Institute of Transportation Studies
University of California, Davis
Energy & Transportation Science Division
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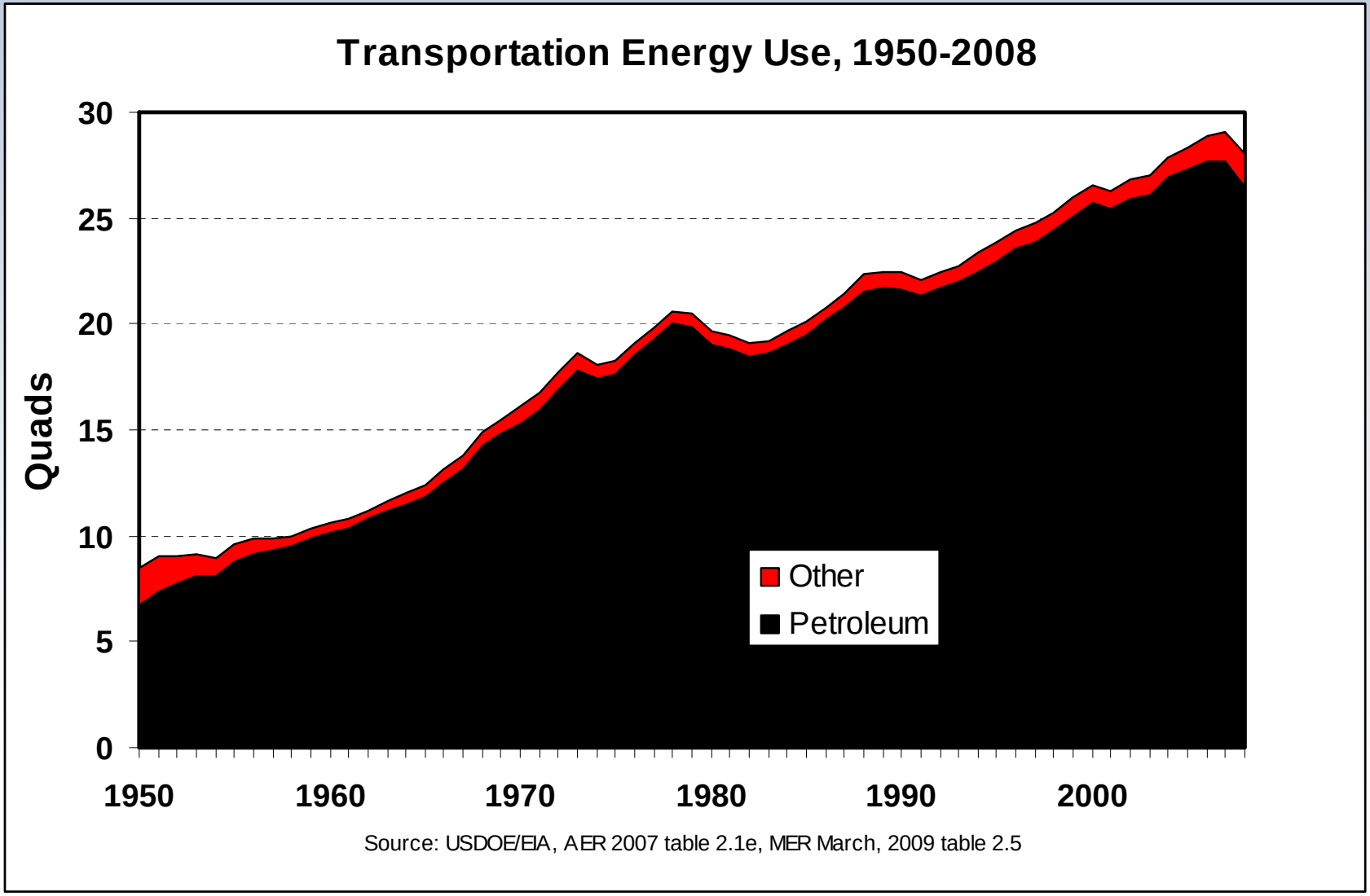
Transportation's Energy Transition

The 2009 Energy Conference
Energy Information Administration

April 7, 2009

ITS UC DAVIS fifteen years THE JOURNEY HAS JUST BEGUN

Petroleum, petroleum and petroleum.



Source: USDOE/EIA, AER 2007 table 2.1e, MER March, 2009 table 2.5

Depletion of conventional oil *outside of OPEC* combined with OPEC's market power and long-term economic interests will require a transition from conventional petroleum to…..

- All the possible options have risks and uncertainties
  - Unconventional petroleum sources
  - Biofuels
  - Hydrogen
  - Electricity
- Can we also achieve our energy goals?
  - Climate protection – 50-80% GHG reduction by 2050
  - Energy security – 11 mbd change in US petroleum Supply/Demand balance by 2030
  - Sustainable energy - ?

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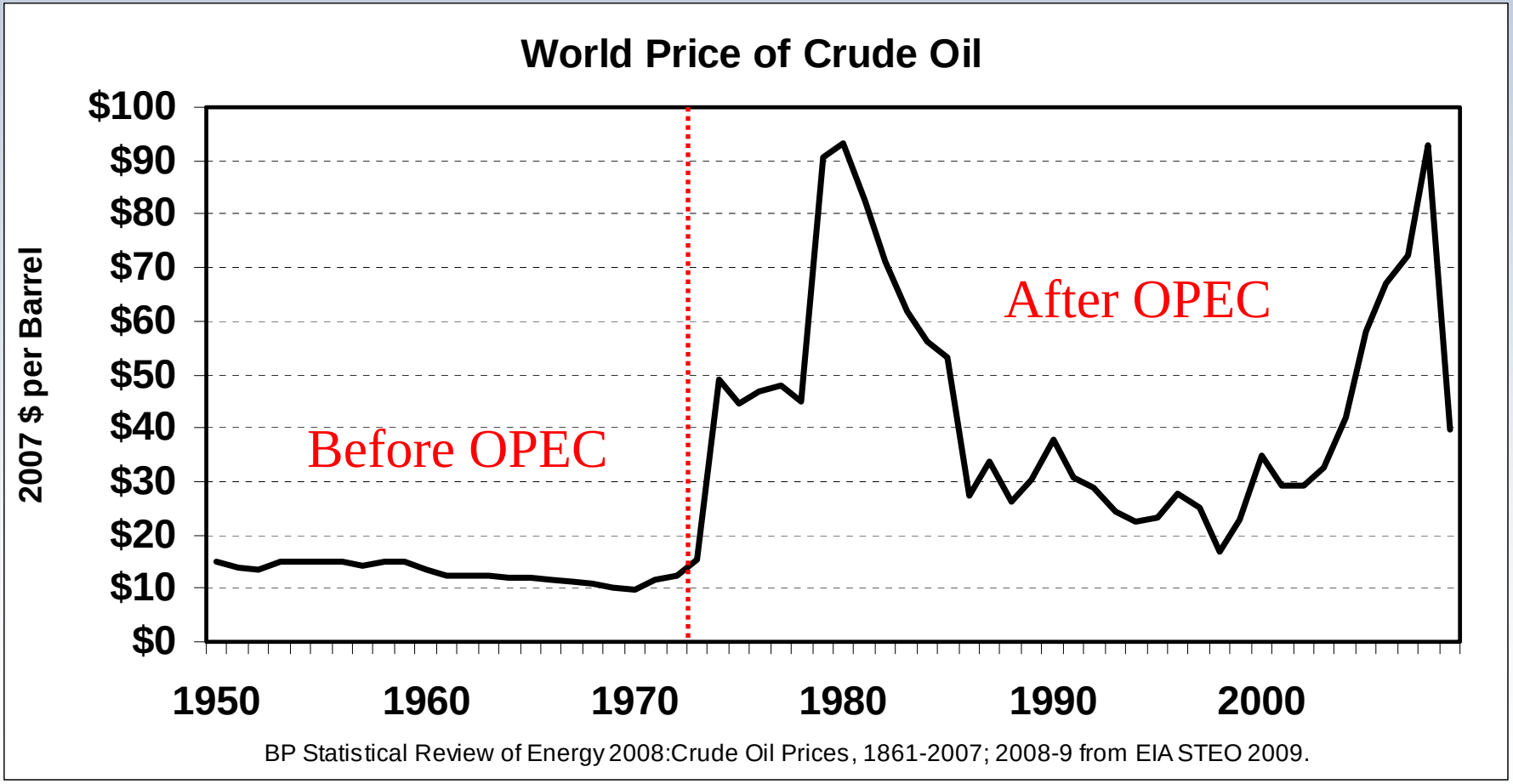
"The real problem we face over oil dates from after 1970: a strong but clumsy monopoly of mostly Middle Eastern exporters operating as OPEC." Prof. M. Adelman, MIT, 2004.



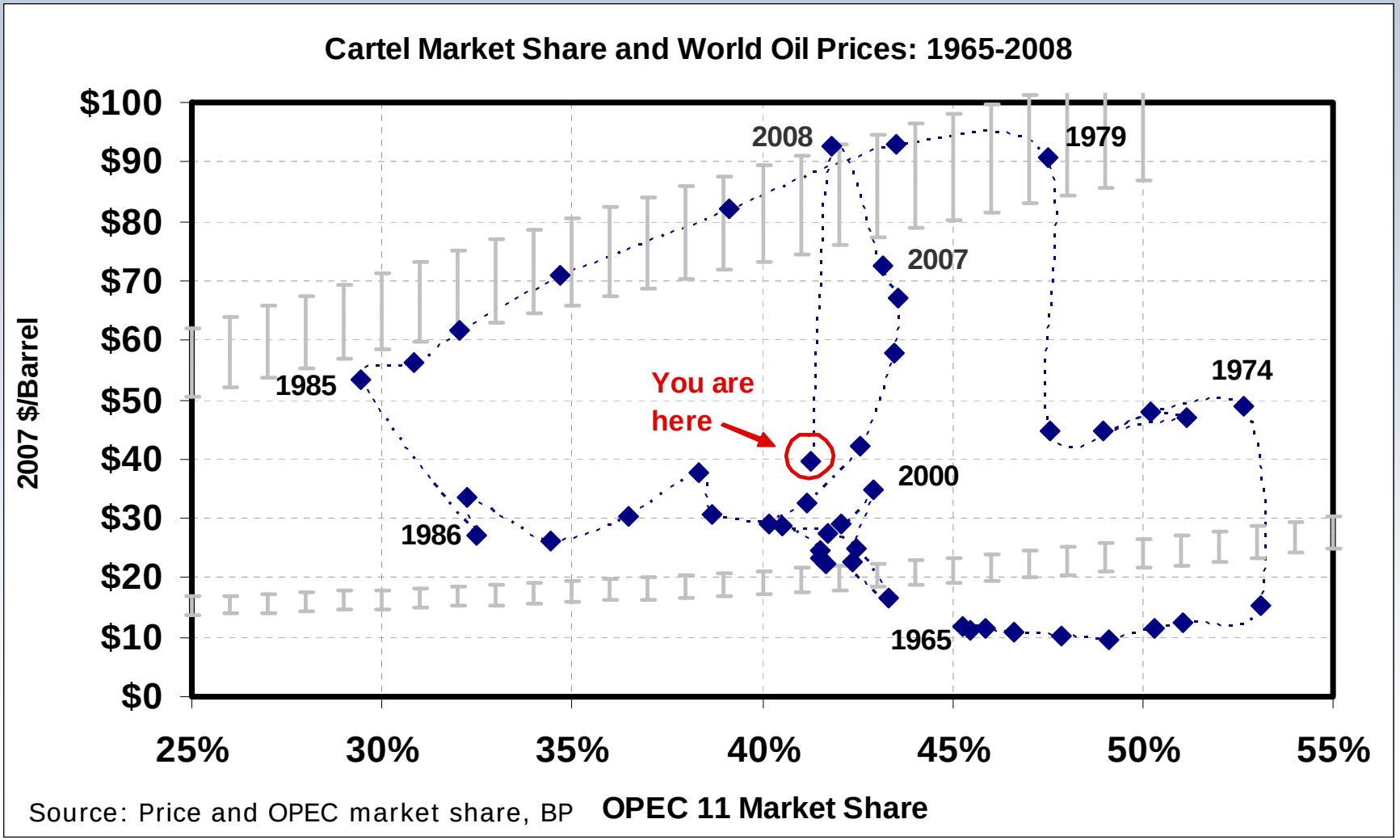
The economic theory of the behavior of partial monopolists, like the OPEC oil cartel, was developed more than half a century ago by Heinrich von Stackelberg.

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

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.

The past 35 years of oil market experience fit the partial monopoly theory remarkably well.



Oil demand elasticities: Long-run = -0.7, short-run = -0.105
Oil supply elasticities: Long-run = 0.60, short-run = 0.06
Assuming linear, annual lagged-adjustment functions, elasticities at $28/bbl.

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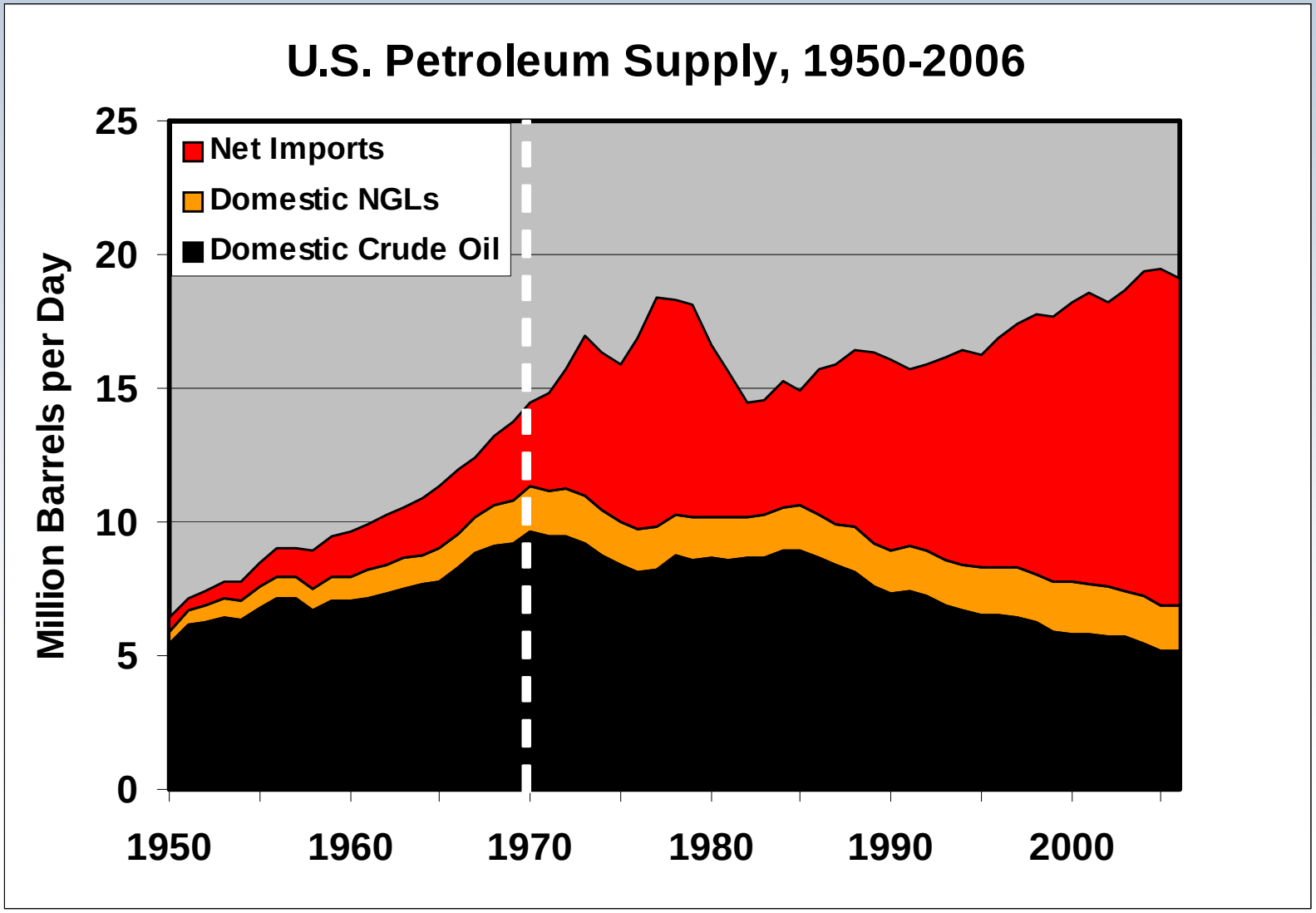
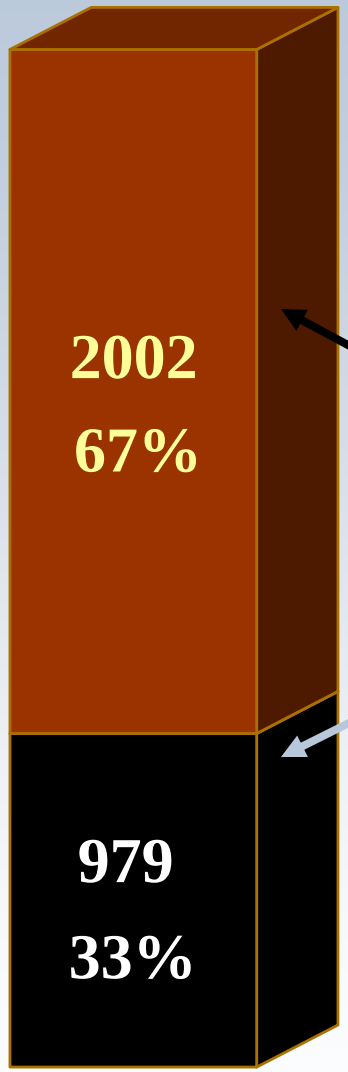
In the early 1970s the cartel's market power was strengthened by growing world demand, its increasing market share and… the *peaking of US crude oil production* in 1970.



The RATE of world oil use should be 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.

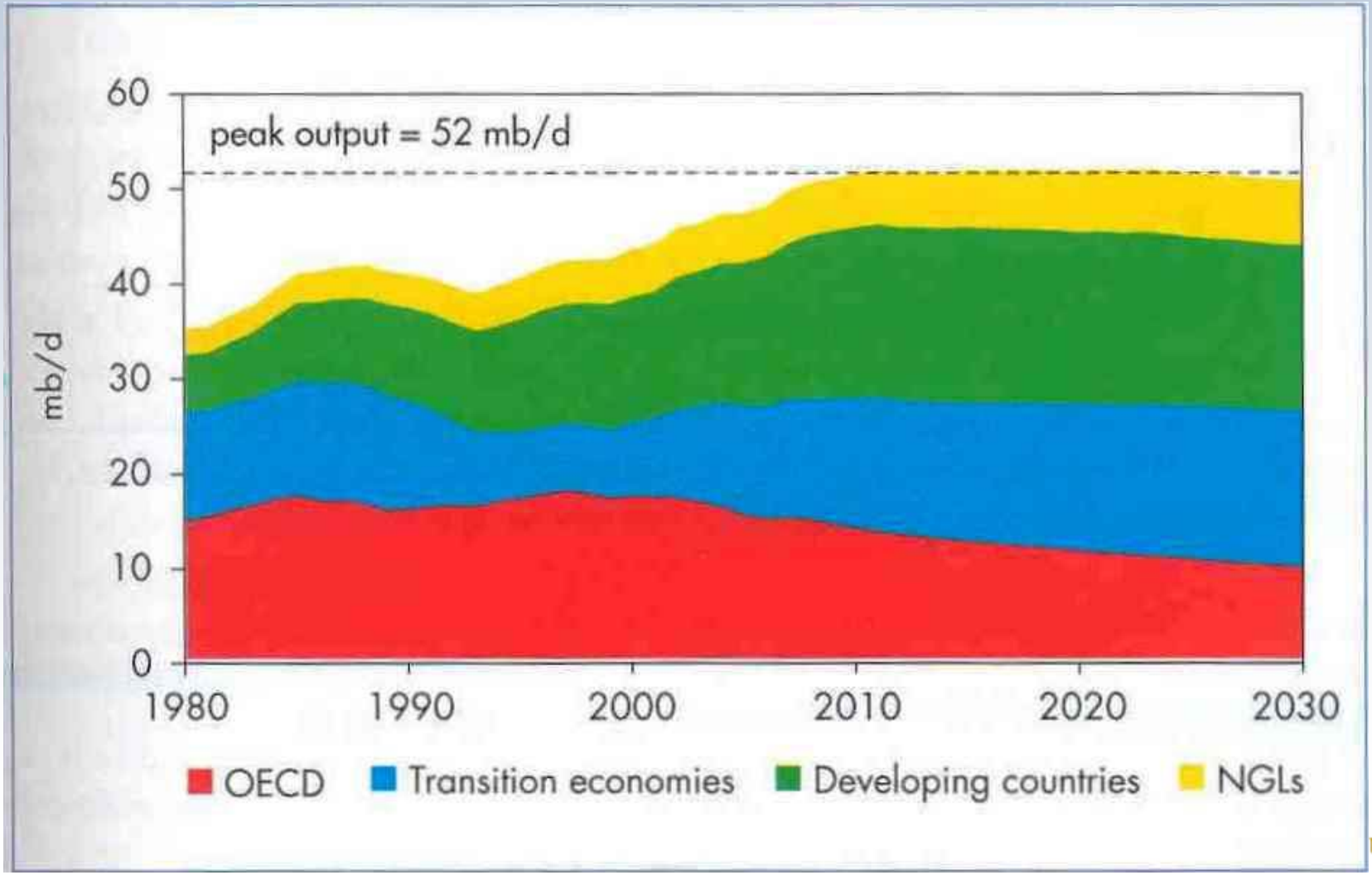
Remaining recoverable conventional crude oil*
Not reserves, ULTIMATE RESOURCES

Cumulative Production to end of *2005*

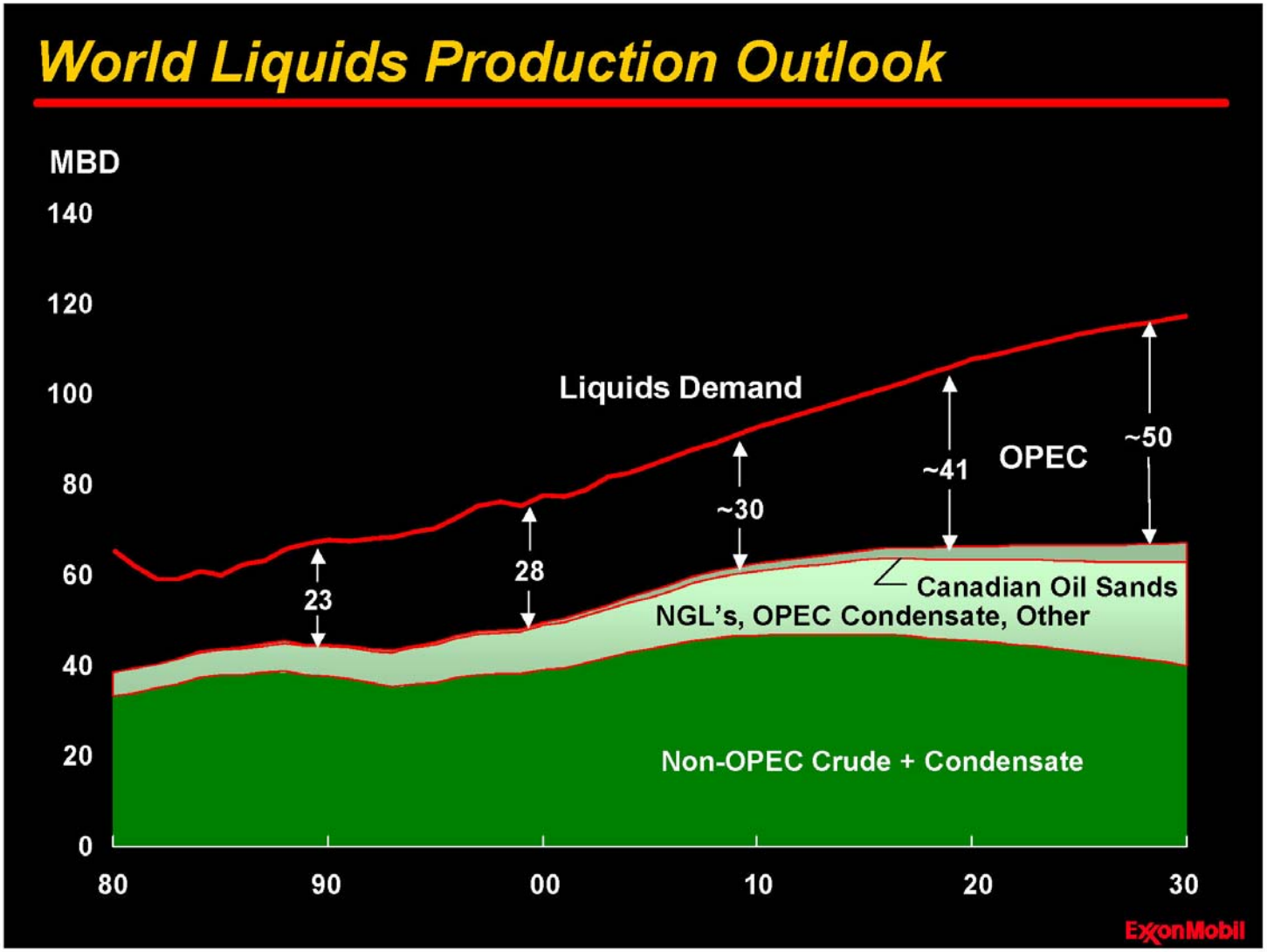
Cumulative Production to the end of *1995* was 710. Over ¼ of all oil ever consumed was consumed in those 10 years.

* From USGS 2000, USGS 1995, and MMS 1996

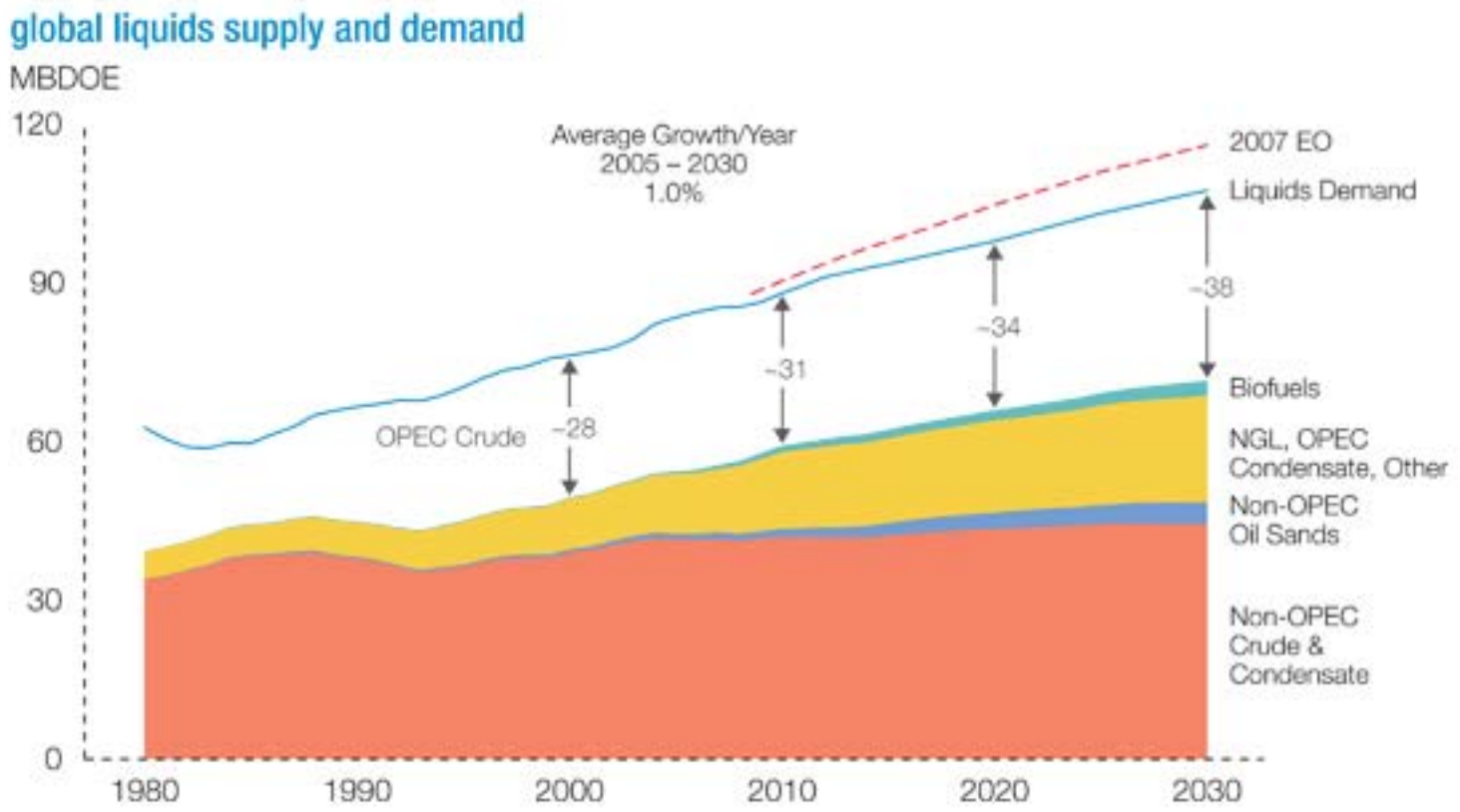
In 2005, the International Energy Agency foresaw a non-OPEC plateau with OPEC supply and unconventional resources filling the gap between non-OPEC supply and growing world demand.



ExxonMobil also saw a non-OPEC peak coming.



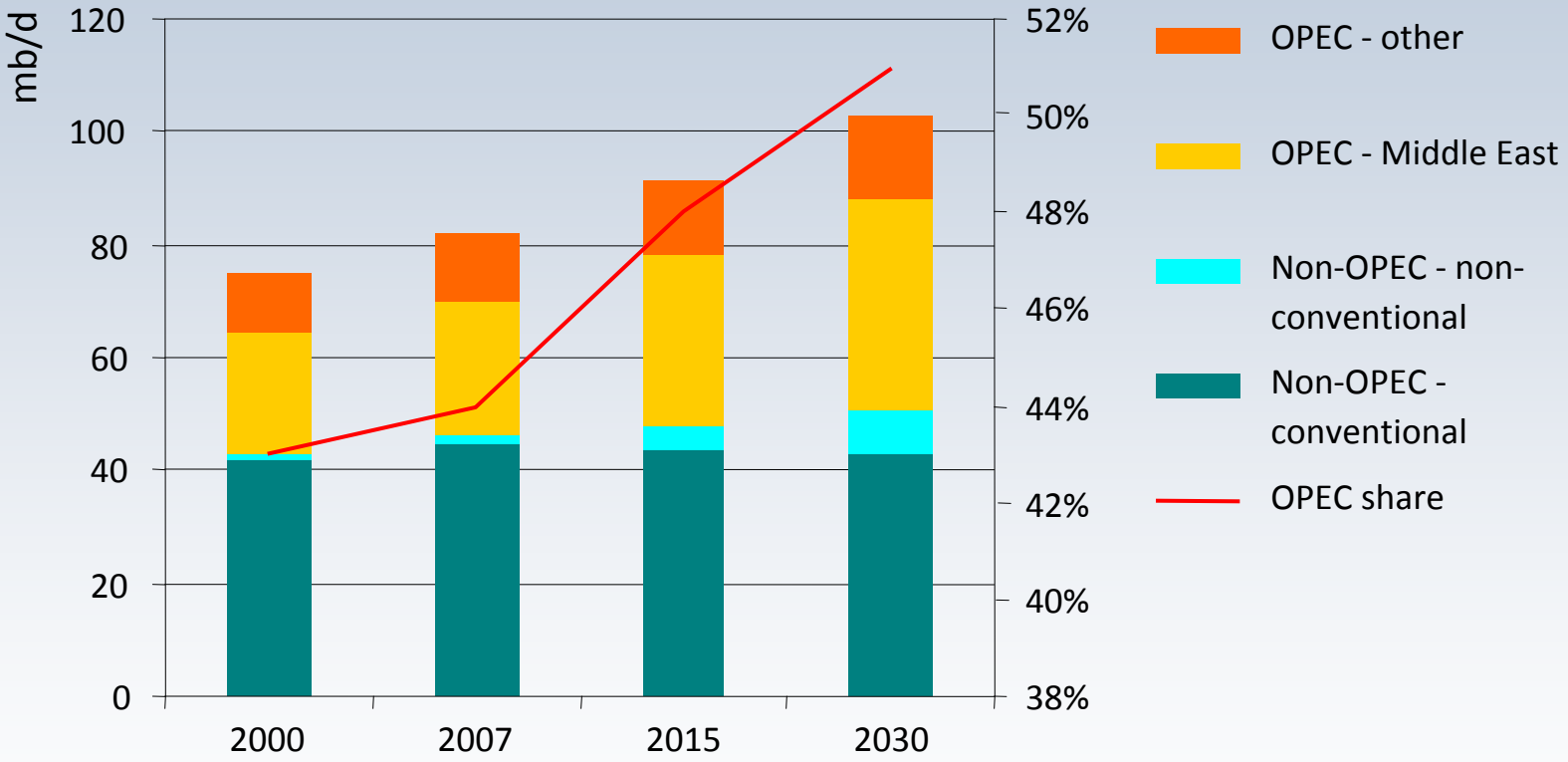
ExxonMobil's 2008 energy outlook was not much more optimistic. Price matters, but not that much.



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

IEA *does* model oil depletion and oil peaking. But the WEO does not reflect OPEC behavior.

World oil production by OPEC/non-OPEC in the Reference Scenario (Lew Fulton, IEA, today)



Production rises to 104 mb/d in 2030, with Middle East OPEC taking the lion's share of oil market growth as conventional non-OPEC production declines

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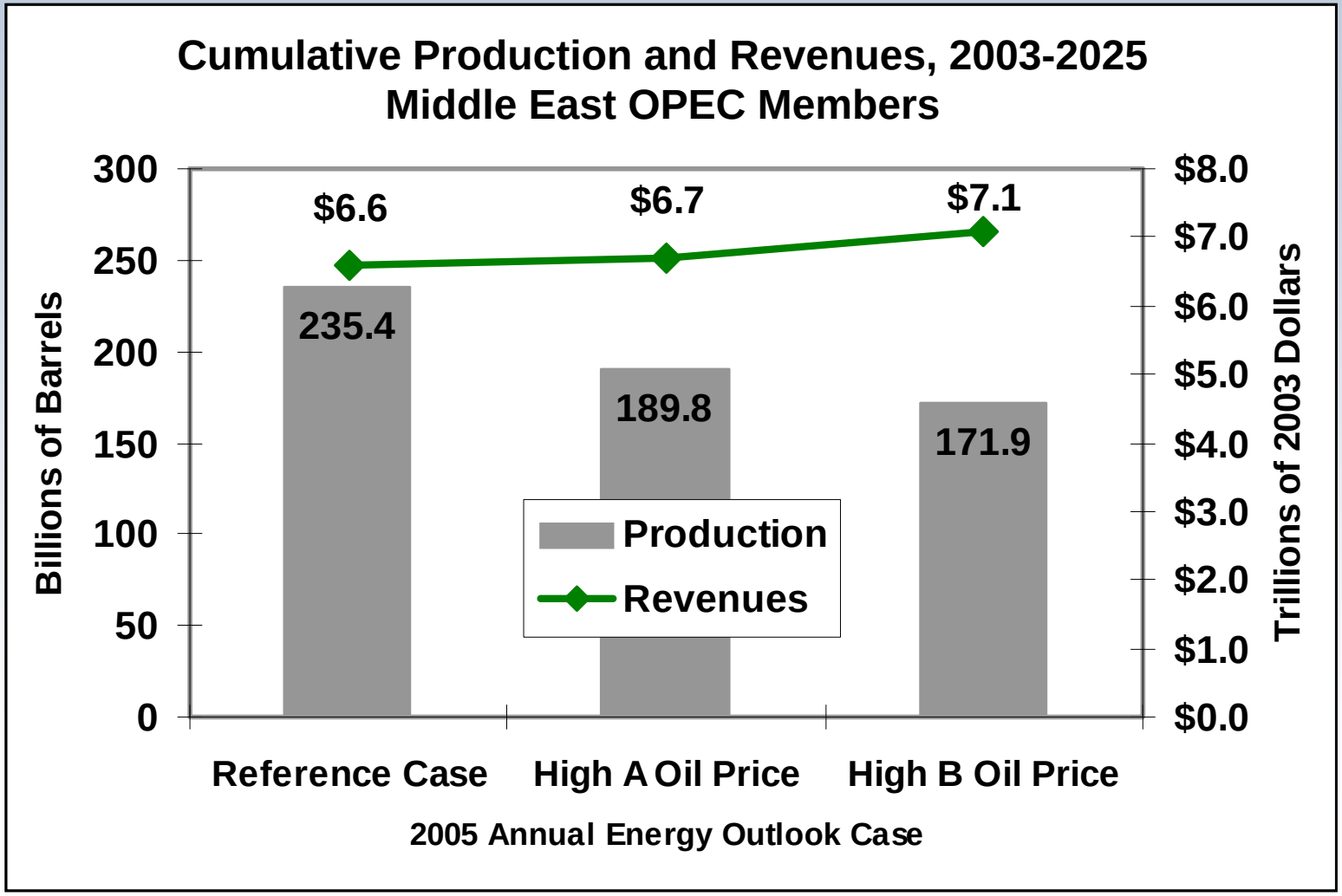
OPEC will not “fill the gap” because they can make more money by leaving the oil in the ground for future generations.



U.S. DOE/EIA, Annual Energy Outlook 2005.

Where does this leave us?

- OPEC will not fill the gap. Something else will.
- “Plenty” of unconventional sources of oil, but…
  - Higher GHG emissions by 10% to 100% (except EOR), which makes petroleum look like a low carbon alternative.
  - Capital intensive, often water intensive and environmentally challenging development.
  - Uncertain policy environment.
- How large a role for biofuels?
  - “Billion ton” study suggested 30%, but…
  - What’s the real benefit given indirect land use effects?
  - Does our biofuels policy make sense?
- Hydrogen? Electricity?
  - Technological breakthroughs required
  - New fuel infrastructure for hydrogen

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What should we do now, given that the necessary technological advances remain uncertain?

- **What are our (quantitative) energy goals?**
  - CLIMATE PROTECTION: 50% to 80% reduction in GHG emissions by 2050 **(-60%)**
  - OIL SECURITY: Reduced demand + Increased supply = **11 mmbd by 2030**
  - SUSTAINABLE ENERGY: ?
- Business-as-usual policies will not get it done.
- Current technology will not get it done.

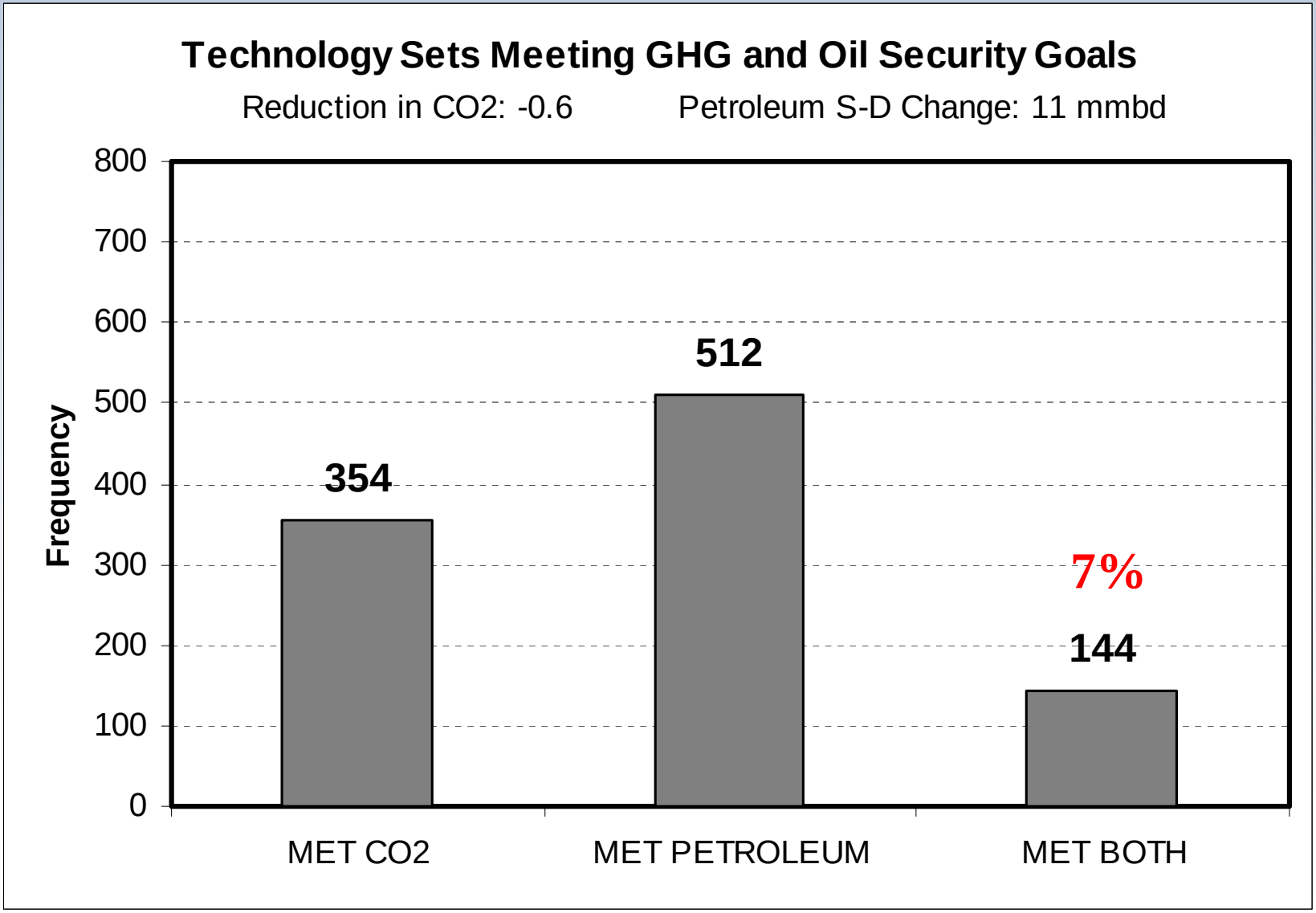
Potential effects of 11 advanced energy technologies on GHG emissions in EIA 2008 Frozen Technology Scenario by 2050.

Carbon Capture & Storage	Coal & gas emission -90%, energy intensity +10%
Nuclear Electricity	Nuclear share from 12% to 32%
Wind Electricity	Replace 18% coal, 50% natural gas
Solar Electricity	Replace 15% primary energy for electricity
Bio-Energy	Displace 3.7 Q for electricity, 6.7 Q additional biofuels for transportation (70% lower GHG)
Electric Drive Vehicles	**Displace 13.2 Q petroleum, increase electricity demand by 6.6 Q**
Transportation Efficiency	**Reduce overall energy intensity by 35%**
Buildings Efficiency	Reduce overall energy intensity by 50%
Industrial Efficiency	Reduce overall energy intensity by 30%
Efficient Generation & Grid	Reduce system-wide energy intensity by 30%
Advanced Fossil Liquids	**W/o CCS increase carbon intensity by 15%**

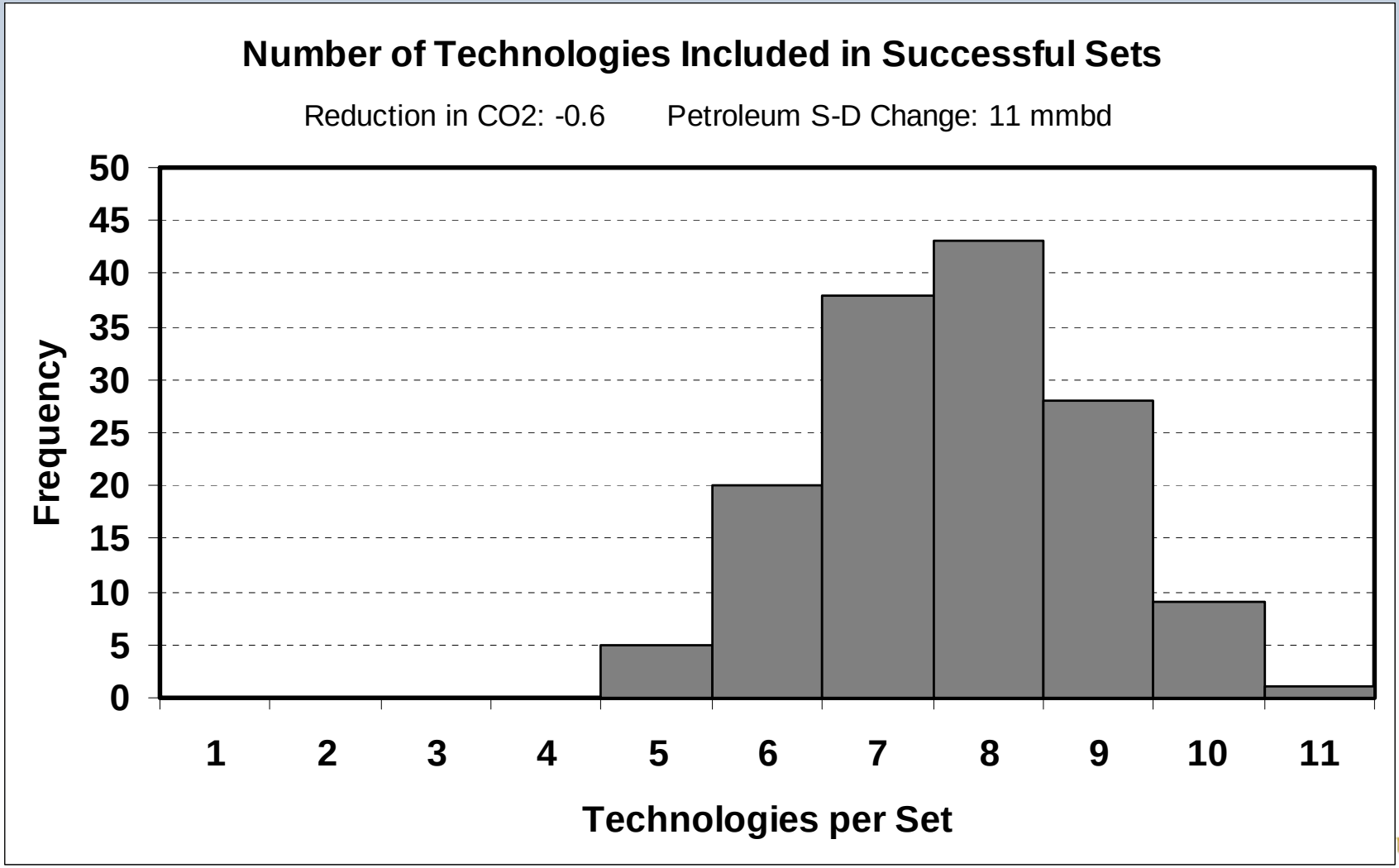
Potential effects of 11 advanced technologies on petroleum supply and demand in 2030.

Carbon Capture & Storage	No direct impact. Reduces carbon intensity of Coal-to-liquids.
Nuclear Electricity	No impact.
Wind Electricity	No impact
Solar Electricity	No impact.
Bio-Energy	Displace 6.7 Q additional petroleum in transportation, 0.7 Q in industry
Electric Drive Vehicles	**Displace 2.5 Q petroleum**
Transportation Efficiency	**Reduce overall energy intensity by 16%**
Buildings Efficiency	Eliminate 2 Q petroleum use in buildings
Industrial Efficiency	Reduce overall energy intensity by 10%
Efficient Generation & Grid	Eliminate petroleum use: -0.9 Q
Advanced Fossil Liquids	Additional domestic supply of 10.1 Q (4.7 mmbd): unconventional oil, EOR, envir. responsible oil production in environmentally sensitive areas.

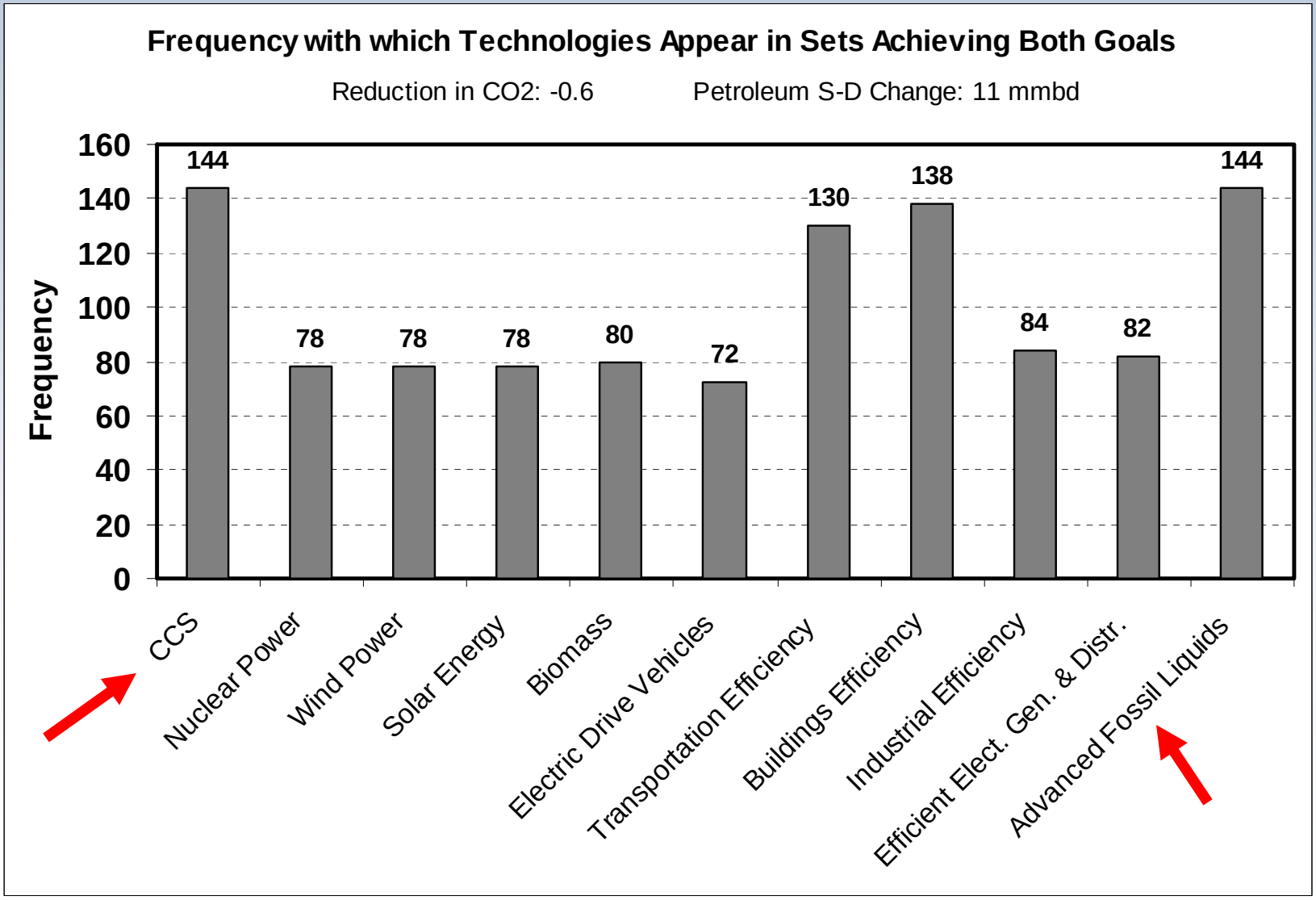
ALL of the eleven technologies are uncertain. If successful, which combinations (out of 2,048) could achieve the energy goals?



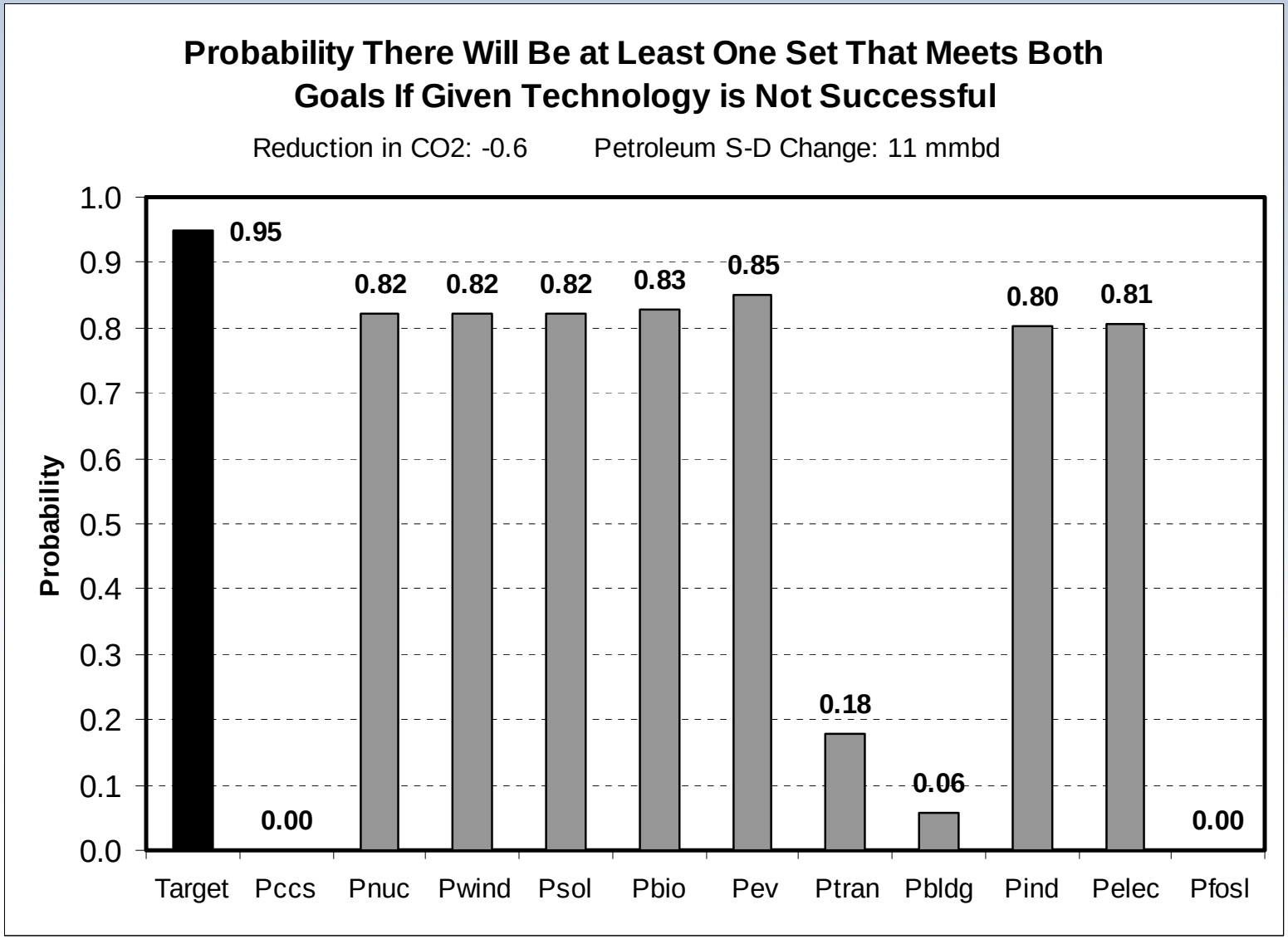
Almost every successful case includes a majority of the technologies.



Two technologies, CCS and Advanced Fossil Liquids, appear in every successful set.



If we want to be 95% sure of meeting both goals we must be 60% certain of successfully developing each technology. How is the 95% certainty affected by the failure of any particular technology?



What does this imply for a successful energy transition for transportation?

- Establish CCS as a proven technology.
- Produce more conventional oil environmentally responsibly, especially via Enhanced Oil Recovery, and work hard to prove technologies like in situ shale oil production.
- Reduce ***Energy Intensity*** of NEW transportation vehicles by 30% to 50% by 2030; across all modes.
- Achieve Biofuel goals with the right kinds of truly low carbon biofuels for the right applications.
- Research, Develop and Demonstrate advanced Energy Efficient Technologies and Hydrogen FCVs, PHEVs and Battery EVs, and subsidize Market Creation as electric drive technologies mature.

THANK YOU.