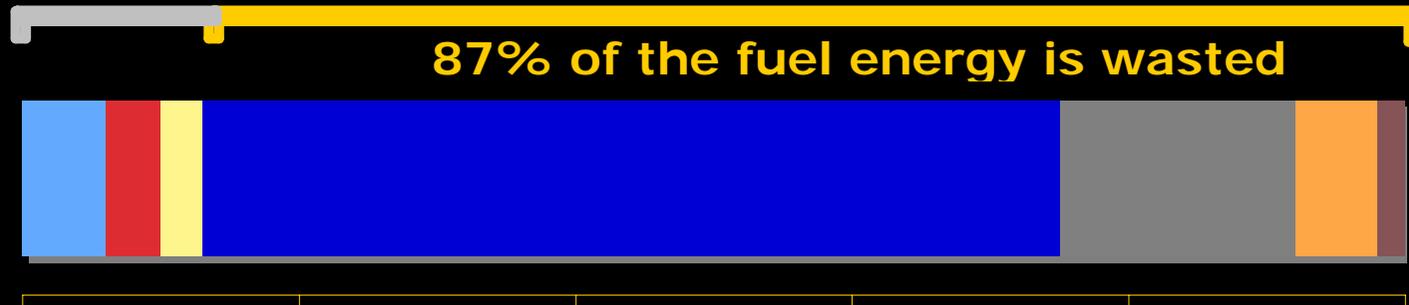




Each day a typical car burns $\sim 100\times$ its weight in ancient plants. Where does that gasoline's energy go?

13% tractive load



0% 20% 40% 60% 80% 100%

■ Braking resistance ■ Rolling resistance ■ Aerodynamic drag
■ Engine loss ■ Idling loss ■ Drivetrain loss
■ Accessory loss

- 6% accelerates the car, 0.3% moves the driver
- Three-fourths of the fuel use is weight-related
- Each unit of energy saved at the wheels saves $\sim 7-8$ units of gasoline in the tank (or $\sim 3-4$ with a hybrid)
- **So first make the car radically lighter-weight!**



Midsized Revolution midsized SUV, 5 adults in comfort, 2 m³ cargo
Ultralight (-53%, 857 kg) but ultrasafe
0-100 km/h in 8.3 s (later 7.2)
28.1 km/L w/gasoline hybrid
48.6 km/"L" w/H₂ fuel cell
40% lower manufacturing capital intensity
~99% lower tooling cost; no body shop, optional paint shop



"We'll take two."
— *Automobile*
magazine

World Technology
Award, 2003

**Show car and a complete virtual design (2000),
uncompromised, production-costed, manufactur-
able; hybrid yields 1-y payback vs Japan gasoline**



Can U.S. automakers use efficiency as a competitive strategy (as Japanese ones just did)?



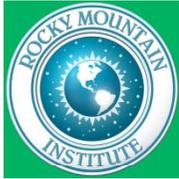
- ◇ Boeing's crisis in 1997 was like Detroit's today
 - Wrenching changes instituted at BCA, including TPS (e.g., moving assembly); manufacturing and costs brought back under control
 - But what about growth? What was in the pipeline after 777?
- ◇ In 2003, Airbus for the first time outproduced Boeing
 - "This is really a pivotal moment...could be the beginning of the end for Boeing's storied airplane business" — analyst Richard L. Aboulafia, 2003
- ◇ Boeing's bold, efficiency-led 2004 response: *787 Dreamliner*
 - $\geq 20\%$ more efficient than comparable modern aircraft, *same price*
 - 80% advanced composite by volume, 50% by mass \longrightarrow
 - > Bigger windows, higher-pressure cabin
 - 3-day final assembly (737 takes 11 days)
 - 817 orders (710 firm + 107 pending), 396 additional options
 - Sold out into 2015—fastest order takeoff of any airliner in history
 - Now rolling out *787's* radical advances to *all* models (Yellowstone)
- ◇ Airbus: Ultra-jumbo *A380*, 2 years late, \sim \$5b over budget
 - Response? Efficient, composite *A350*—probably too late
- ◇ Might U.S. automakers try to do this to Japanese rivals?



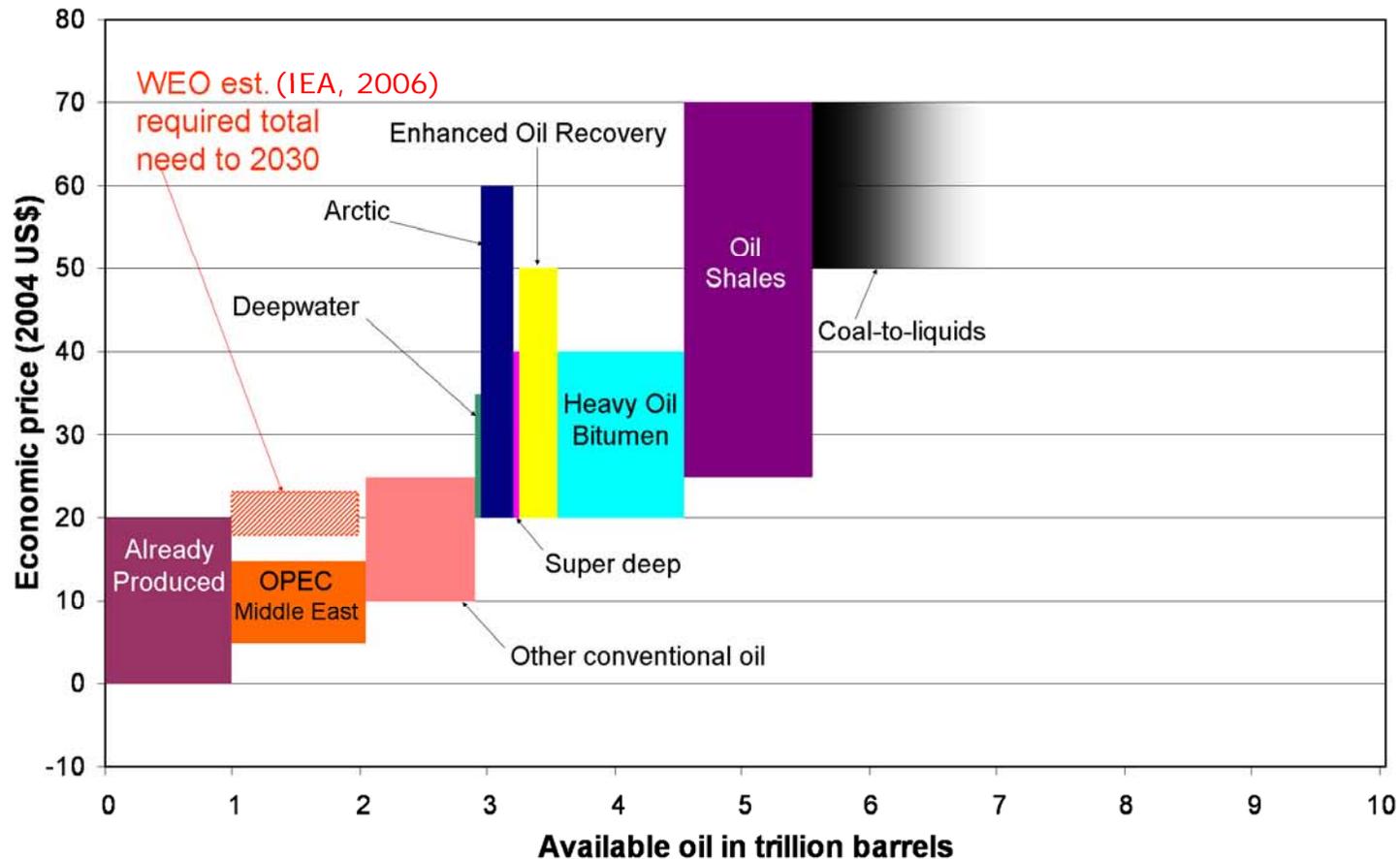


Implementation is underway via “institutional acupuncture”

- ◇ RMI’s 3-year, \$4-million effort is leading & consolidating shifts
- ◇ Need to shift strategy & investment in six sectors
 - Aviation: Boeing did it (*787 Dreamliner*)...and beat Airbus
 - Heavy trucks: Wal-Mart led it (with other buyers being added)
 - Military: emerging as the federal leader in getting U.S. off oil
 - Fuels: strong investor interest and industrial activity
 - Finance: rapidly growing interest/realignment will drive others
- ◇ Cars and light trucks: slowest, hardest, but now changing
 - Alan Mulally’s move from Boeing to Ford with transformational intent
 - Workers and dealers not blocking but eager for fundamental innovation
 - Schumpeterian “creative destruction” is causing top executives to be far more open to previously unthinkable change
 - Emerging prospects of leapfrogs by China, India, ?new market entrants
 - Competition, at a fundamental level and at a pace last seen in the 1920s, will change automakers’ managers or their minds, whichever comes first
 - RMI’s two transformational projects and “feebate” promotion will help too



The oil industry's conventional wisdom: approximate long-run supply curve for world crude oil and substitute fossil-fuel supplies



Source: BP data as graphed by USDoD JASON, "Reducing DoD Fossil-Fuel Dependence" (JSR-06-135, Nov. 2006, p. 6, www.fas.org/irp/agency/dod/jason/fossil.pdf), plus (red crosshatched box) IEA's 2006 *World Energy Outlook* estimate of world demand and supply to 2030, plus (black/gray) RMI's coal-to-liquids (Fischer-Tropsch) estimate derived from 2006–07 industry data and subject to reasonable water constraints. This and following graphic were redrawn by Imran Sheikh (RMI)