Transforming Transportation

Toward a Very Efficient, Low-Carbon Energy Future

…as seen by a policy wonk, regulator, and academic

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University of California, Davis

and

Board Member, California Air Resources Board

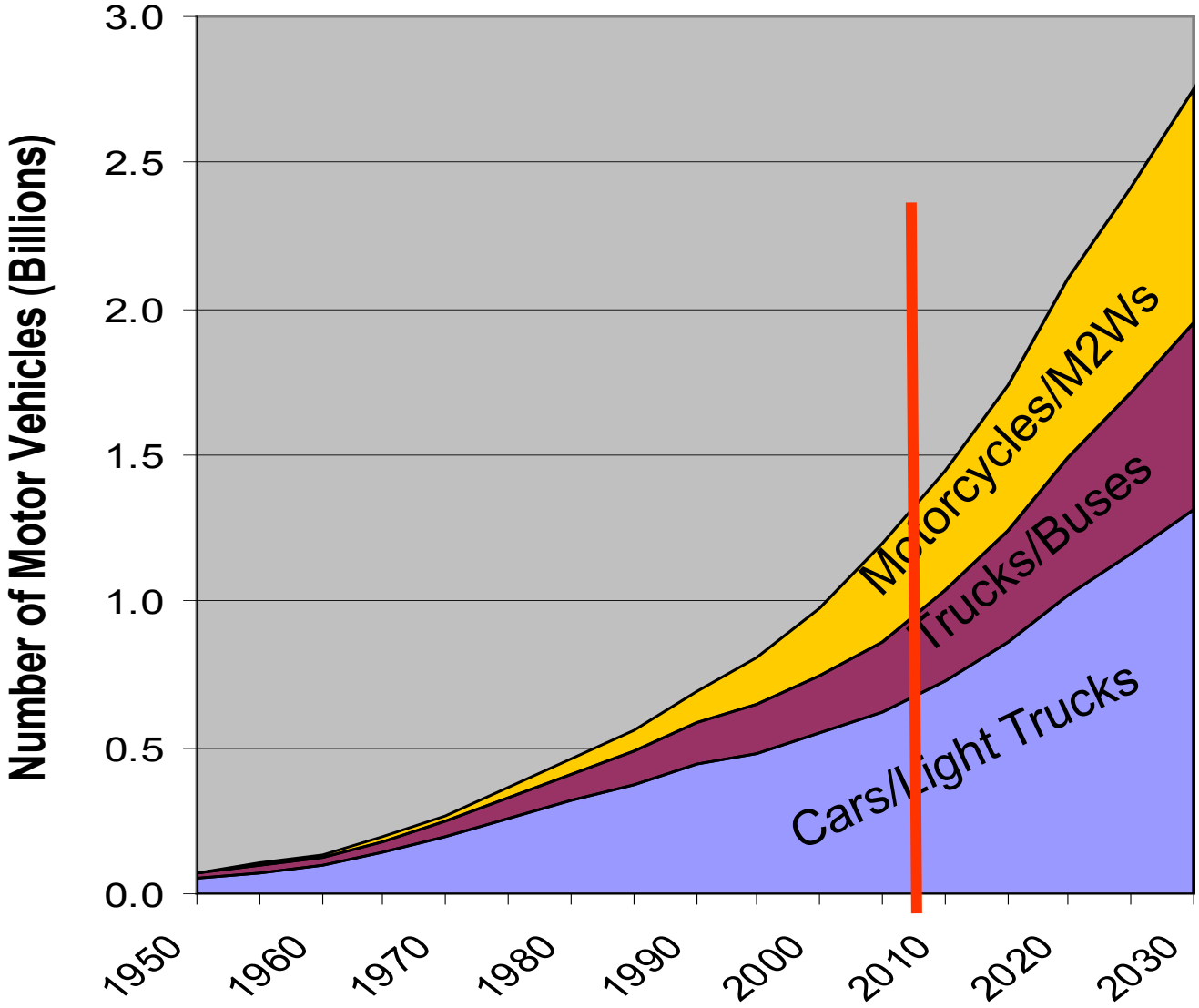
DOE Annual Merit Review

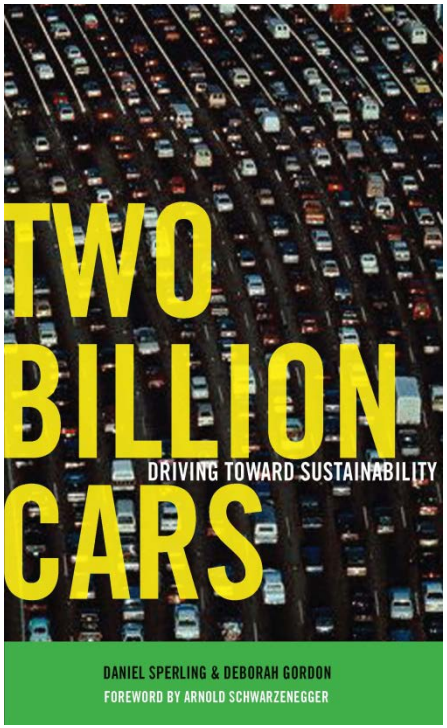
Arlington, VA

14 May 2012

Good news and bad news

Soaring Global Demand for Vehicles (and Oil)

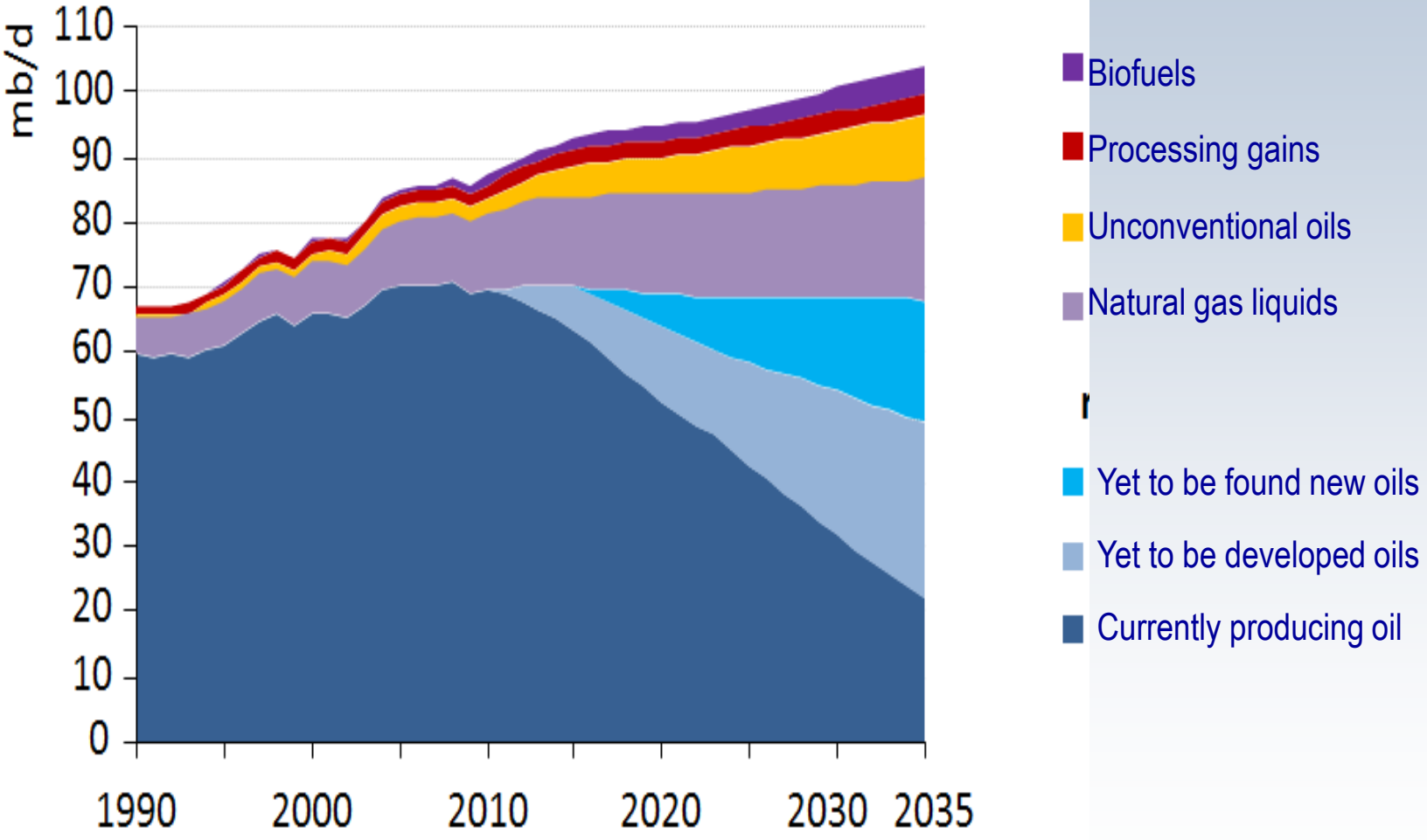




Sperling and Gordon (2009), based on DOE, JAMA, other

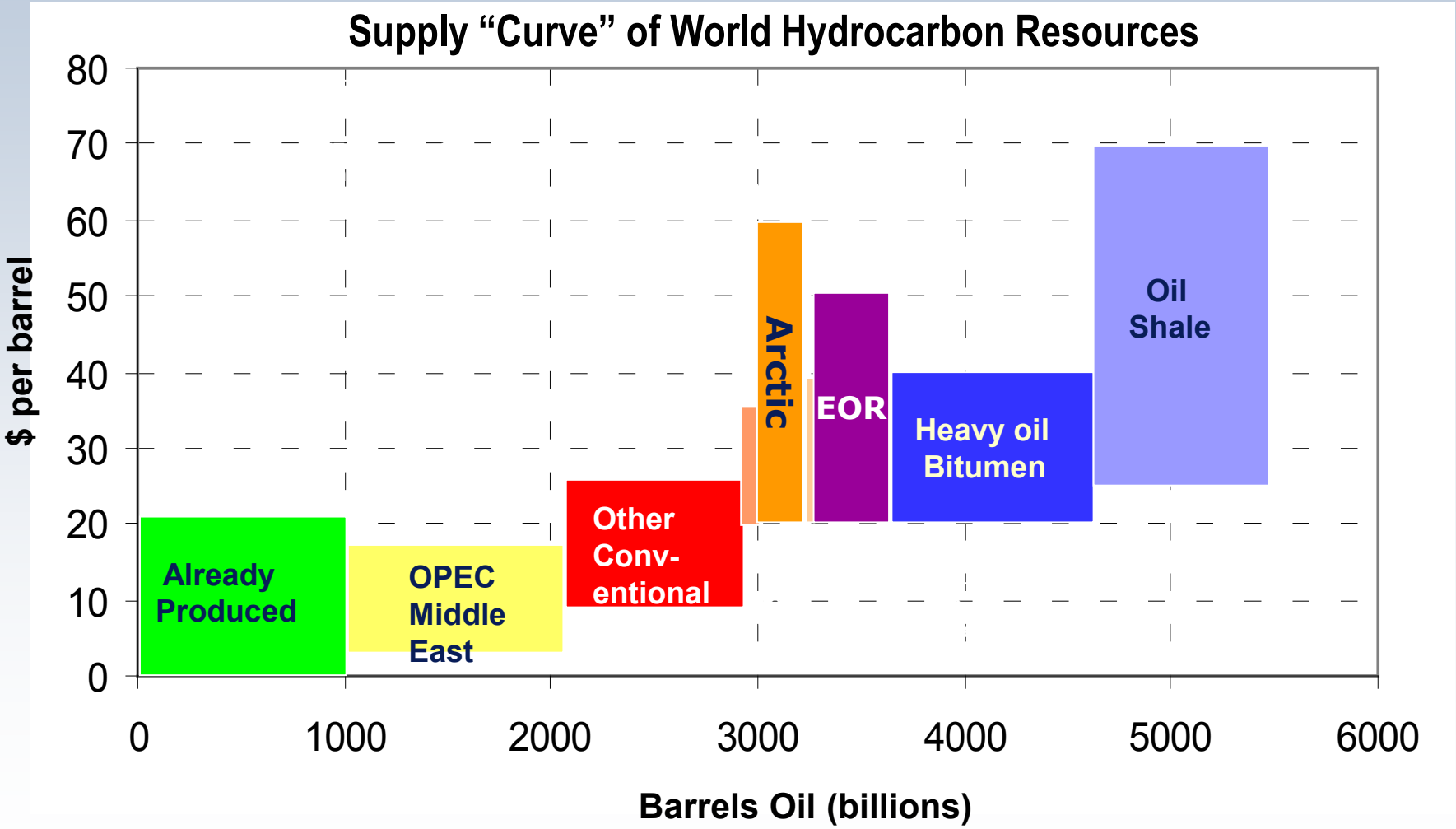

STAHLER.
THE COLUMBUS DISPATCH
2011
WE
MUST
REDUCE
OUR
DEPENDENCY
ON
MIDEAST
OIL.

“Oil” Ain’t What it Used to Be
(according to ExxonMobil)



Source: Exxon International Energy Agency, 2011 World Energy Outlook

Carbonization of Transportation Fuels



IEA, 2005

April
2006


APRIL 3, 2006
www.time.com AOL Keyword: TIME
SPECIAL REPORT GLOBAL WARMING
TIME
BE WORRIED. BE VERY WORRIED.
Climate change isn't some vague future problem—it's already damaging the planet at an alarming pace. Here's how it affects you, your kids and their kids as well
EARTH AT THE TIPPING POINT
HOW IT THREATENS YOUR HEALTH
HOW CHINA & INDIA CAN HELP SAVE THE WORLD—OR DESTROY IT
THE CLIMATE CRUSADERS

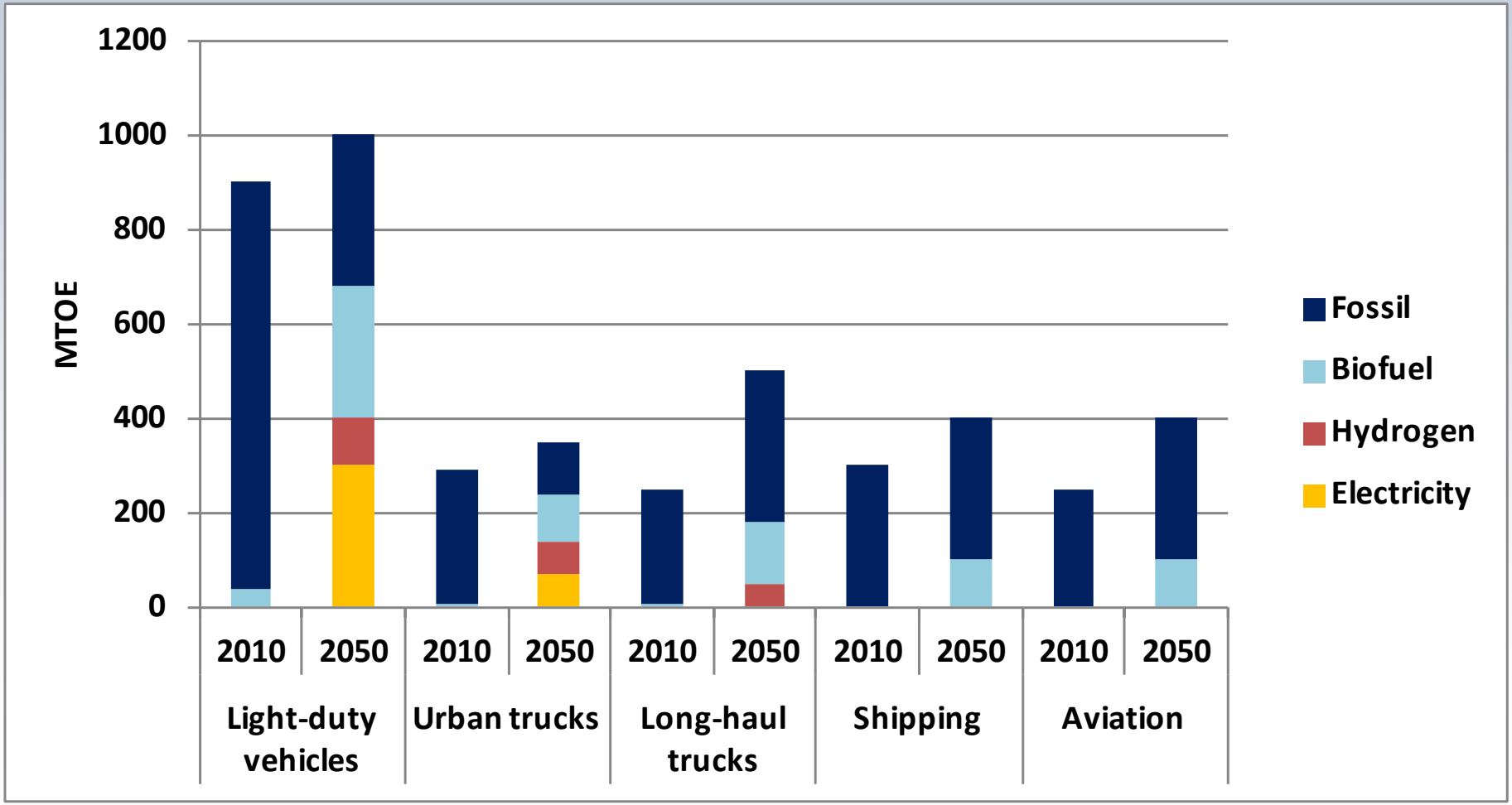
Even Oil Minister of Saudi Arabia Says…

"Greenhouse gas emissions and global warming are among humanity's most pressing concerns. Societal expectations on climate change are real, and our industry is expected to take a leadership role." (Jan 2012)

What does this mean for transportation?

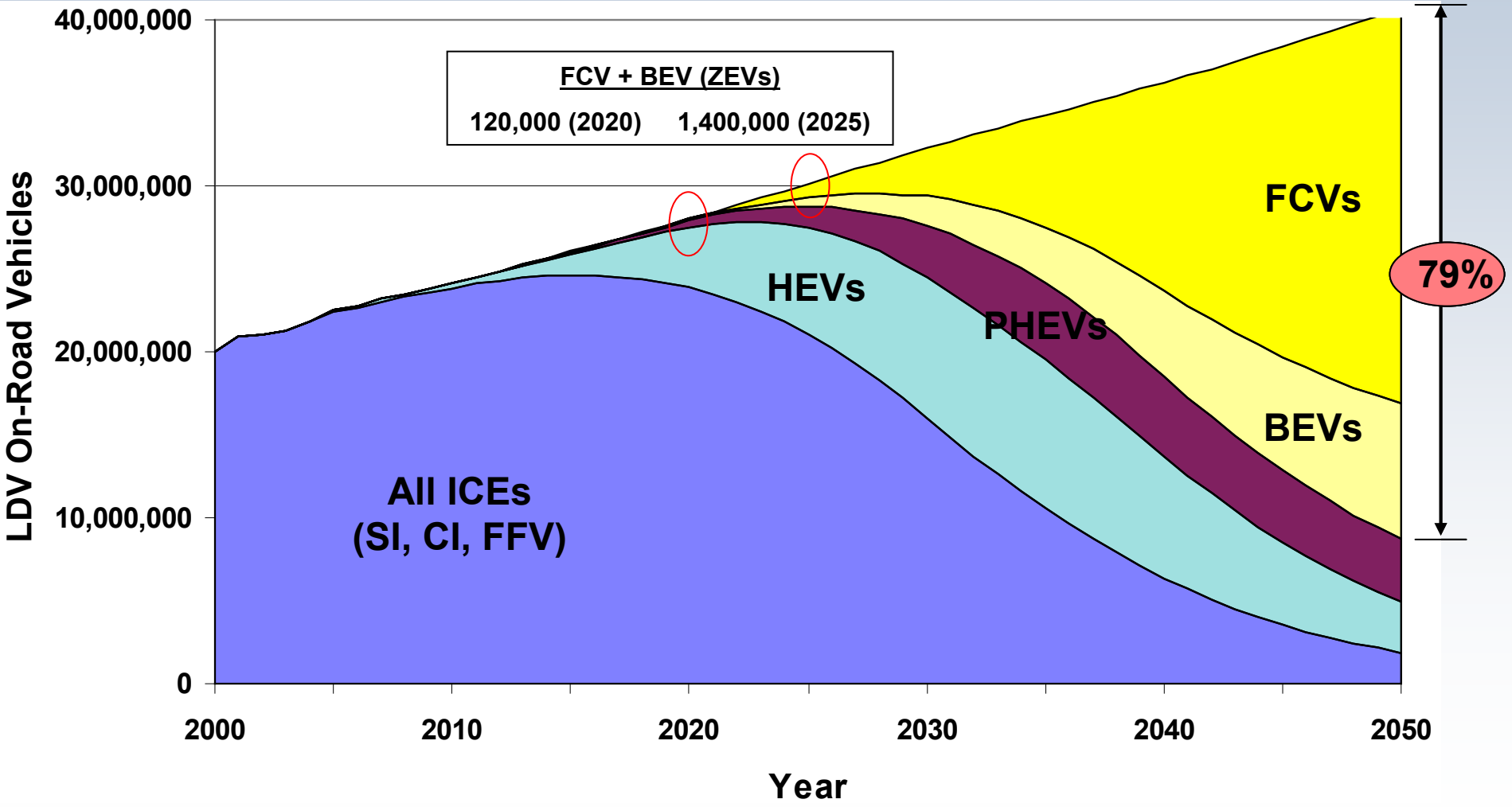
IEA 2050 Global Scenario to Meet 450 ppm (2°C)

75% of energy for LDVs & urban trucks is biofuels, H2, electricity



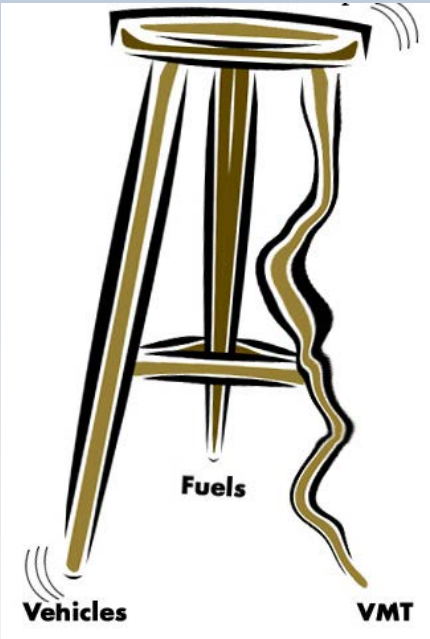
IEA, 2012, provided by Lew Fulton

California (CARB) Scenario for LDVs to Achieve 60-80% Reduction in GHGs by 2050



CARB scenario (2) for light duty vehicles, to justify aggressive ZEV requirements

Transforming Transportation



- Transforming vehicles
- Transforming fuels
- Transforming mobility

Why gov't initiative is needed (R&D and policy)

A Long List of Market "Failures"

- **Environmental and energy externalities**
- **Principal agent problem** (rental cars, truck trailers, company cars)
- **Network externality**. Complementary products requiring large *non-recoverable* investments and investments that cannot be made by individual consumers—such as when different vehicles or different infrastructures are required (H2, bike paths for biking, smart paratransit, etc)
- **Technology lock-in**
- **Market power** (cartels, oligopolies, etc)
- **High entry barriers in auto industry**
- **R&D under-investment** due to:
  - industry diffusion (ag industry)
  - R&D spillovers. When R&D findings cannot be fully captured (leading to under-investment in R&D)
  - Learning-by-doing spillovers where mfg savings not fully captured
- **Consumer cognition** (eg, buying cars), resulting in under-investment in efficiency (related to information and loss-aversion)
- **Volatile oil prices** create uncertainty which leads to under-investment in alternatives

1st Leg

The Motor Vehicle Revolution

Cars of future will be far more efficient and will be powered mostly by electric-drive

1) Vehicle efficiency improvements are far easier and less expensive than previously thought….

   Lightweight materials, transmissions, engines, hybridization

2) New evidence suggests that batteries and fuel cells will be far less expensive than previously thought

3) Trucks and planes are bigger challenges—modest increases in energy efficiency and dominant user of biofuels

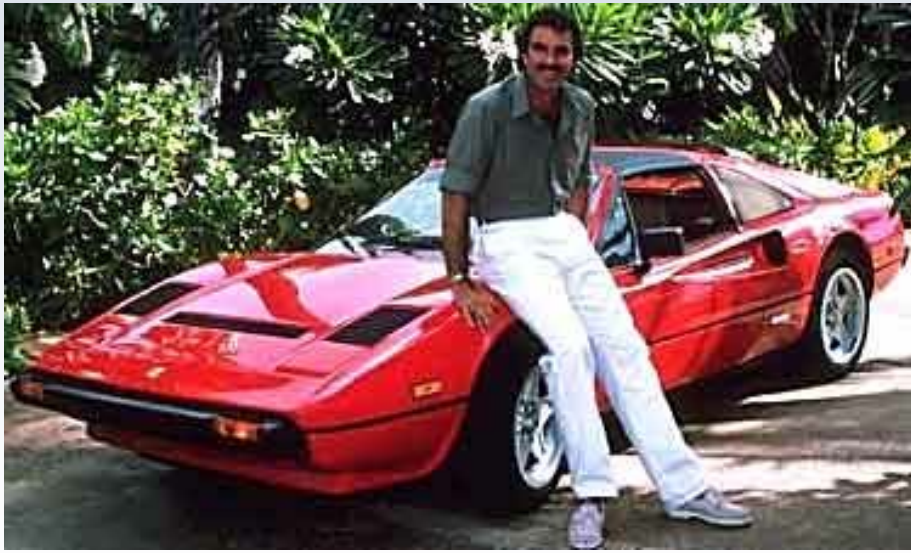
1st Leg
Vehicles

Horsepower Race is Over!

Toyota RAV4, 2008

7.3 seconds from 0-60 mph

Ferrari 308 GTS, 1984

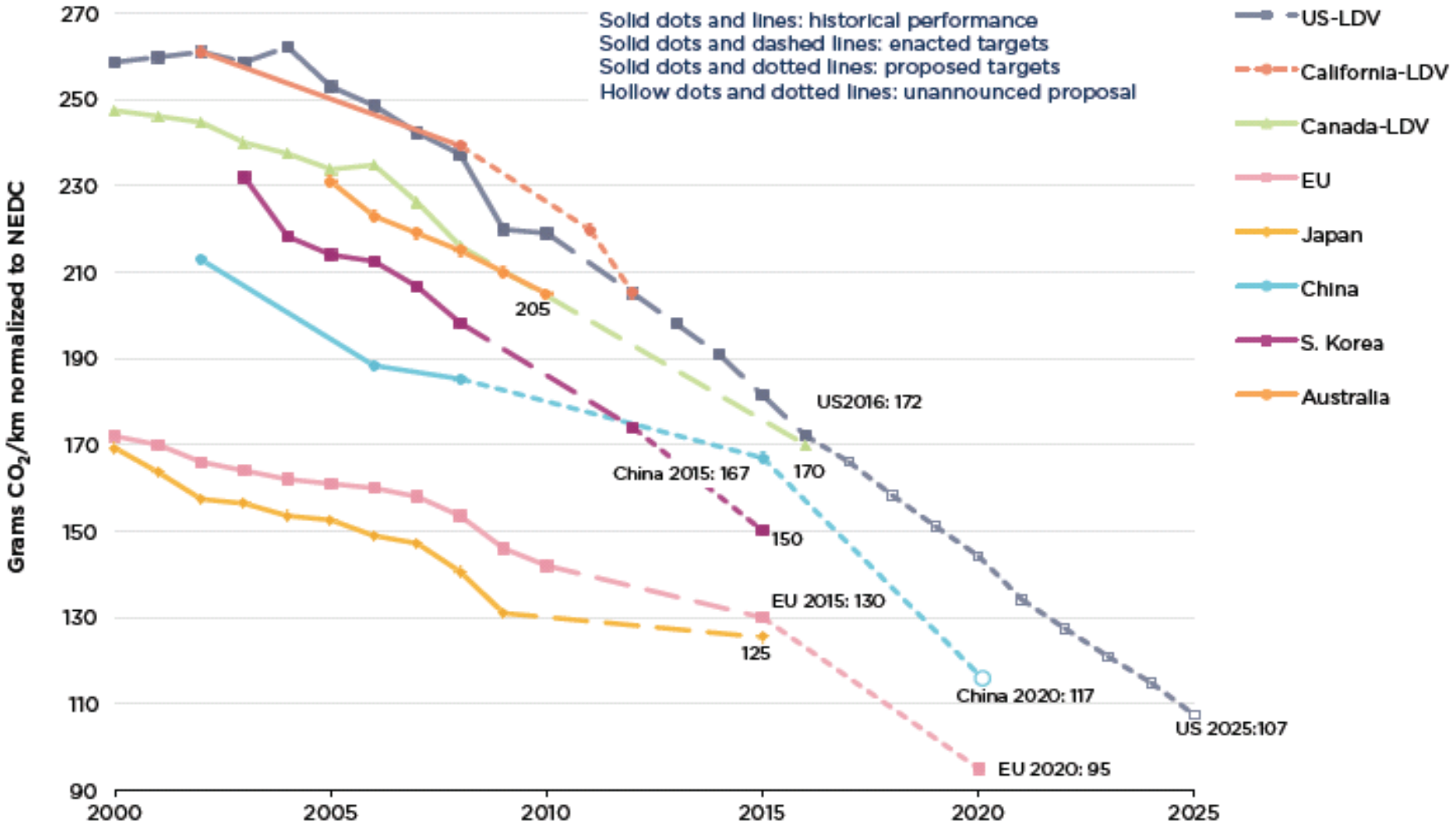


7.3 seconds from 0-60 mph

Tom Selleck as Magnum, PI

Vehicle Efficiency Improving Everywhere

(doubling in US from 2010 to 2025)



[1] China's target reflects gasoline fleet scenario. If including other fuel types, the target will be lower.
[2] US and Canada light-duty vehicles include light commercial vehicles.

Many Energy Efficient Technologies Are Being Commercialized—thanks to many in this room

Vehicle system	Technology	Approximate GHG-per-mile reduction *	Percent U.S. adoption (MY2008) #
Engine	Variable valve timing	2-8%	53%
	Cylinder deactivation	3-6%	6%
	Turbocharging	2-5%	2%
	Gasoline direct injection (stoich. and lean)	10-15%	4%
	Compression ignition diesel	15-40%	0.1%
	Digital valve actuation	5-10%	0%
	Homogeneous charge compression ignition	15-20%	0%
Transmission	5 speed	2-4%	32%
	6+ speed	3-5%	21%
	Continuously variable	4-6%	8%
	Automated manual, dual clutch	4-8%	1%
Overall vehicle	Lightweighting	10-20%	–
	Aerodynamics	5-8%	–
	Tire rolling resistance	2-8%	–
	Efficiency auxiliaries (steering, alternator, A/C)	2-10%	–
	Stop-start mild hybrid	5-7%	0.2%
	Hybrid electric system	20-50%	2.2%

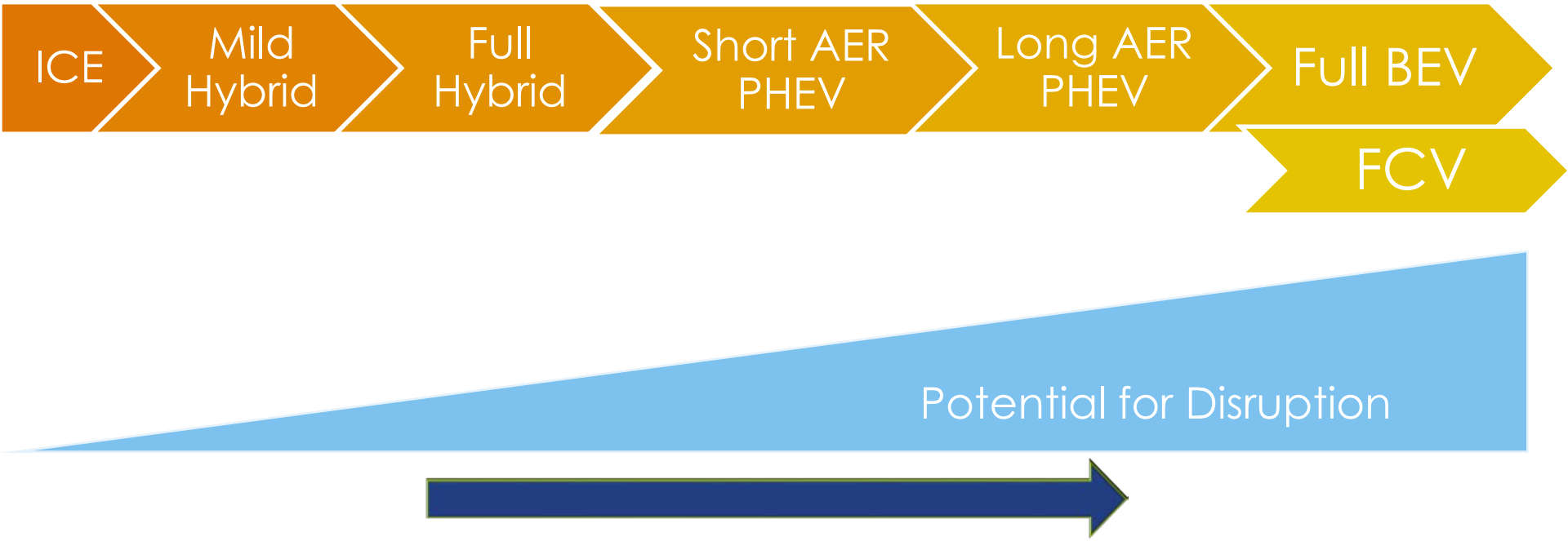
** Many technologies can be combined, but percents are not strictly additive; Estimations are based on NAS 2002 CAFE; US EPA/NHTSA, 2009; NESCCAF, 2004. # From US EPA, 2009*

Aggressive 2025 Stds Can Be Met with "Conventional" Vehicle Technology

(US/CARB Analysis of Technology Needed for Compliance)

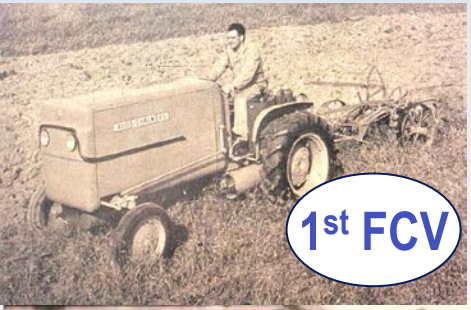
% change/yr GHG/CAFE	% Hybrids	% PEVs
4%	18	0
5%	43	1

Continuum of Electrification



PEVs and FCVs Poised for Commercial Success—Finally?!

Old Generation EVs/FCVs



New Generation PEVs/FCVs (w/strong industry support)

2nd Leg

Transforming Fuels

The Stone Age did not end for lack of stone, and the Oil Age will end long before the world runs out of oil.

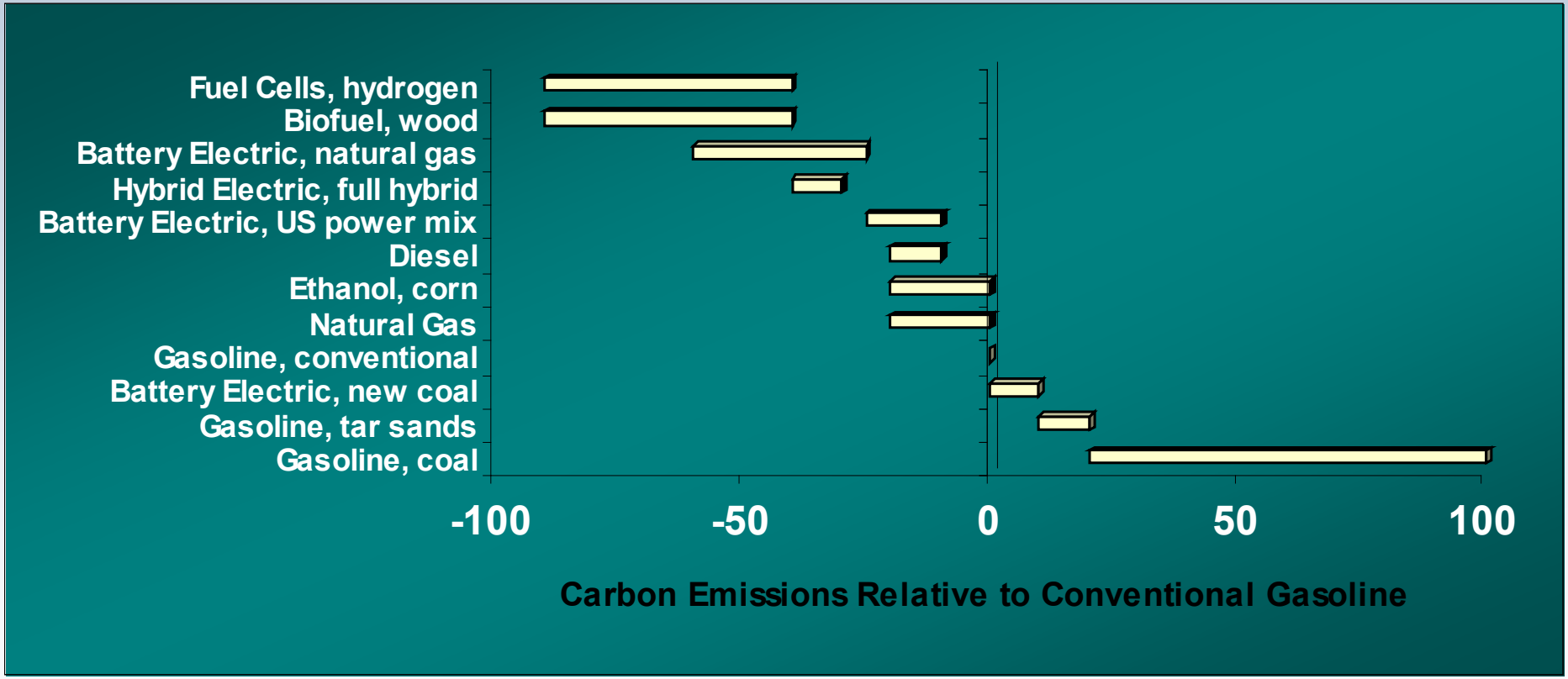
Sheikh Zaki Yamani, Saudi Arabian oil minister for 2+ decades

- Today: Transport is 94% dependent on oil
- Future: Diversity of Fuels

BIOFUELS **HYDROGEN** **ELECTRICITY**

Many Promising Replacements

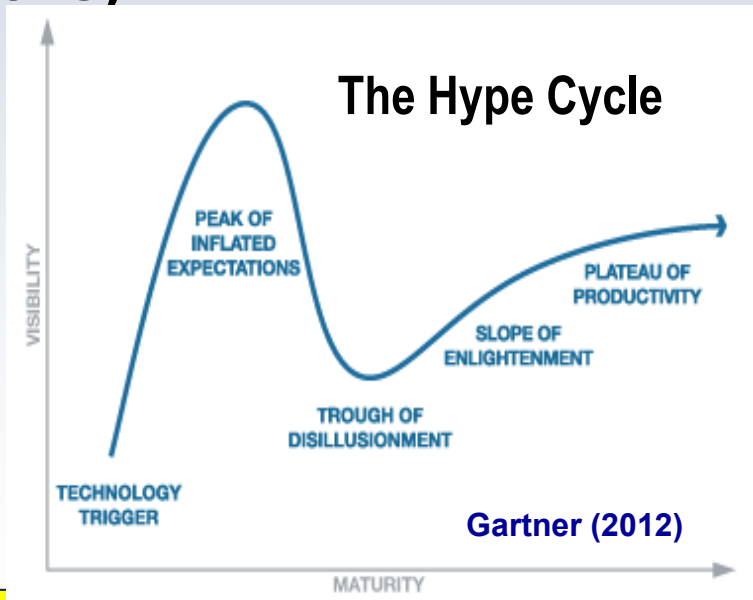
Some better than others…



Fuel *du jour* Phenomenon

Disruptive and wasteful

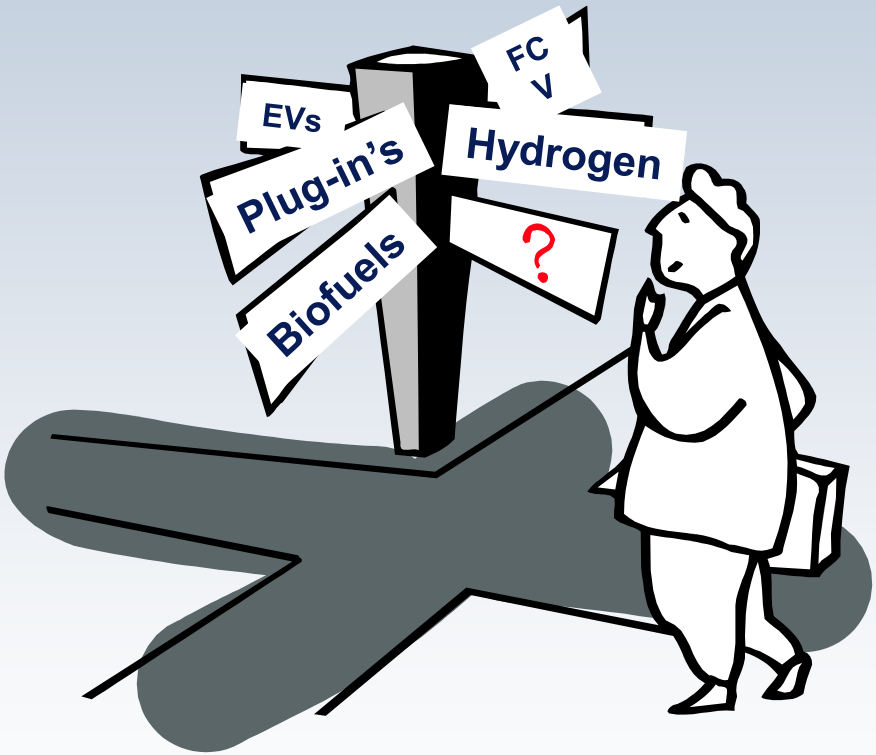
- 30 years ago – Synfuels (oil shale, coal)
- 25 years ago – Methanol and CNG
- 20 years ago – Electricity (Battery EVs)
- 10 years ago – Hydrogen (Fuel cells)
- 5 years ago – Ethanol
- Today – Electricity (again)
- *What's next?*



GOVERNMENT POOR AT PICKING WINNERS …
NEED DURABLE POLICY (such as low carbon fuel standard)

All energy alternatives are difficult and face major barriers

- Biofuels
- Hydrogen and FCVs
- EVs
- CNG



And thus need flexible, performance-based, technology-forcing policy

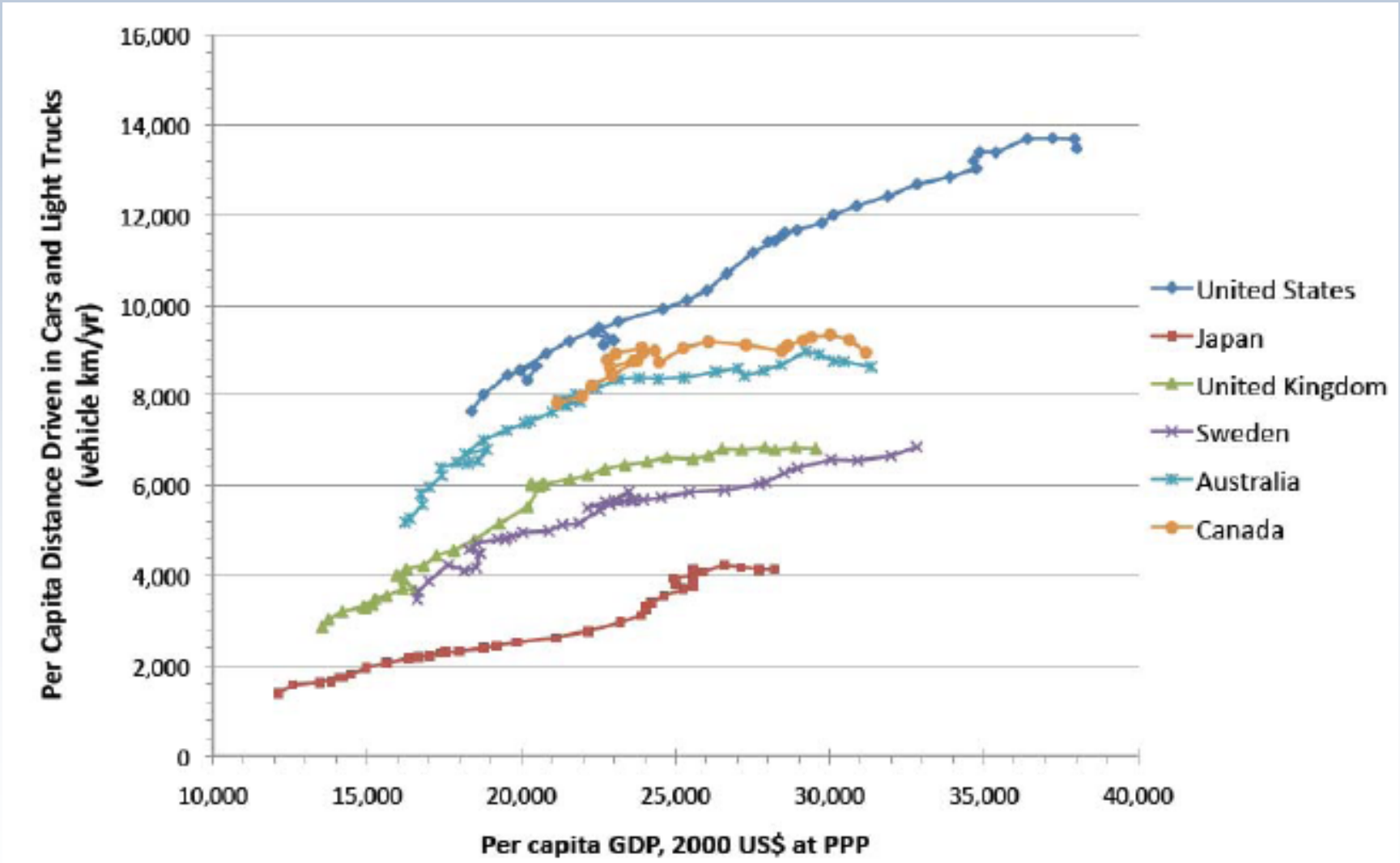
3rd Leg

Transforming Mobility (and Land Use)

In U.S. and abroad, we've created a transportation monoculture, with shrinking choices and increasing sprawl.

Many ways to provide equal accessibility at less cost—with less energy and GHG emissions

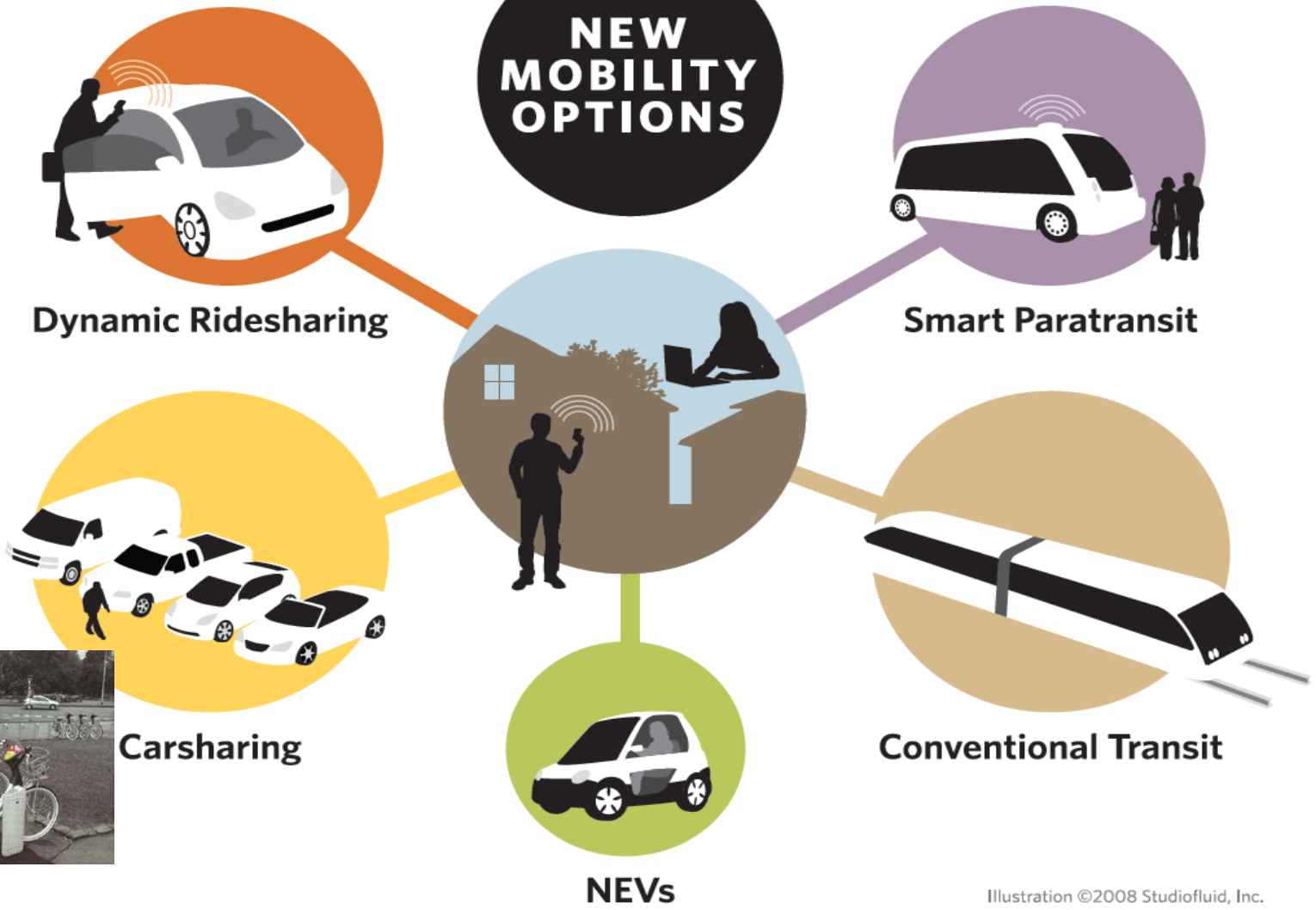
Americans Drive Much More than Others



Source: Millard-Ball and Schipper (2010).

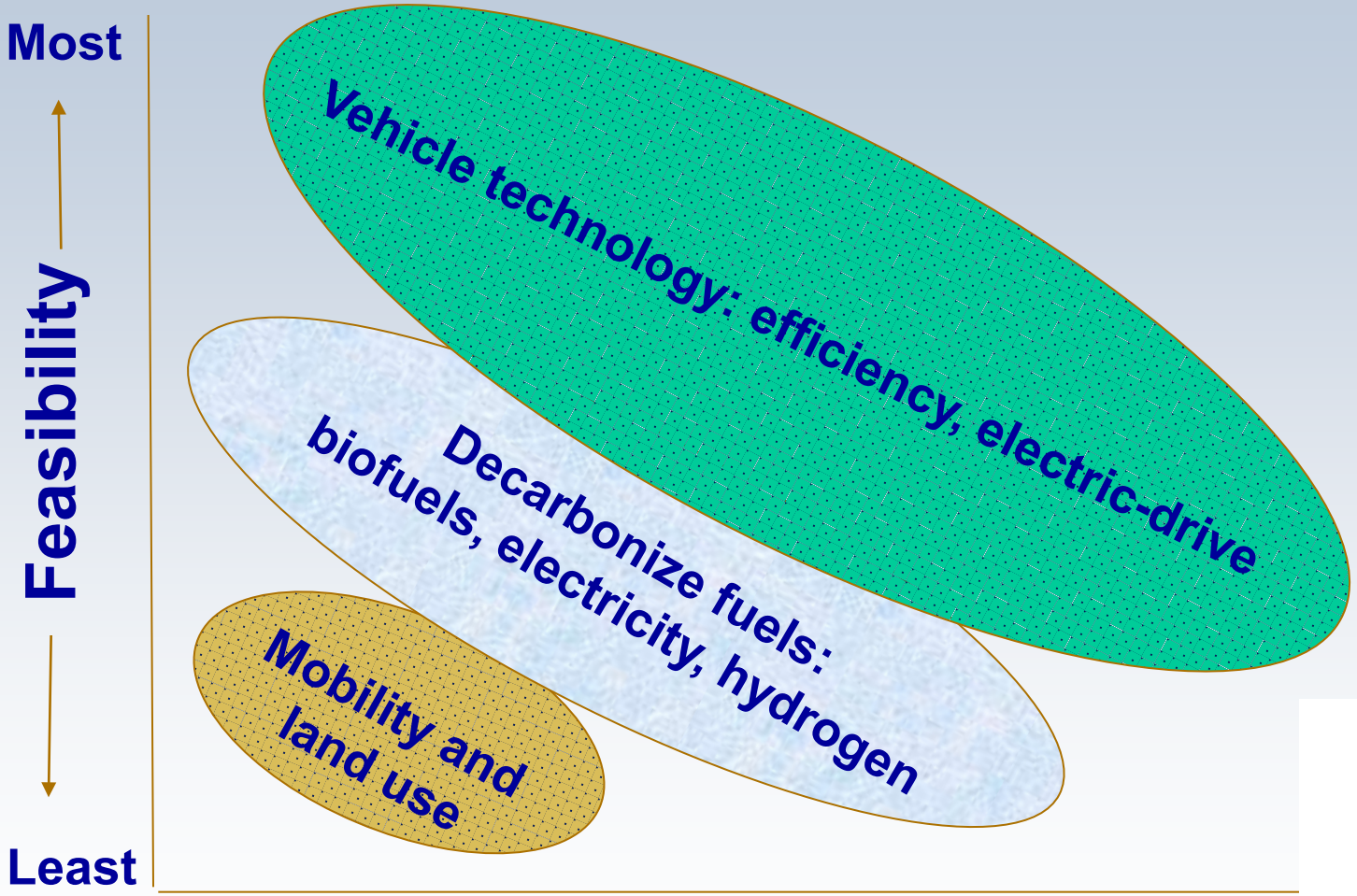
Not all vehicle trips are “high value”!

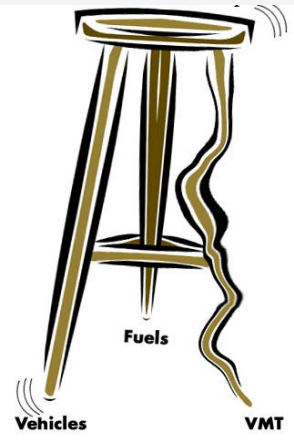
Key Strategy: Innovation to Expand Traveler Choice



Vehicle Transformation Is Fastest and Easiest

(in near and medium term in OECD countries)





What does this all mean?

- **Future is highly uncertain—for consumers, industry, and policymakers**
  - BEVs or FCVs?
  - electricity and H2 (from NG) with CCS?
  - What type of PHEV will dominate? PHEV10, PHEV40, with NG or biofuels?
  - How much and what type of charging infrastructure?

→ Portfolio Approach—All of the Above!

→ Ramp up R&D (gov't and industry)

→ Policy leadership with technology, fuels, VMT

(doing fairly well with vehicles, but not fuels or VMT)

ITS UCDAVIS

"We stand at a crossroads. One path leads to despair, the other to destruction. Let's hope we choose wisely."

Woody Allen

Headed into a painful century… but humans are incredibly creative. Eventually we will rise to the challenge—with leadership from all of you!

Thank You