

FORCES SHAPING THE Vehicle of the Future

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What will shape automotive progress?

- ≡ Demand for personal mobility
- ≡ Value of personal time, safety and security
- ≡ Information technology (IT) capabilities
 - ◆ Connectivity } *Networked autonomy* rather than
 - ◆ Automation } independent autonomous operation
- ≡ Spatial constraints (megacity regional densities)
- ≡ Environmental constraints
 - ◆ Criteria air pollution
 - ◆ Greenhouse gas (GHG) emissions
- ≡ Energy price volatility
 - ◆ But *NOT* hydrocarbon resource scarcity



Source: Freep.com



Time? Safety? Security?

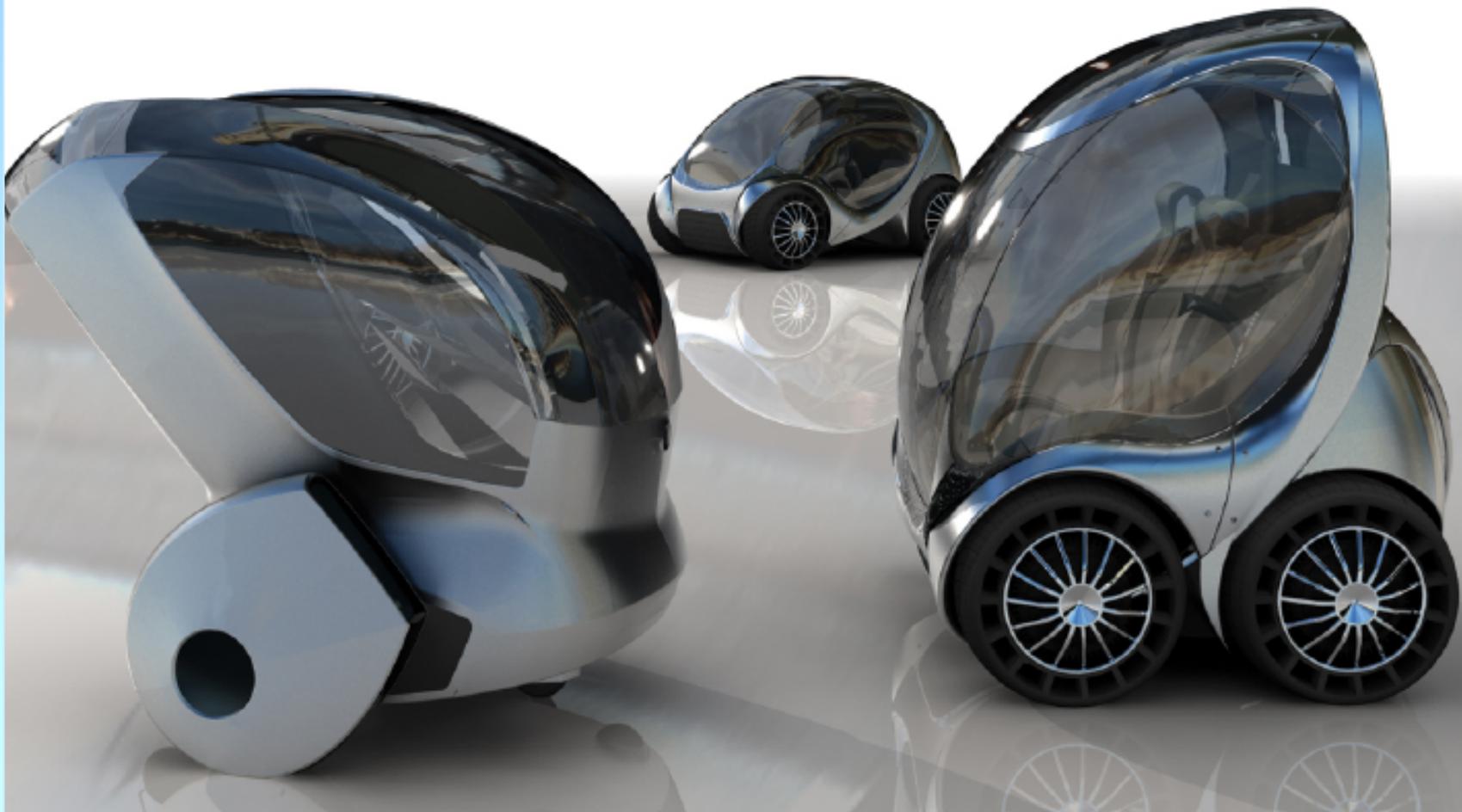
Google's autonomous research car



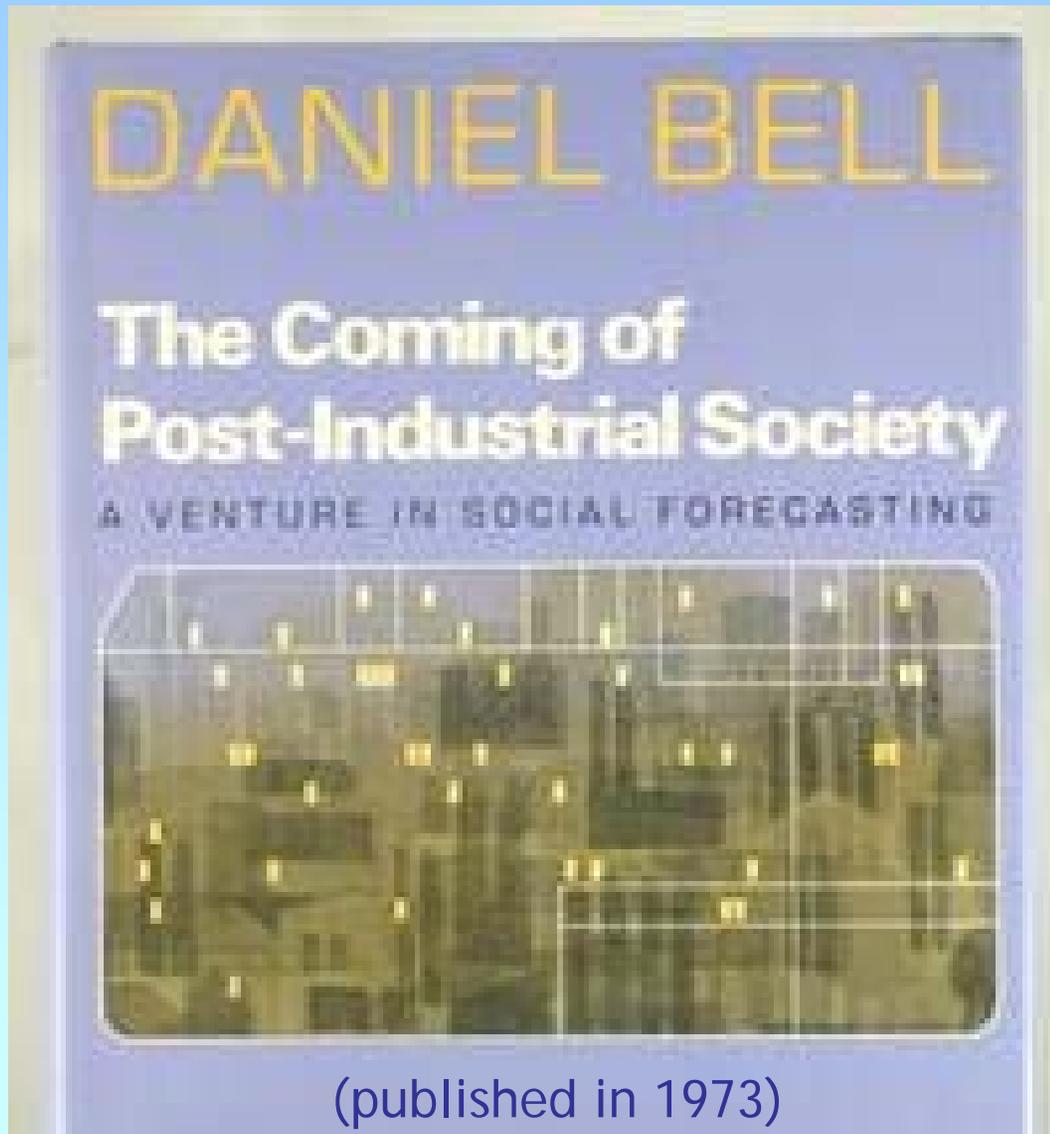
Reinventing the Automobile

Personal Urban Mobility for the 21st Century

William J. Mitchell, Christopher E. Borroni-Bird, and Lawrence D. Burns



Moving into the era of **POSTMOBILITY**



Predicted profound changes in industry, commerce, culture and other aspects of social organization that would be brought about by information technology

“A post-industrial society is basically an information society.”

-- Daniel Bell

"Postmobility"

- ⌘ We are now at the cusp of a major paradigm shift
 - ◆ Information technology will finally truly touch transportation
 - ◆ 21st century humans are too **bad** to drive *and* too **good** to drive
 - ◆ Steadily progressing feature automation and connectivity will lead to networked automated ***mobility systems***
 - ◆ Not robot cars operating on a "dumb" infrastructure like today's
- ⌘ Compelling value propositions:
 - ◆ Free up drivers' time and attention (for selling new services)
 - ◆ Do for crashes what's been done for tailpipe pollution
 - ◆ Enable step changes in fuel efficiency
 - Decouple power performance expectations from mobility
 - Decouple safety from purely physical design solutions
 - Will ***facilitate*** rather than ***require*** electrification
- ⌘ Path of such disruptive change is impossible to predict

A slowdown in mobility? NO WAY!

≡ Just as

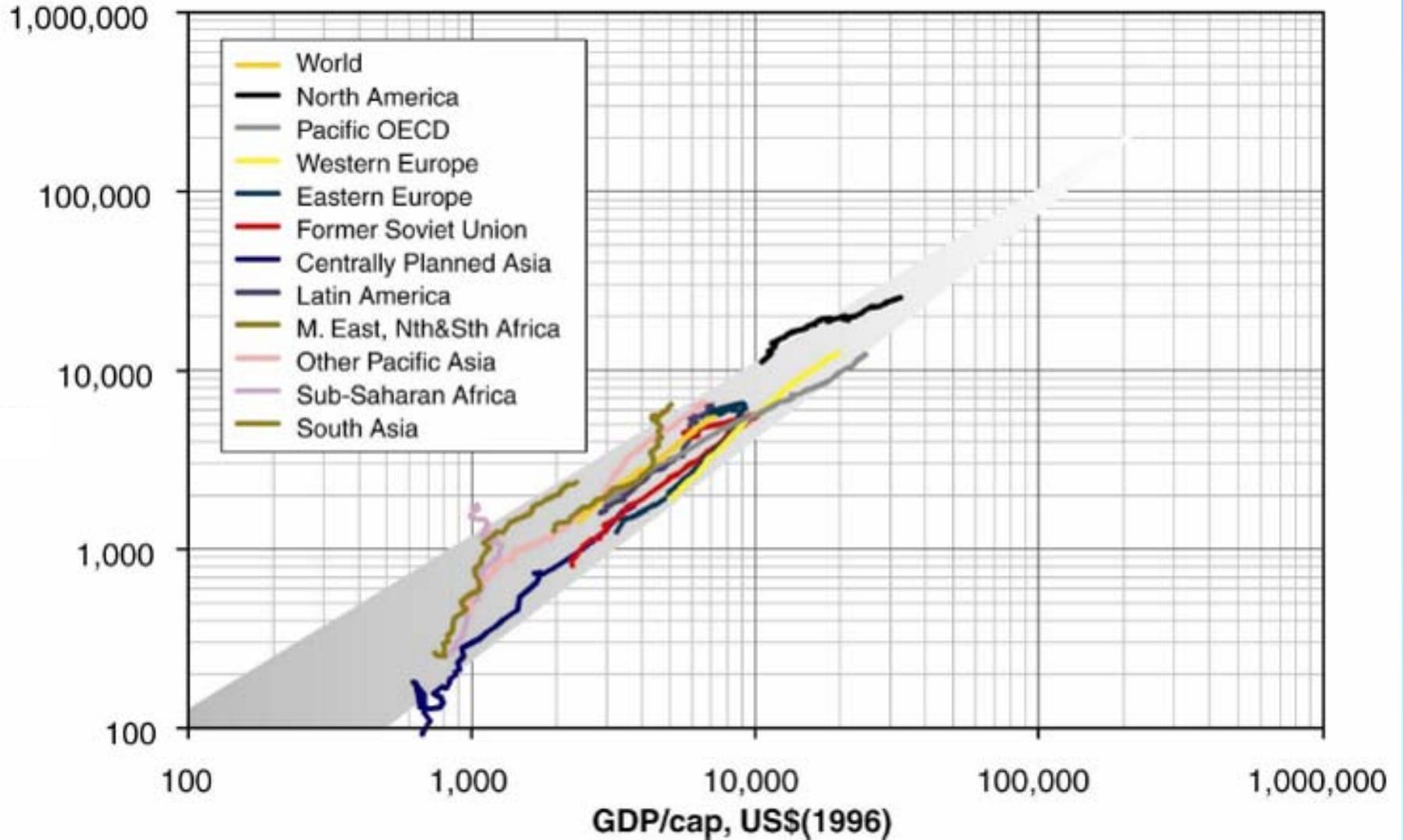
- ◆ Post-industrial age did not mean the end of industry
- ◆ Post-modernism did not do away with modernism

≡ **Postmobility** will not mean the end of mobility

- ◆ Rather, mobility *per se* will be taken for granted
- ◆ Information and connectivity will become the defining principles for mobility going forward
- ◆ The "movement" problem has long since been solved; the challenge now is making it far more efficient
 - in terms of the value of time
 - in terms of how it serves other economic and social activities
 - in terms of resource and environmental impacts

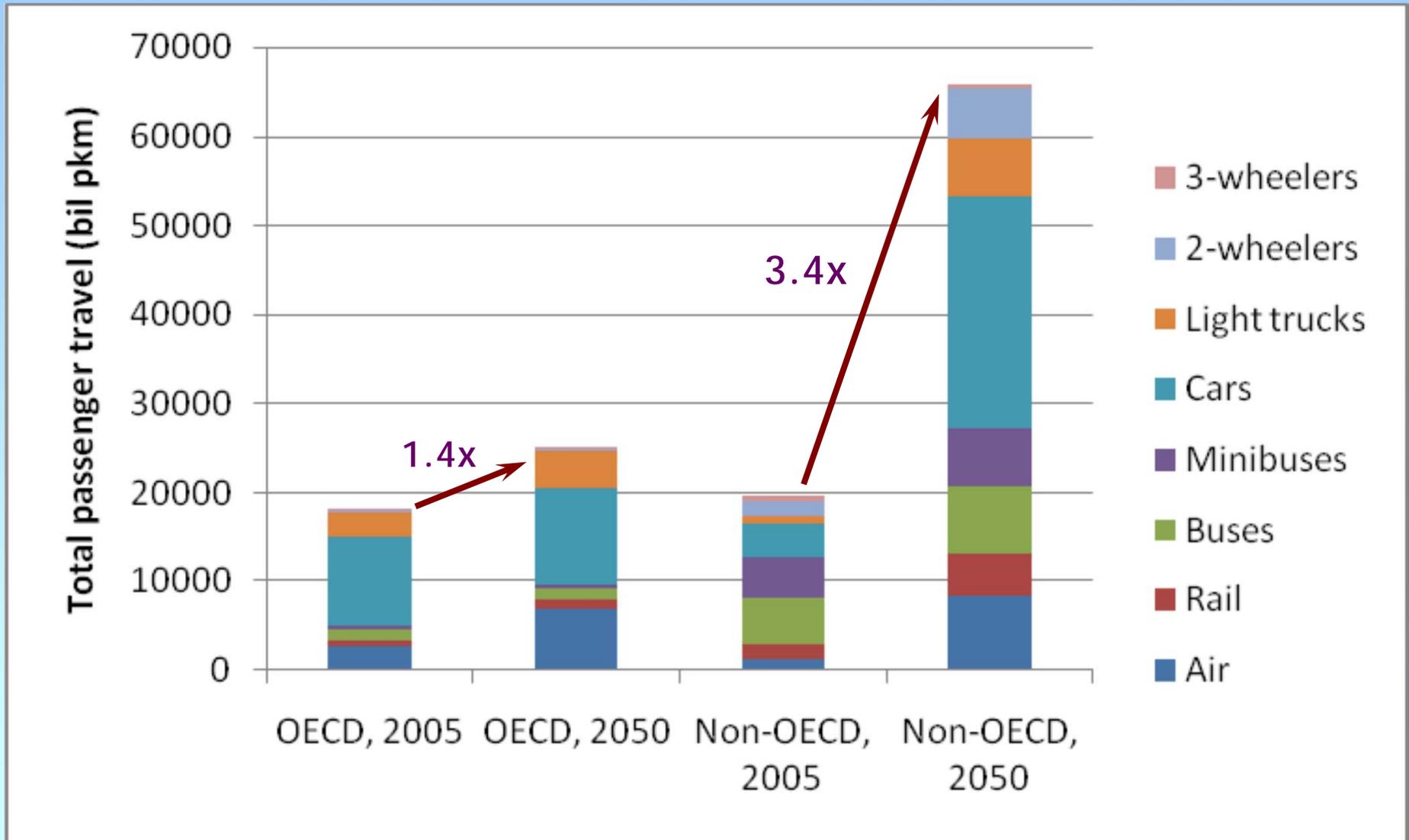
Transportation Activity and Income

per capita travel, km/yr per person



Projected Passenger Travel by Mode and Region

IEA baseline scenario, 2005 levels with projections for 2050



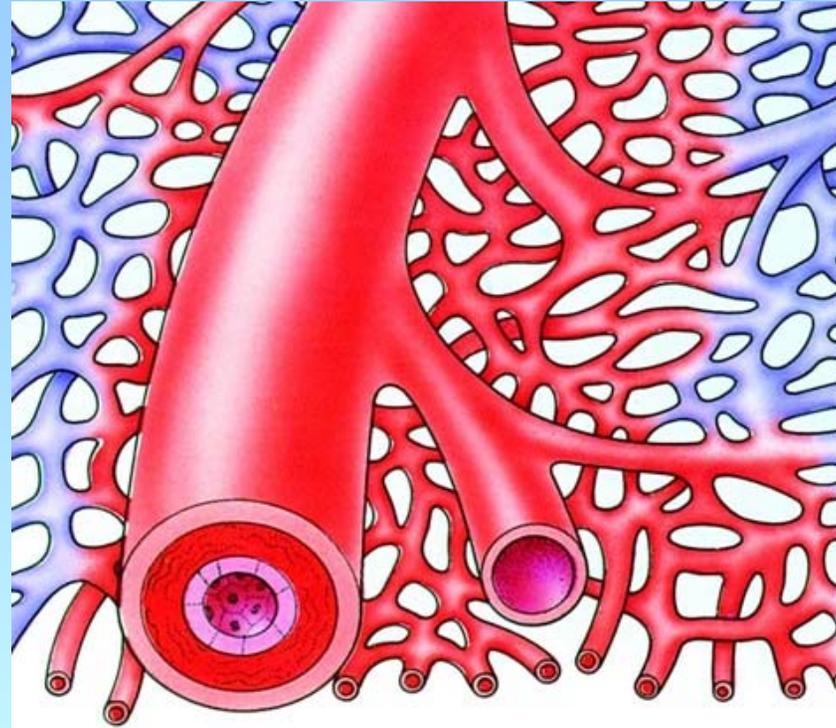
Source: IEA (2009) *Transport, Energy and CO₂: Moving Toward Sustainability*

What is tomorrow's transportation in China?

Development of a smart integrated system

Source: Prof. Huang Zhen,
Shanghai Jiao Tong University

Presentation at US-China
Research Symposium, University
of Michigan, May 2011



Arteries



Veins



Capillaries

Influences going forward

- ⌘ Global automobile use is growing steadily even as many nations invest in the advanced transit and high-speed rail
- ⌘ The vast majority of increase in car ownership will be in the developing world
- ⌘ One thing that we now have and, more significantly, that the consumer classes of emerging economies are growing up with, is information technology
- ⌘ Massive data processing, sensing and networking abilities fall in cost and rise in ubiquity ("the internet of things")
- ⌘ The future of transportation will be shaped more by the needs and capabilities of emerging economies than by the desires of mature economies

Is the problem oil or carbon?

- ⌘ It is common to equate the two and therefore assume that alternatives are needed soon
 - ◆ Because oil is peaking (resource depletion)
 - ◆ Because of geopolitics and security risks
- ⌘ However
 - ◆ We have already run out of atmosphere's ability to safely absorb excess CO₂
 - ◆ There is no shortage of fossil resources that can, at market-affordable prices, supply convenient liquid fuels for many more decades
 - ◆ **Resource Wars** can be handled in ways other than trying to stop using the resource being fought over

The
Atlantic

**WE WILL NEVER
RUN OUT OF OIL**

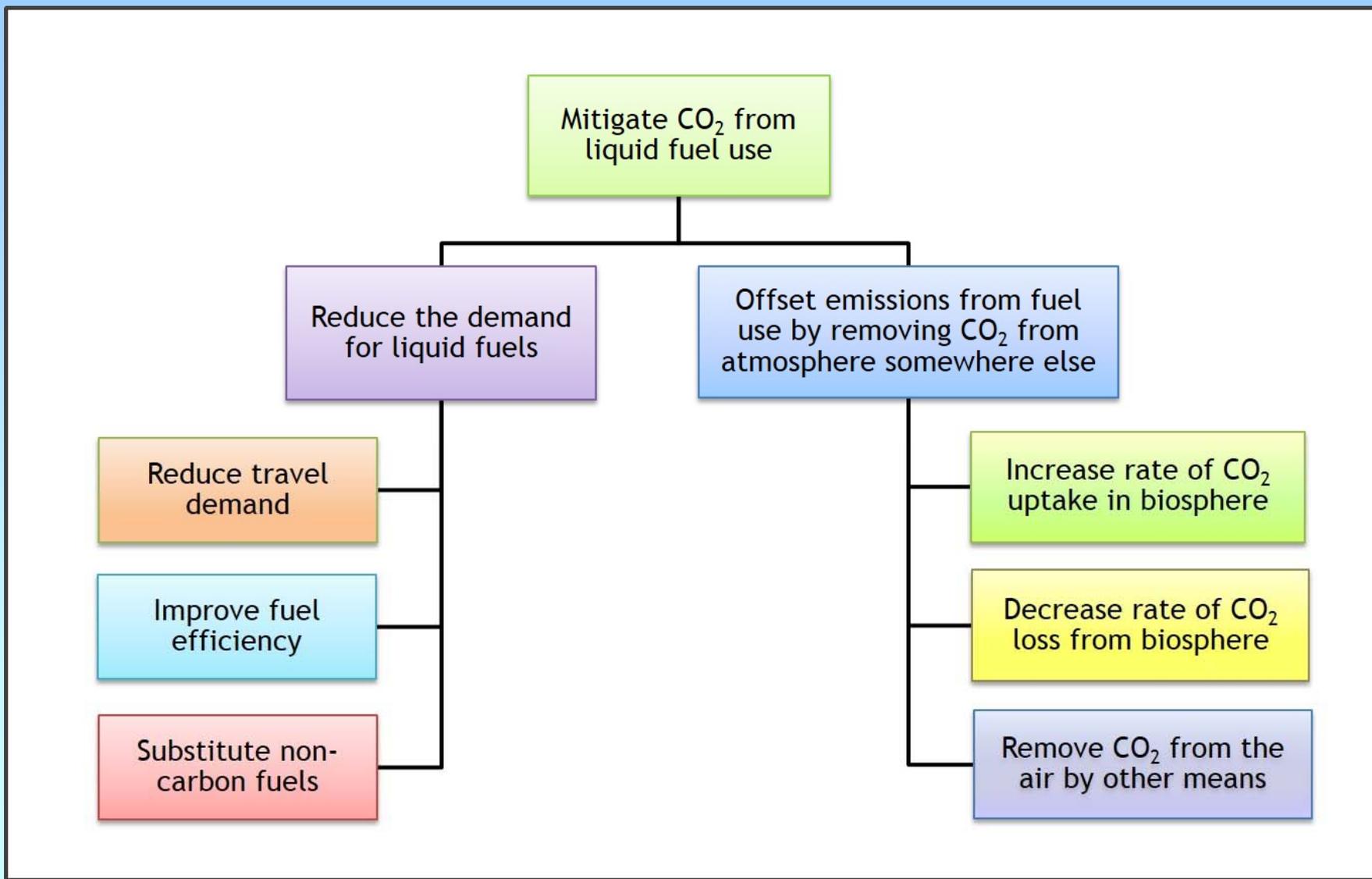


MAY 2013
THEATLANTIC.COM

Cover story,
May 2013

Why the
**FOSSIL-
FUEL BOOM**
is good for
America,
bad for
Saudi Arabia—
and scary
for the planet
By **Charles C. Mann**

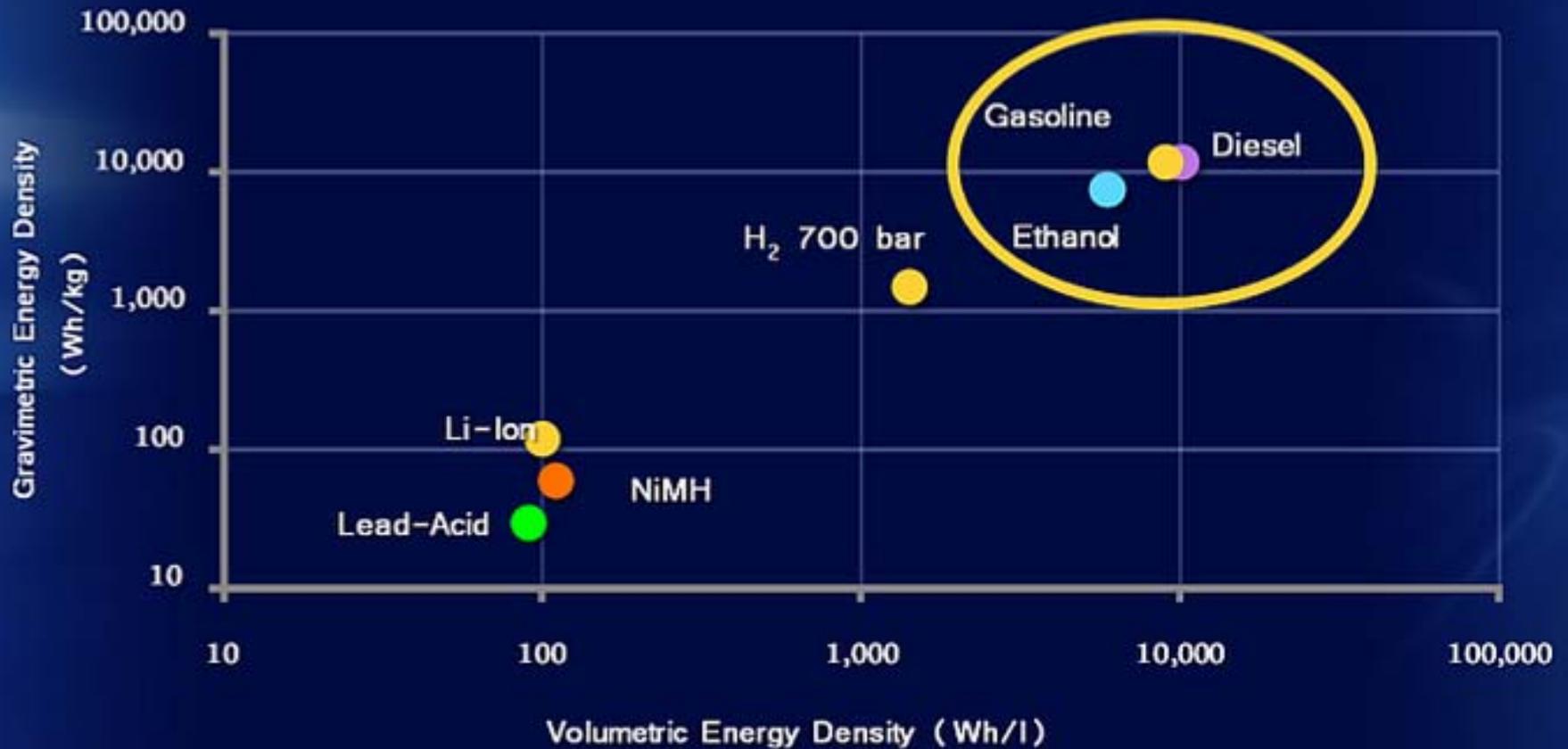
The Liquid Carbon Challenge



Source: www.carsclimate.com/2014/10/LCC1.html

ENERGY STORAGE DENSITY

(Including Fuel Tank/Battery)



Source: General Motors, Tom Stephens presentation at RFA, 16 Feb 2010

New Ford F-150 pickup (MY 2015)



Aluminum alloy body cuts mass by 700 pounds (about 12%)



China to impose deeper cuts of EV, plug-in hybrid subsidies

Bloomberg | 2015/5/1

China said it will cut subsidies on electric vehicles and plug-in hybrids more than it previously considered, even as sales lag behind an official target. The finance ministry will reduce subsidies on the vehicles by 40 percent in 2019 to 2020 from the 2016 level, according to a statement posted on the ministry's website Wednesday. The amount is double the size of the cut the ministry said it was considering in December.

China's motorist population tops 300 million

Automotive News China, 2 Dec 2014

The number of motorists in China now exceeds 300 million, up from 200 million at the end of 2010, the Ministry of Public Security reported.

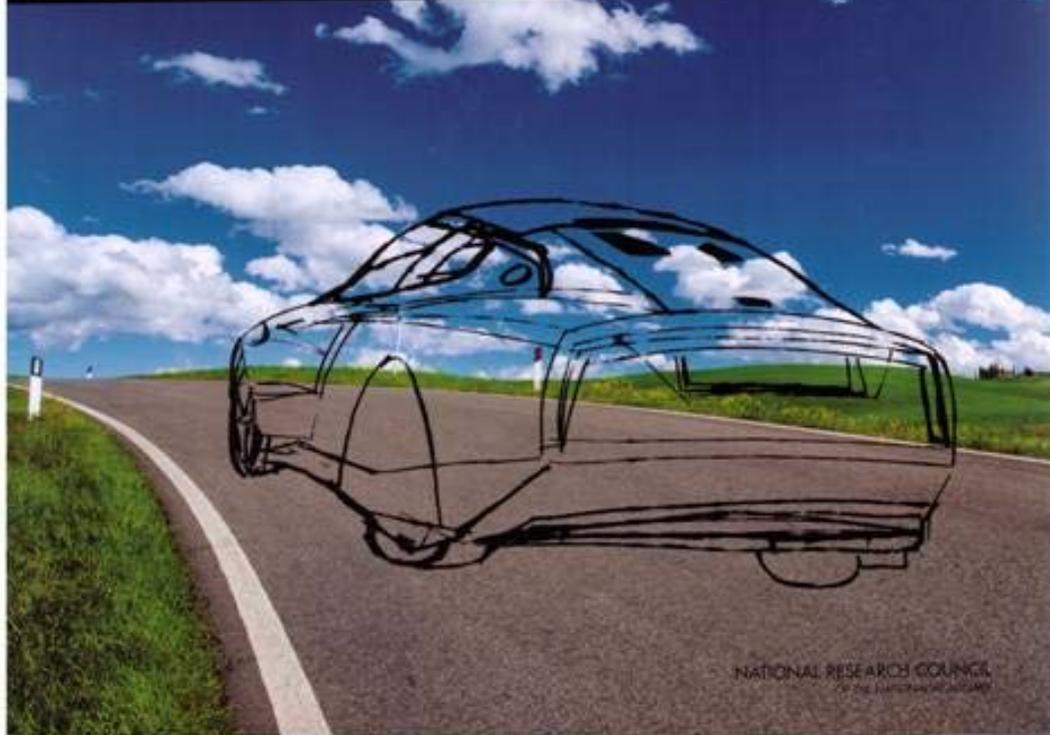


Rising income, growing families drive buyers to big people haulers, SUVs

Yang Jian | 2014/5/9

SHANGHAI -- Full-sized people haulers and SUVs used to be a tiny and stagnant segment of China's vast passenger vehicle market. In the past, only rich people and businesses could afford those vehicles, but times have changed. These days, rising numbers of young Chinese consumers are buying big

TRANSITIONS TO **ALTERNATIVE VEHICLES AND FUELS**



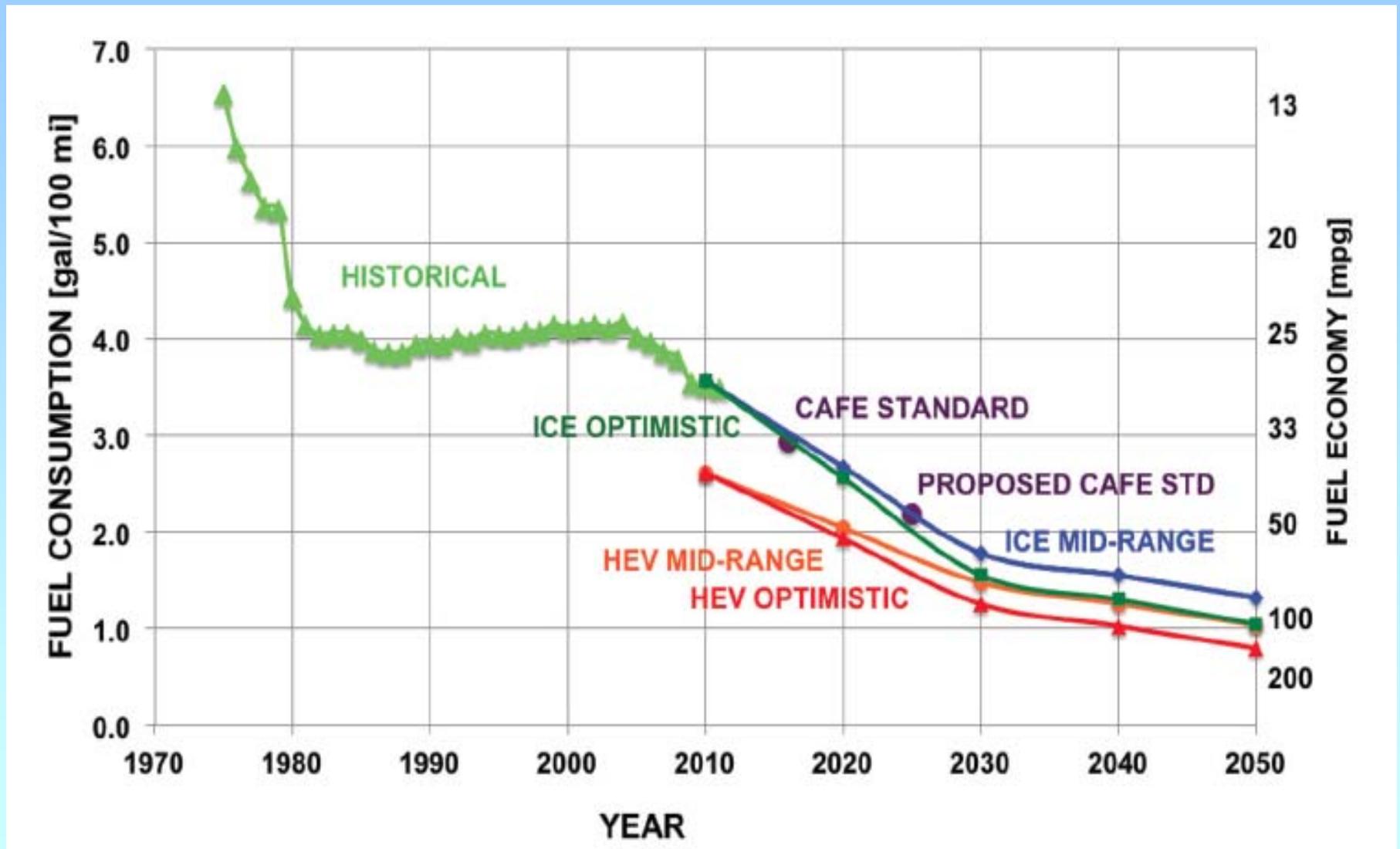
National Research Council (NRC) report, March 2013

Examined ways to reduce U.S. light duty vehicle petroleum use and GHG emissions to 80% below the 2005 level by 2050

Discussed a range of options but emphasized scenarios combining higher fuel economy with:

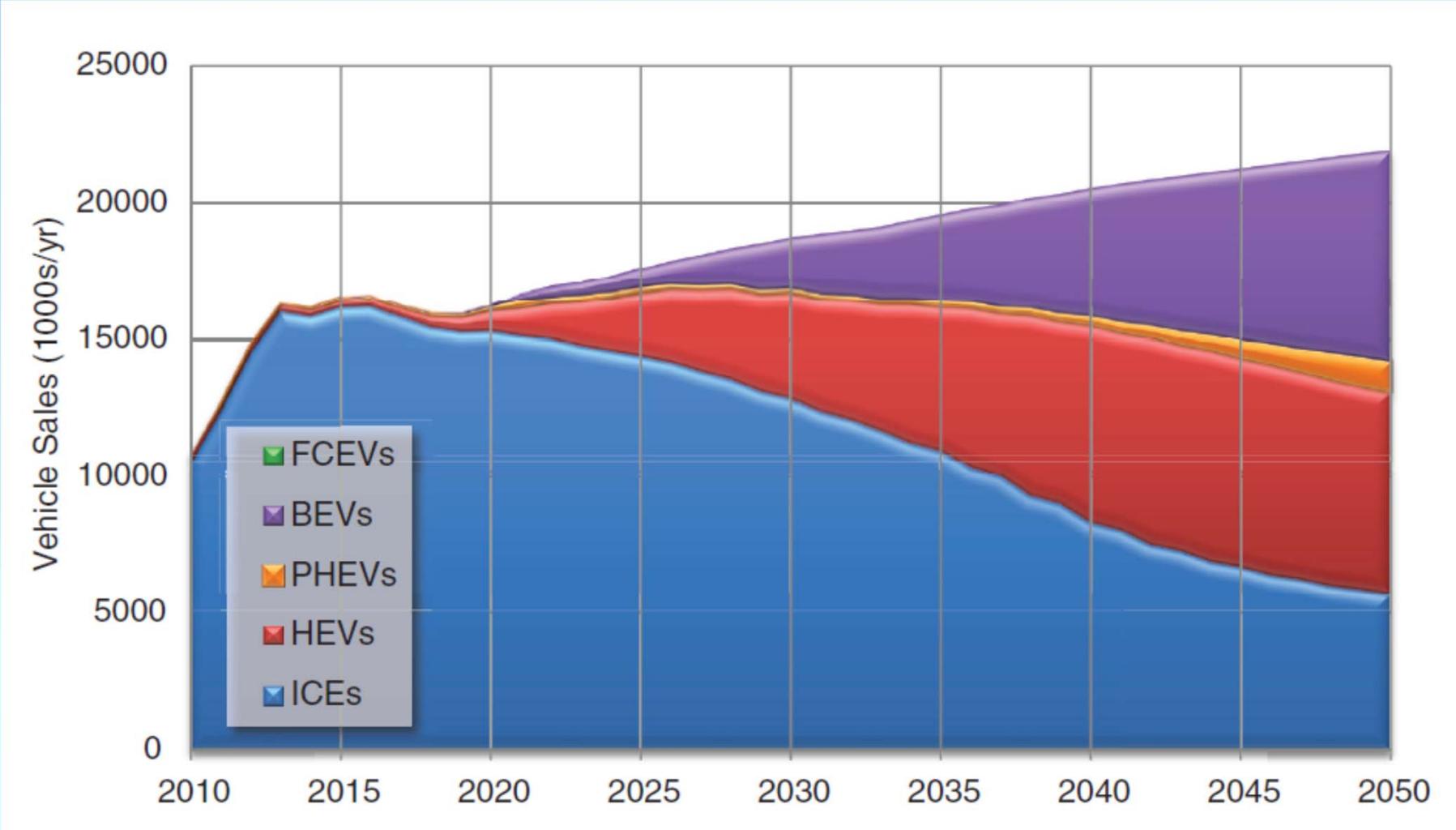
- drop-in biofuels
- electricity (BEVs & PHEVs)
- hydrogen fuel cell vehicles

NRC (2013) LDV Fuel Economy Potentials



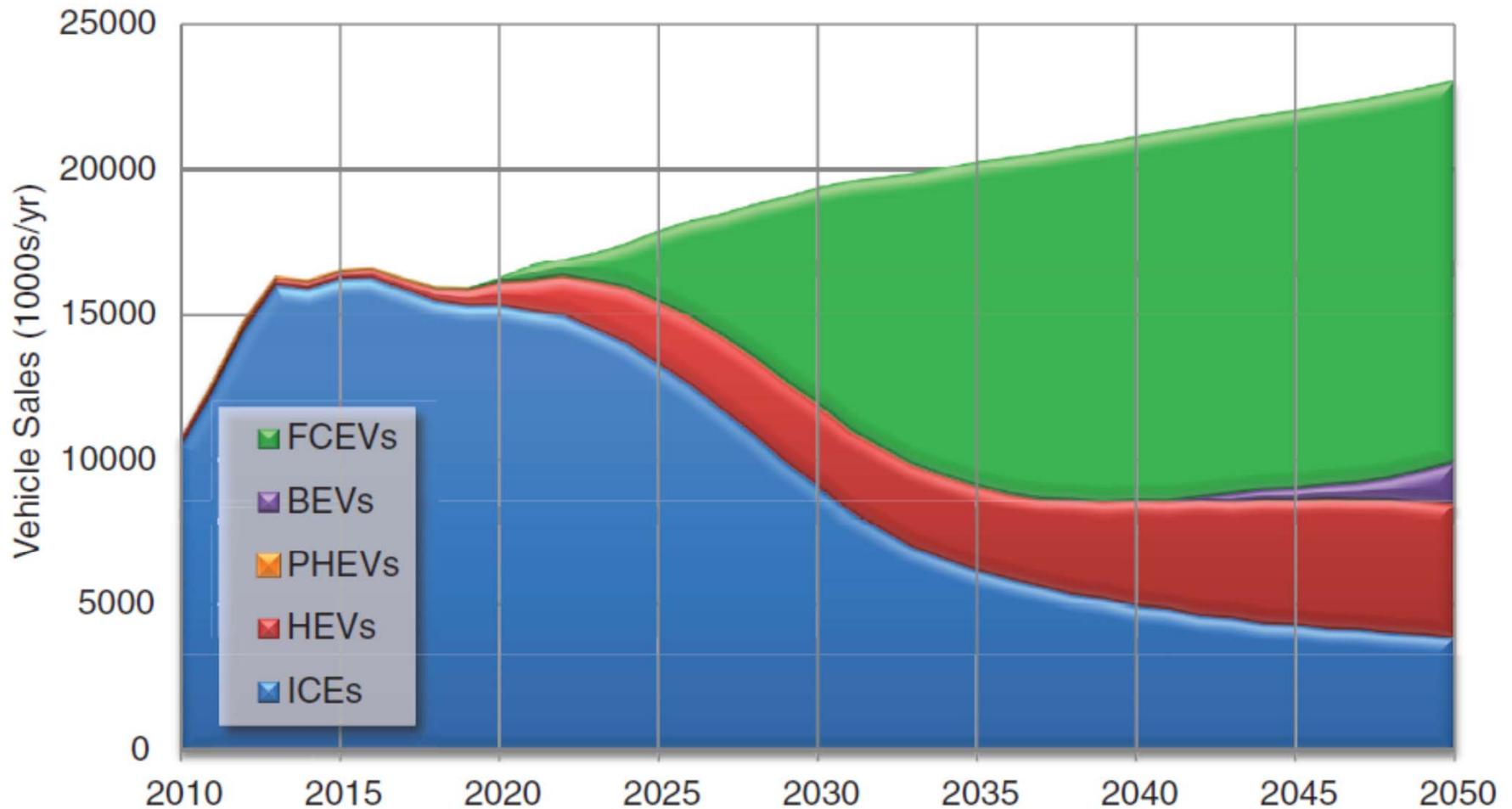
Source: NRC Transitions to AFVs 2013

Electric vehicle subsidy scenario



Source: NRC (2013), Figure 5.20

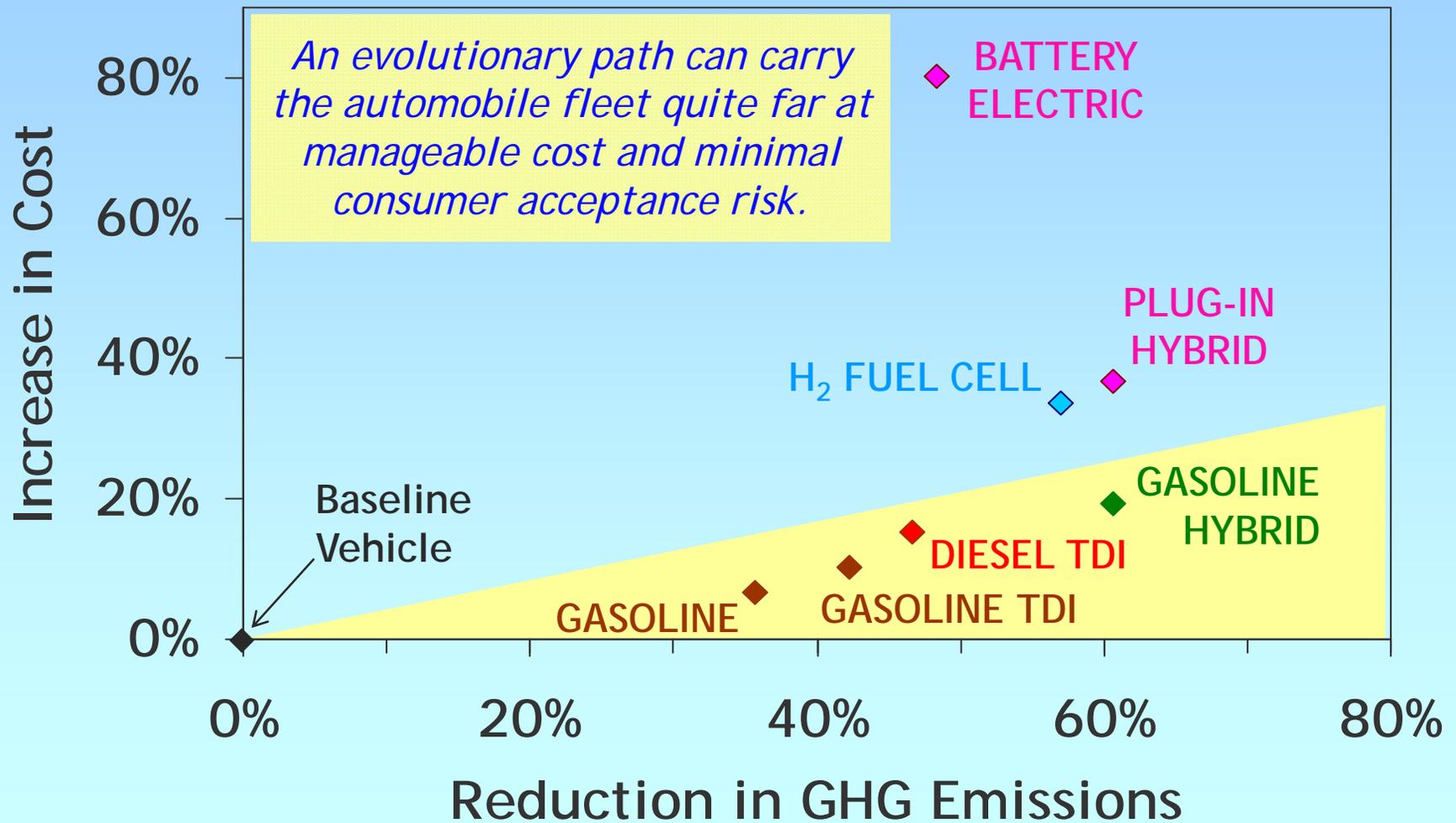
H₂ fuel cell vehicle subsidy scenario



Source: NRC (2013), Figure 5.22

Relative Technology Benefits and Costs

Projected cost impacts and GHG reductions for efficiency-optimized midsize cars in 2035 relative to a 2005 baseline



Like most transportation energy studies to date, NRC (2013)

- ⌘ did not seriously consider Postmobility
- ⌘ had just a few paragraphs buried in an appendix:

F.1.4 A Potential Disruptive Change: Autonomous Vehicles

A possibility that could portend truly disruptive change in the LDV sector over the next few decades is the emergence of autonomous, self-driving vehicles. All major automakers, as well as transportation agencies in many countries, have research, development, and demonstration programs underway to explore intelligent transportation system (ITS) technologies. Implementing ITS is likely to require making substantial new infrastructure investments, facing the complexities of human factors and the man-machine interface, and working through numerous institutional issues about responsibility and liability for vehicles operating with varying degrees of autonomy. Nevertheless, it is likely that by mid-century some form of ITS technology will begin to reshape personal mobility.

The general concept involves cars that are still individually owned and operated but driven by computer rather than under direct human control. Although some autonomous vehicles might be part of publicly managed networks, the greatest potential for a paradigm shift is likely to involve autonomous cars that preserve the core appeal of personal mobility while freeing drivers of the time, attention, and skill required to navigate and operate vehicles themselves. Robot vehicles could be dispatched for goods movement and to securely transport non-drivers such as children, the disabled, or the elderly.

Engines as Chips?

- Customer valuation is already shifting from "hard" to "soft" content
- The powertrain is becoming less of a value center, so costs must drop
- Engine to be seen as a "necessary evil" (bit of an exaggeration, but powertrain will just be taken for granted)
- Compete with electric driven options (if only to keep them at bay)

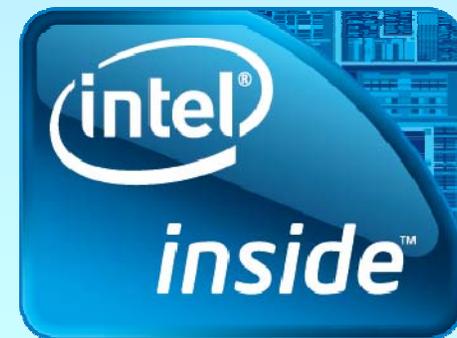


Ford Fiesta 1.0L EcoBoost 3-cyl



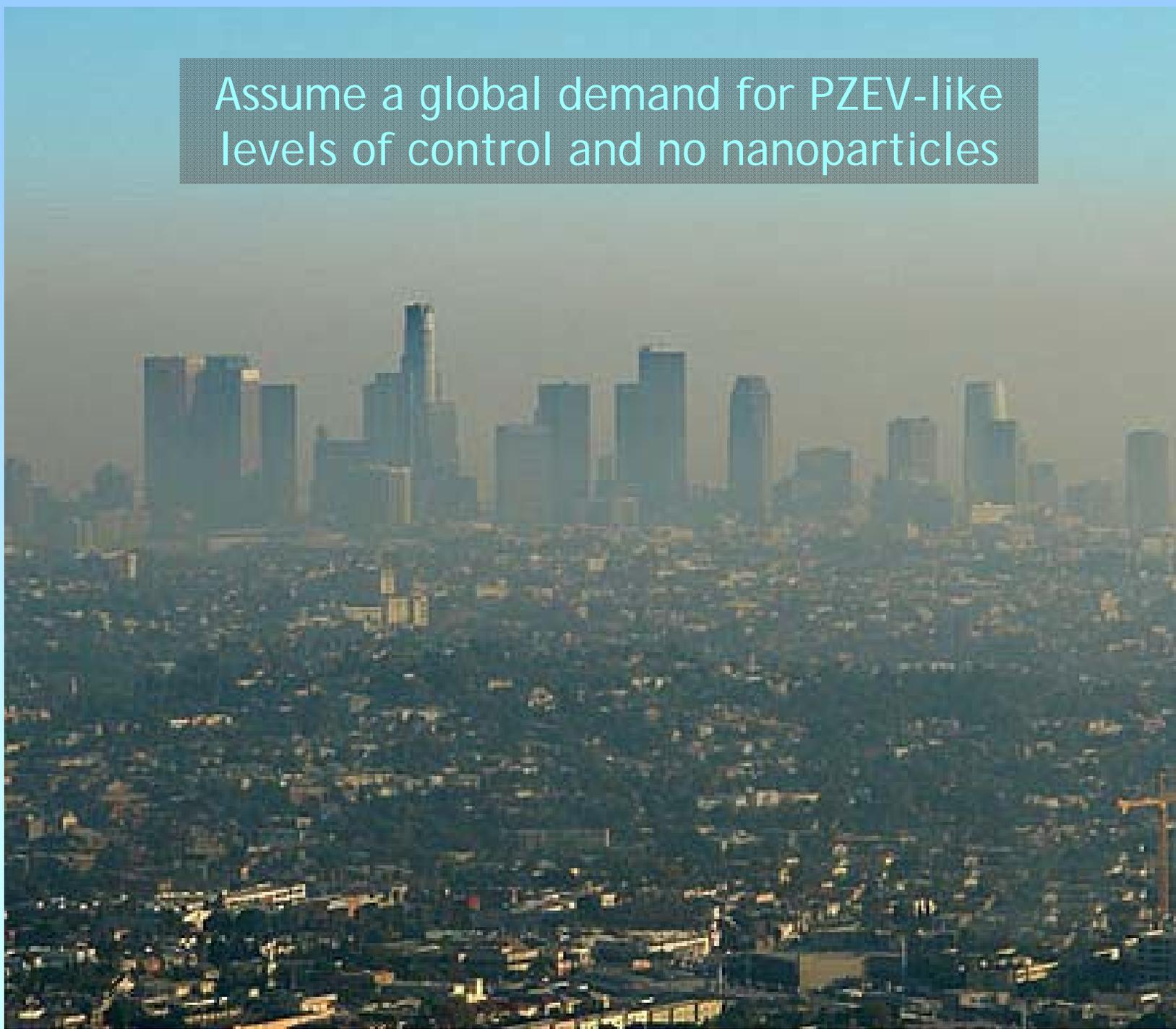
Hyundai Tucson fuel cell engine

POWERTRAINS BECOME
MUCH MORE LIKE



Assume a global demand for PZEV-like levels of control and no nanoparticles

<http://www.arb.ca.gov/videos/clskies.htm>



Commodity prime movers

- ≡ ICEs will need to be more like batteries
 - ◆ Range of “standard” shapes, sizes and performance characteristics: small/low power to large/high power
 - ◆ High volume manufacturing with ultra-high degrees of automated quality control
- ≡ But what will be the underlying “mechanistry”?
 - ◆ Breakthrough ICE technologies that can meet the performance needs of a Postmobility system
 - ◆ A given technology will see relatively long periods of continuous improvement, but
 - ◆ Will also see intense competition for particular designs that are profitable over fairly short product cycles

Conclusions

- ≡ The postmobility age is upon us
 - ◆ Intelligence will define vehicles more than motive ability
 - ◆ Networked autonomy will lead to very different, and in many ways less demanding, propulsive requirements
 - ◆ What will be very demanding is the need for high efficiency, vanishingly small criteria emissions and commodity cost
- ≡ Evolutionary technology change
 - ◆ Has greatly mitigated environmental harm by a combination of regulatory guidance and great engineering
 - ◆ Advanced internal combustion engines can play a major role in a transportation "revolution by evolution"
- ≡ A disruptive transformation involving automated vehicles is difficult to predict, but it may become
 - ◆ The biggest opportunity for new value creation in mobility since Henry Ford developed mass production

Thank you!

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Some recent short articles:

The smarter road to electric cars. *Automotive Engineering International Online*
www.sae.org/mags/aei/12251

What's Next for the Automobile? Introduction to SA Classics Special Issue: The Rise of the Automobile, *Scientific American*, January 2015.

www.scientificamerican.com/article/what-s-next-for-the-automobile/