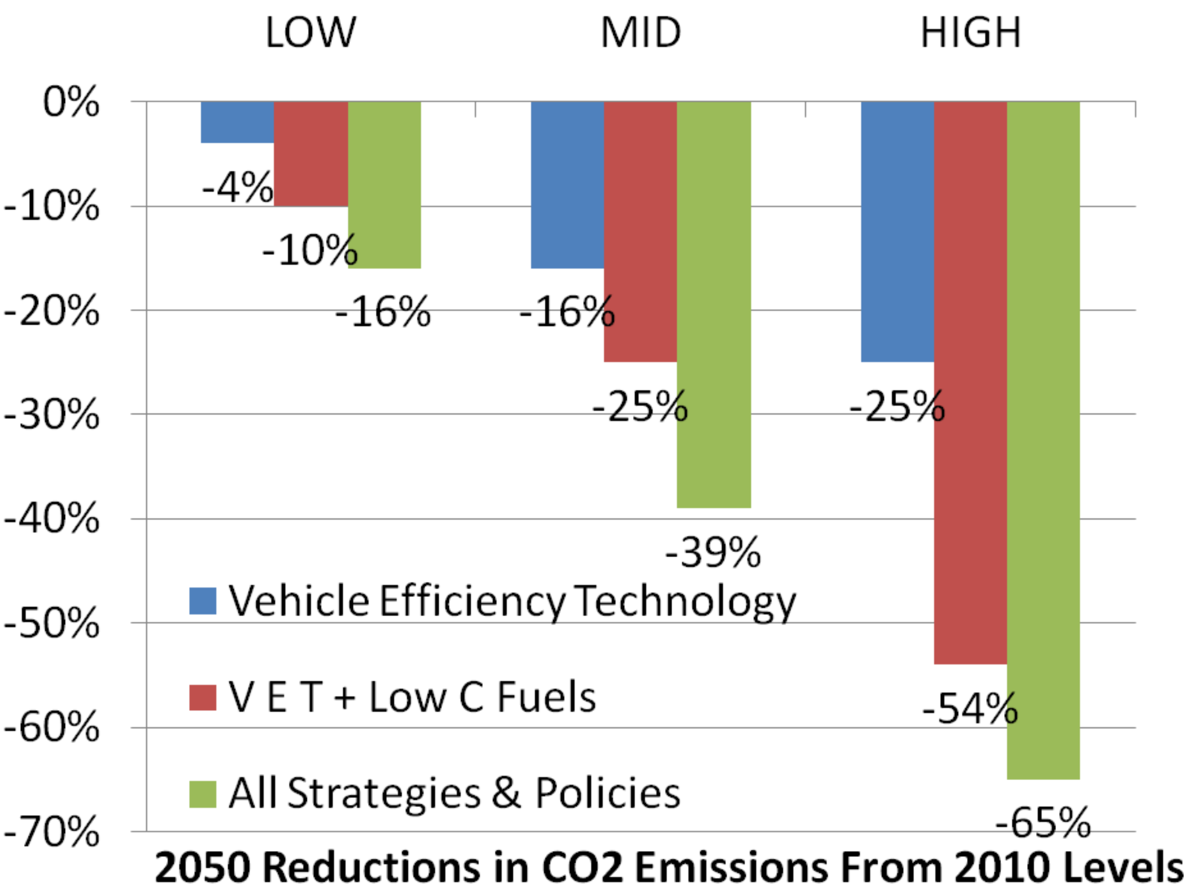
Achieving reductions in energy intensity of 50% or more could hold global transport energy use to today's level in 2050 and reduce the need for alternative low-carbon energy by a factor of 4.

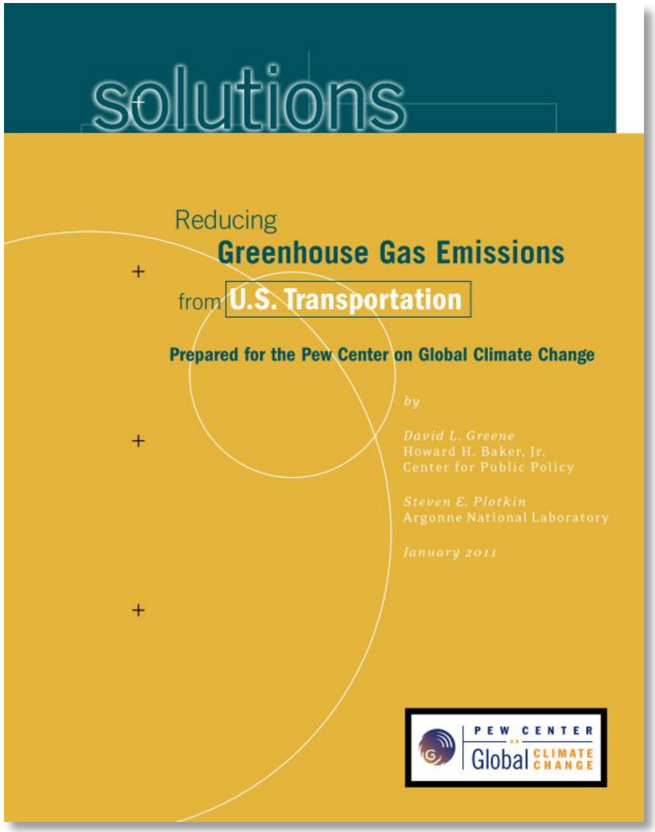
Table 1. Impact of Transport Energy Efficiency Improvement on Energy Use in 2050 (Exajoules)

Mode	Energy Use 2007	Growth Rate %	Extrapolated Energy Use 2050	Efficiency Improvement (% reduction)	Efficient Energy Use 2050	Energy Use With Rebound 2050
Road	103	2.0%	241	70%	72	87
Air	11	3.0%	39	60%	16	18
Water	9	2.0%	21	50%	11	12
Rail	5	1.0%	8	50%	4	4
TOTAL	128		309		102	121

A balanced, cost-effective strategy for mitigating GHG emissions and reducing petroleum dependence will include more than efficiency improvement. And there are other transportation issues.

MATE CHANGE

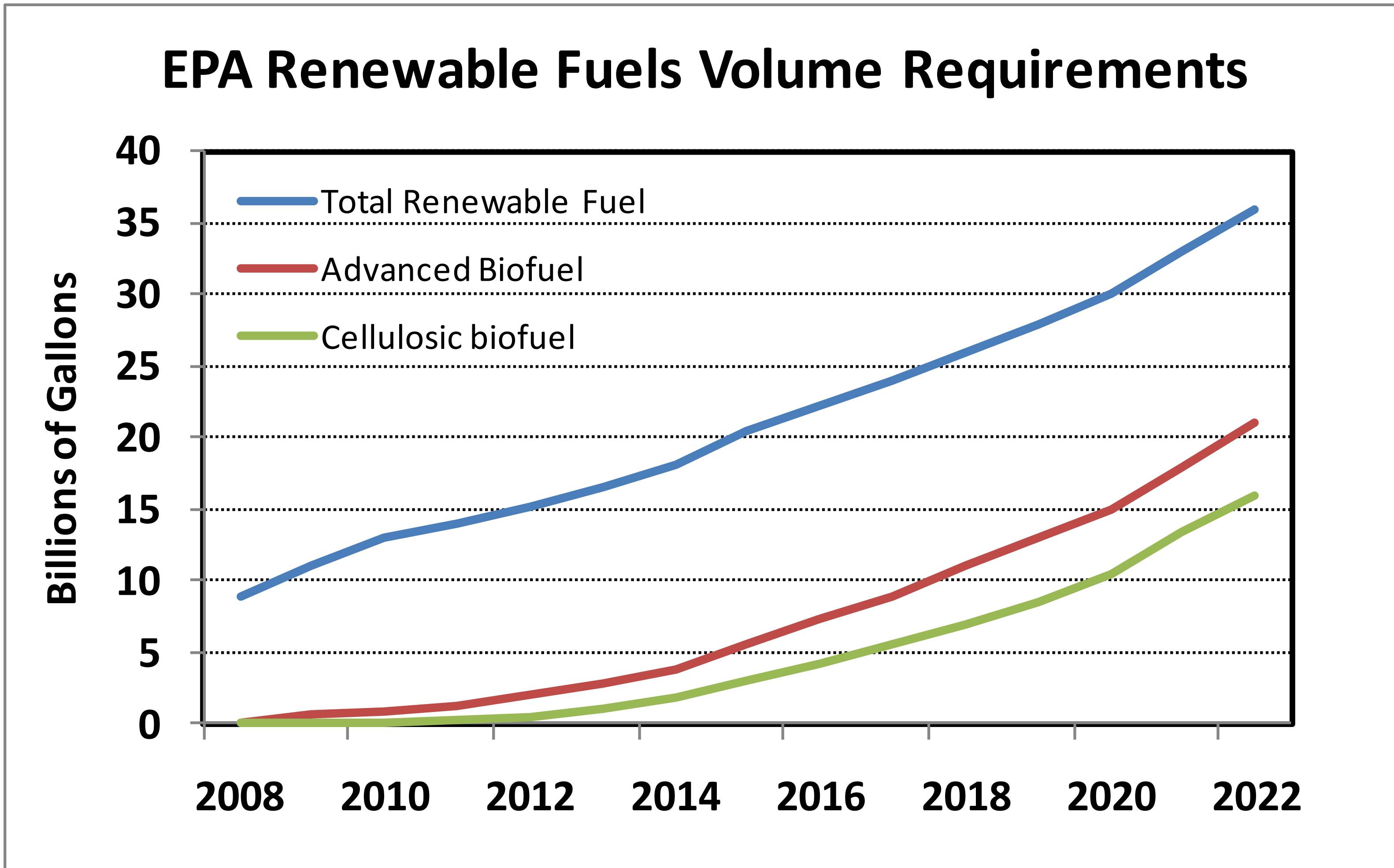




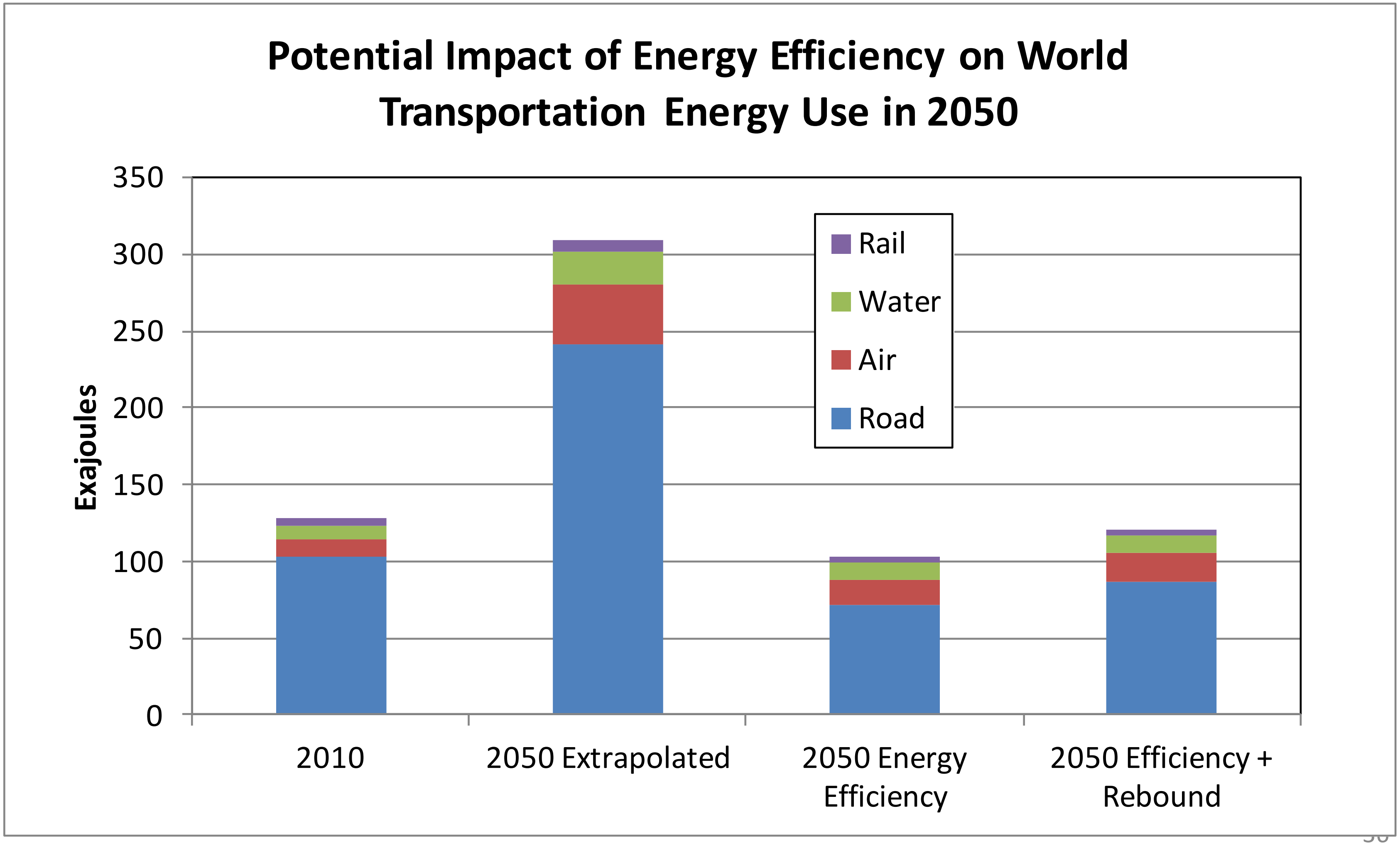
AASHTO

U.S. Department of Transportation
Federal Highway Administration

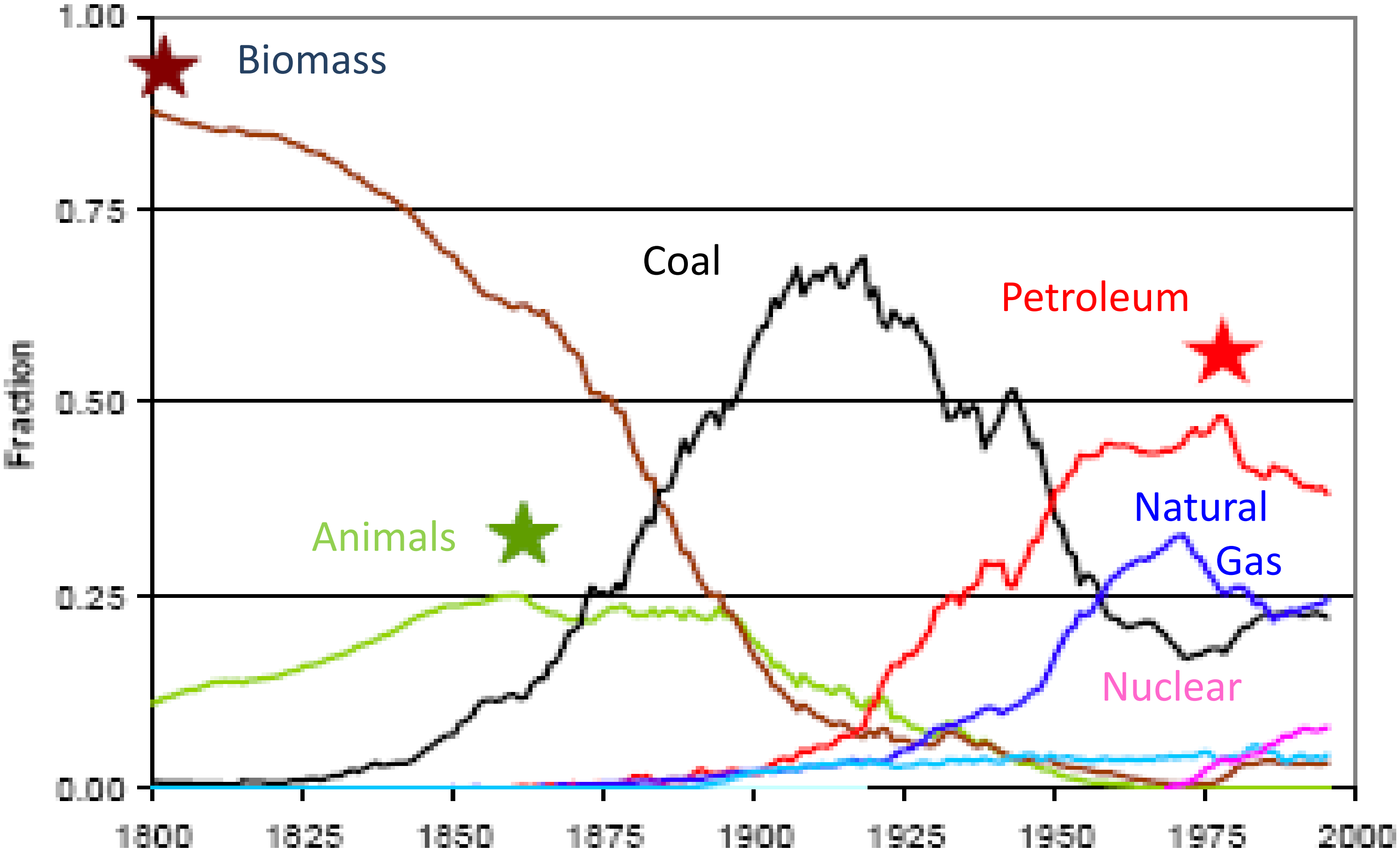
The Renewable Fuels Standard 2 is ambitious but cellulosic biofuel is off to a very slow start. 2011 requirement of 250 million gallons reduced to 6.6 million. Major questions remain.



Holding transportation energy use to today's level would buy time for an energy transition and help make it affordable. But it won't happen without technological advances and effective public policy.



The great energy transformations of the past were driven by technology and market forces.
Achieving a transition for the public good poses a new challenge.



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

THANK YOU.