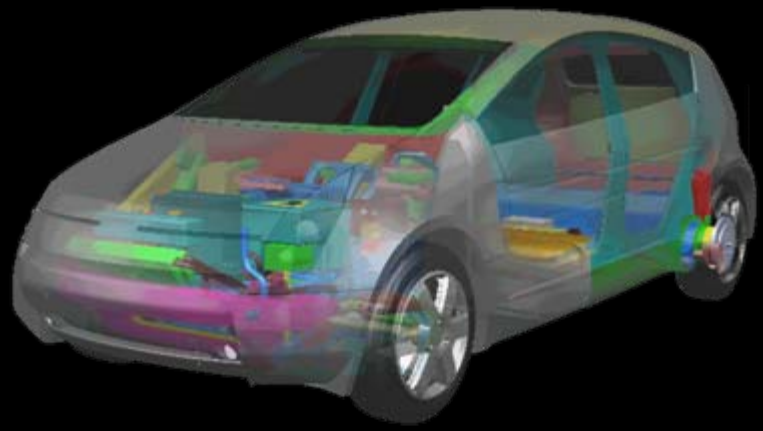

ROCKY MOUNTAIN
INSTITUTE

Volvo Prize Seminar, Stockholm, Sweden, 1 November 2007

Profitable, Business-Led Solutions to the Climate, Oil, and Nuclear Proliferation Problems



To be truly radical is to make hope possible, not despair convincing.

— Raymond Williams

Amory B. Lovins

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Energy policy: a multiple-choice test

Would you rather die of:

1. climate change?
2. oil wars?
3. nuclear holocaust?

The right answer, often left out, is:

4. none of the above

Let's just use energy in a way that saves money, because that will solve the climate, oil, and proliferation problems—not at a cost but at a profit

What has reduced energy intensity already done? What more can it do?

- During 1975–2006, the U.S. made a dollar of real GDP with 48% less total energy, 54% less oil, 64% less directly used natural gas, 17% less electricity, and two-thirds less water
  - Despite stagnant light-vehicle efficiency for >20 years, and perverse incentives rewarding electricity sales in 48 states
  - Nobody noticed: we haven't paid attention since the mid-1980s
- Full use of today's best end-use efficiency techniques would deliver the same or better services but save:
  - half the oil, at a sixth of its price
  - half the natural gas, at an eighth of its price
  - three-fourths of the electricity, at an eighth of its price
- Investing to achieve those savings over several decades would cost 6× less than buying the energy, and would make energy prices lower and less volatile
- Proper pricing matters less than barrier-busting

Q. How is climate protection like the Hubble Space Telescope?

A. Both got messed up by a sign error

The incorrect *assumption* that climate protection will be costly is the biggest obstacle to climate protection, and is reinforced daily in virtually all media

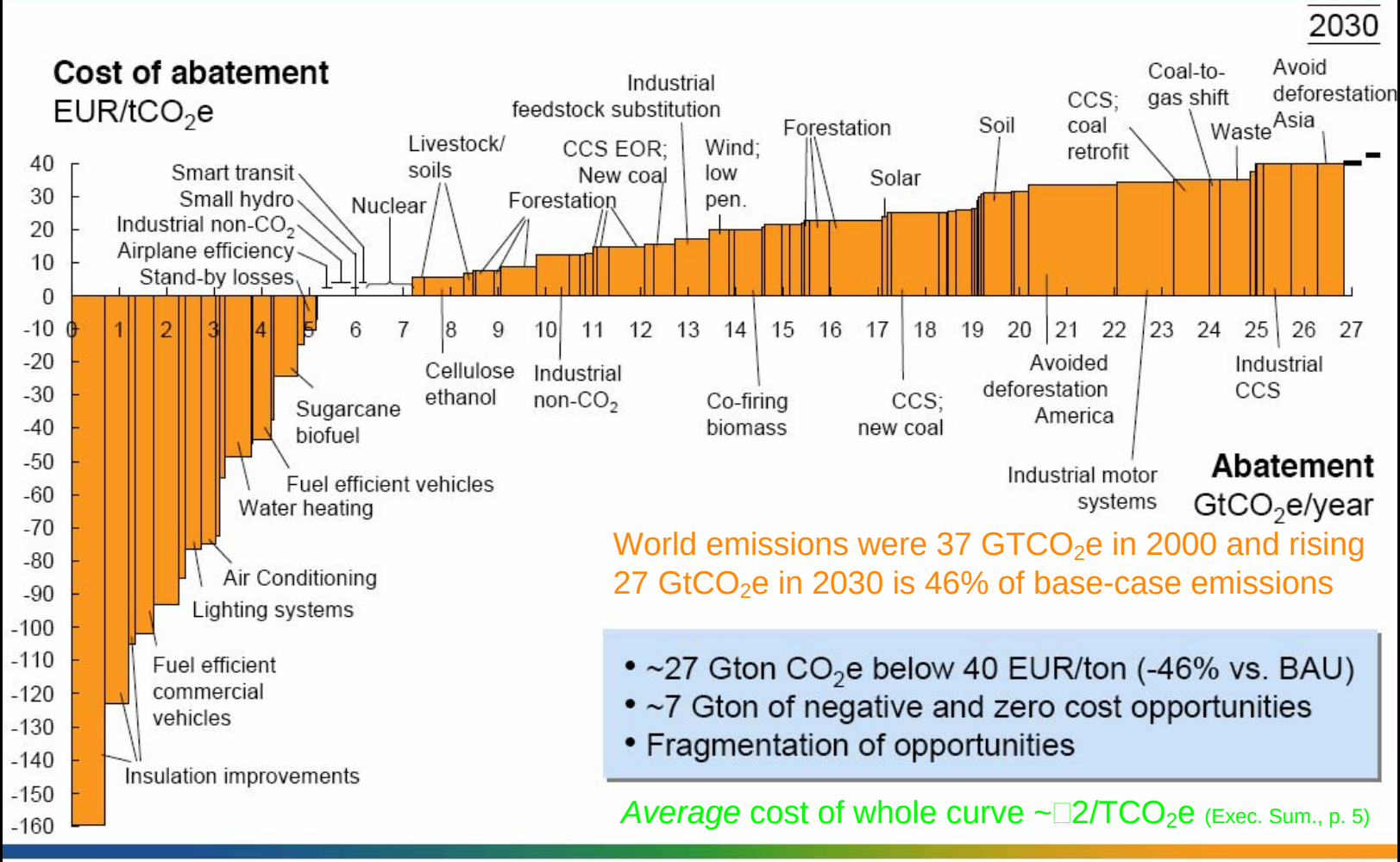
Saving energy is cheaper than buying it, so firms are starting to buy energy efficiency whether or not they worry about climate

- IBM and STMicroelectronics
  - CO_2 emissions –6%/y, fast paybacks
- DuPont's 2000–2010 worldwide goals
  - Energy use/$ –6%/y, add renewables, cut absolute greenhouse gas emissions by 65% below 1990 level
  - By 2006: actually cut GHG 80% below 1990, $3b profit
- Dow: cut E/lb 22% 1994–2005, $3.3b profit
- BP's 2010 CO_2 goal met 8 y early, $2b profit
- GE pledged 2005 to boost its eff. 30% by 2012
- Interface: 1994–2006 GHG –60% (–9.2%/y)
- TI new chip fab: –20% en., –35% water, –30% capex
- So while the politicians endlessly debate theoretical "costs," smart firms race to pocket real *profits!*

2007 Vattenfall / McKinsey supply curve for abating global greenhouse gases

(technologically *very* conservative, esp. for transport)

Global cost curve of GHG abatement opportunities beyond business as usual



World emissions were 37 $GTCO_2e$ in 2000 and rising
27 $GtCO_2e$ in 2030 is 46% of base-case emissions

- ~27 Gton CO_2e below 40 EUR/ton (-46% vs. BAU)
- ~7 Gton of negative and zero cost opportunities
- Fragmentation of opportunities

Average cost of whole curve ~□2/TCO_2e (Exec. Sum., p. 5)

Profitable climate protection

- Global CO_2 emissions will triple by 2100 if we reduce E/GDP by 1%/y; level off if 2%/y; and drop—stabilizing the Earth's climate—if ~3%/y. Is that feasible?
- The U.S. has spontaneously saved >2%/y since '97; 3.4%/y 1981–86; 3.2%/y in '01 & '05, 4.0% in '06
- California was ~1 percentage point faster; its new homes use 75% less energy; still saving much more
- China did even better—saved >5%/y for >20 y, 7.9%/y 1997–2001; energy efficiency is top priority
- Attentive corporations routinely save ~6–9%/y
- Even Japan can profitably save 2/3 of *its* energy, so the US, with 2–3× more E/GDP, has a long way to go
- Oil causes 42% of all CO_2 emissions, electricity 40%

Independent, transparent, peer-reviewed, uncontested, DoD-cosponsored, Sept 04

Covered by any papers here?

For business / mil. leaders

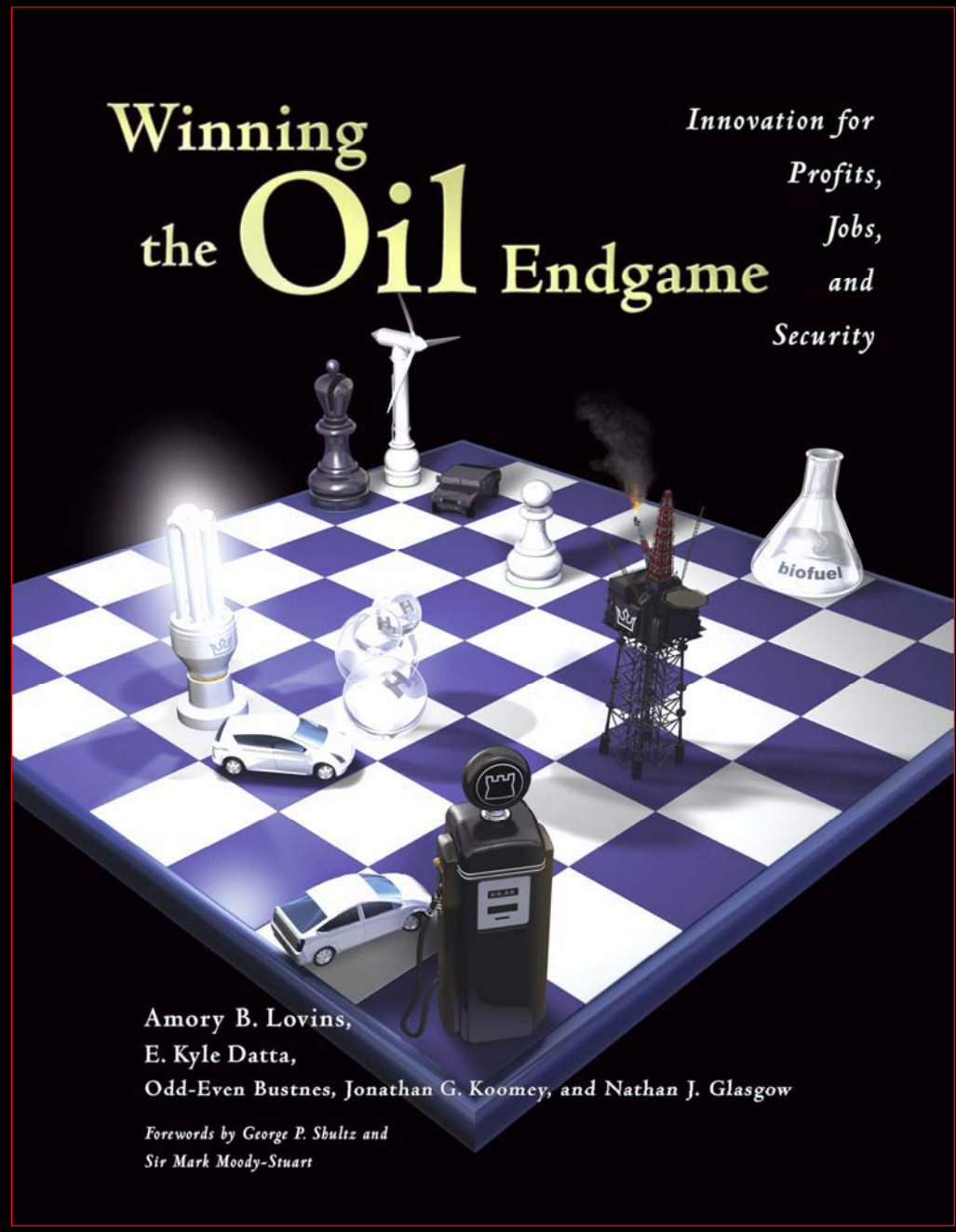
Based on competitive strategy cases for cars, trucks, planes, oil, military

Book and technical backup are free at:

www.oilendgame.com

Over the next few decades, the U.S. can eliminate its use of oil and revitalize its economy, led by business for profit

(So, probably, can Sweden)



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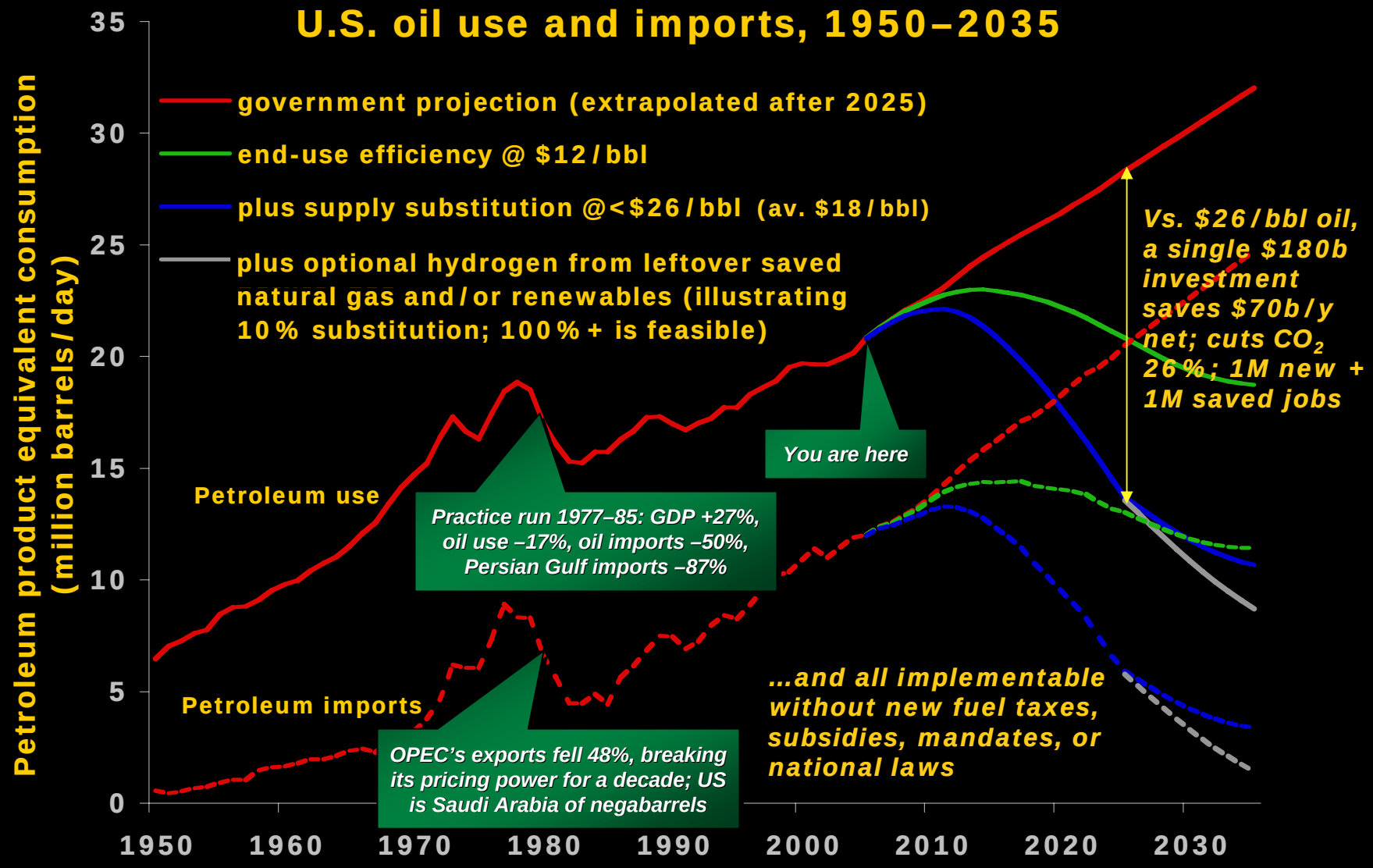
A profitable US transition beyond oil (with best 2004 technologies)



Vehicles use 70% of US oil, but integrating low mass & drag with advanced propulsion saves ~2/3 very cheaply

CARS: save 69% at $0.15/L

Surprise: ultralighting is ***free —*** offset by simpler automaking and the 2× smaller powertrain

250 km/h, 2.5 L/100 km

PLANES: save 20% free, 45–65% @ ≤$0.12/L

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

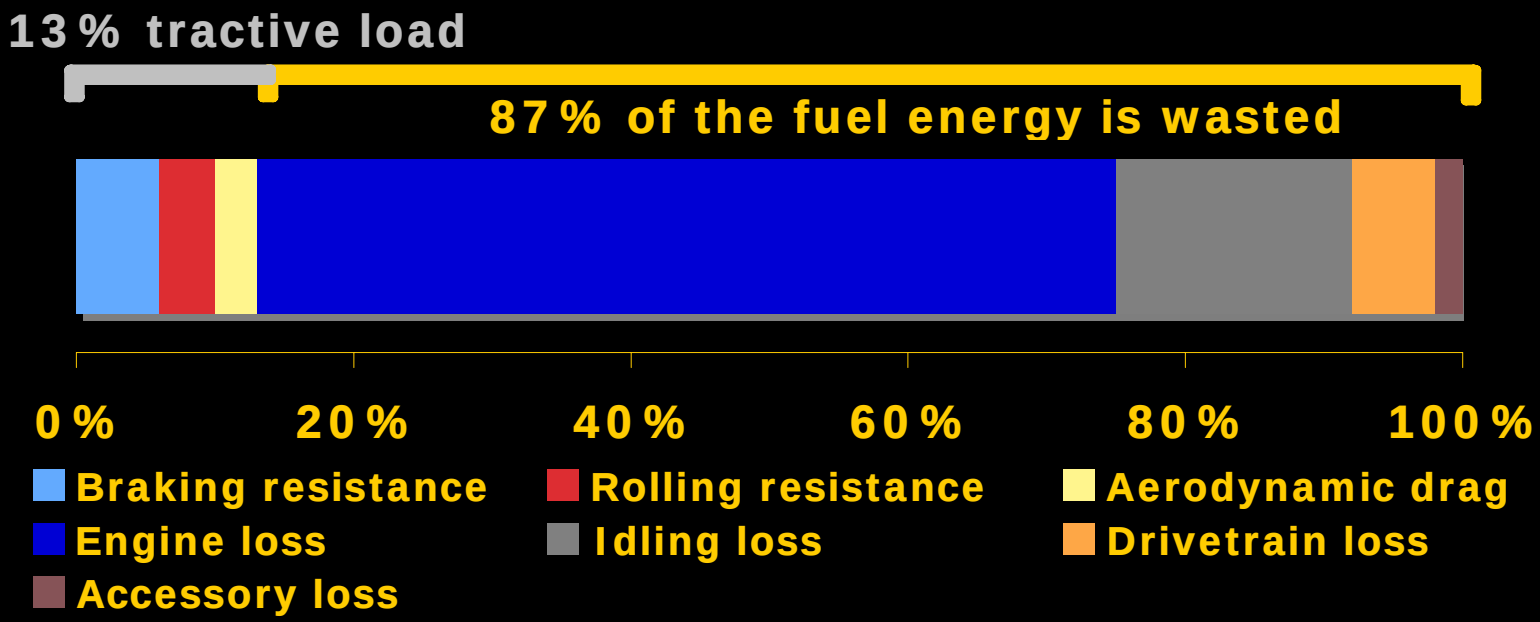
BLDGS/IND: big, cheap savings; often *lower* capex

TRUCKS: save 25% free, 65% @ $0.07/L

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Technology is improving faster for efficient end-use than for energy supply

Each day, your car uses ~100× its weight in ancient plants. Where does that fuel energy go?



- 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 ~7–8 units of gasoline in the tank (or ~3–4 with a hybrid)
- **So first make the car radically lighter-weight!**

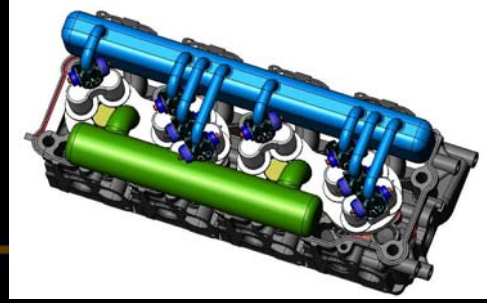

Midsize Revolution *midsize SUV, 5 adults in comfort, 2 m³ cargo*
Ultralight (–53%, 857 kg) but ultrasafe
0–100 km/h in 8.3 s (later 7.2)
3.56 L/100 km w/gasoline hybrid
2.06 "L"/100 km w/H_2 fuel cell
40% lower manufacturing capital intensity
~99% lower tooling cost; no body shop, optional paint shop
ROCKY MOUNTAIN INSTITUTE
"We'll take two."
— *Automobile* magazine
World Technology Award, 2003
Show car and a complete virtual design (2000), uncompromised, production-costed, manufacturable; hybrid yields 1-y payback *vs* EU gasoline

Toyota's 1/X concept car (Tokyo Motor Show, 26 Oct 2007)

- 2× *Prius* efficiency, similar interior vol. (4 seats)
- 3× lighter (420 kg)
- carbon-fiber structure
- 0.5-L flex-fuel engine
- plug-in hybrid-electric
- powertrain under rear seat), rear-wheel drive

This design, the closest yet shown by a major automaker to RMI's Hypercar® concept, was announced 10 Oct 07—a day after Toray was reported to be planning a ¥30b plant to mass-produce carbon-fiber autobody panels and other components for Toyota and others

Emerging powertrain breakthroughs too…

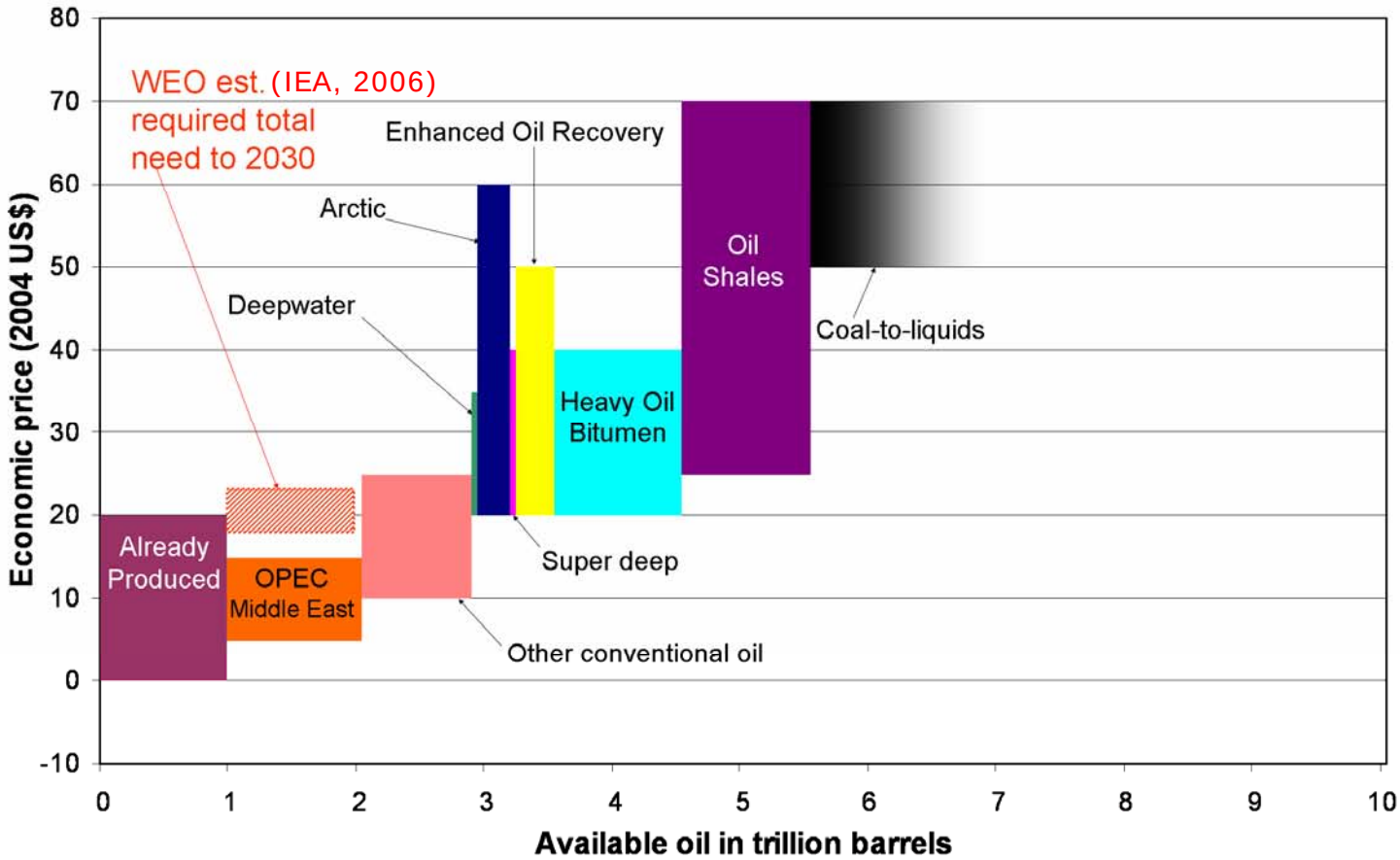


- Fast, small, light, cheap, proven, mature electronic valves permit extremely precise fuel and air injection under real-time closed-loop control
- This in turn permits unusual event sequences and combustion cycles in camless engines
- Those are expected to yield ~55–60% efficiency from any fuel (on the fly), with >50% higher torque, >30% smaller size, >10% lower cost, and extremely low emissions with no cleanup
- The first such prototype “digital engine” ran 30 January 2007 in a test cell at Sturman Industries near Colorado Springs, Colorado (Eric Cefus, ecefus@sturmanindustries.com, 719 686 6068)

Implementation is underway via "institutional acupuncture"

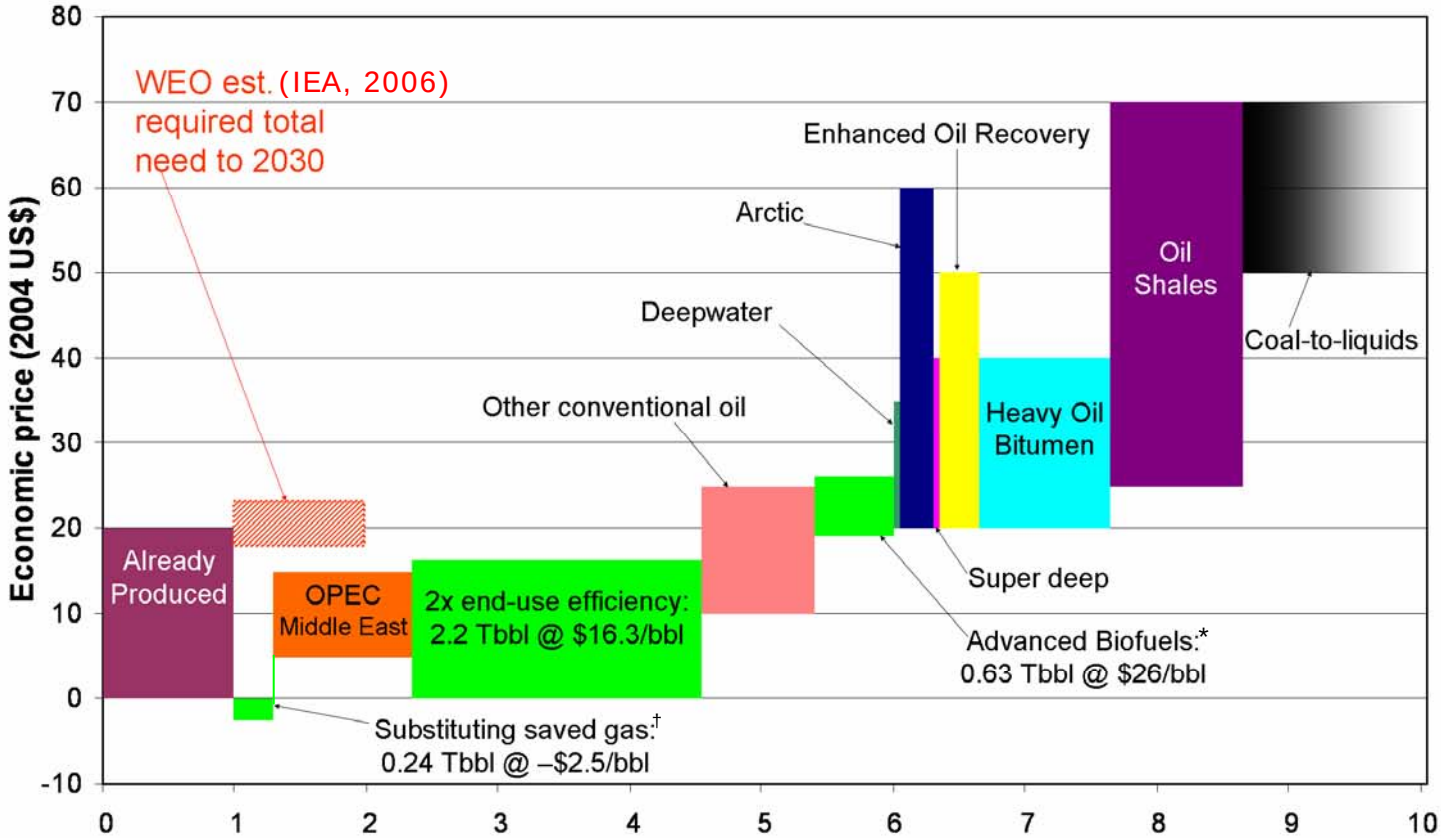
- RMI's 3-year, $4-million effort is leading & consolidating shifts
- Need to shift strategy & investment in six sectors
  - Aviation: Boeing did it (*787 Dreamliner*)…and beat Airbus
  - Heavy trucks: Wal-Mart led it (with other buyers being added)
  - Military: emerging as the federal leader in getting 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)

How that supply curve stretches ~3 Tbbl if the U.S. potential shown in *Winning the Oil Endgame* scales, very approximately, to the world

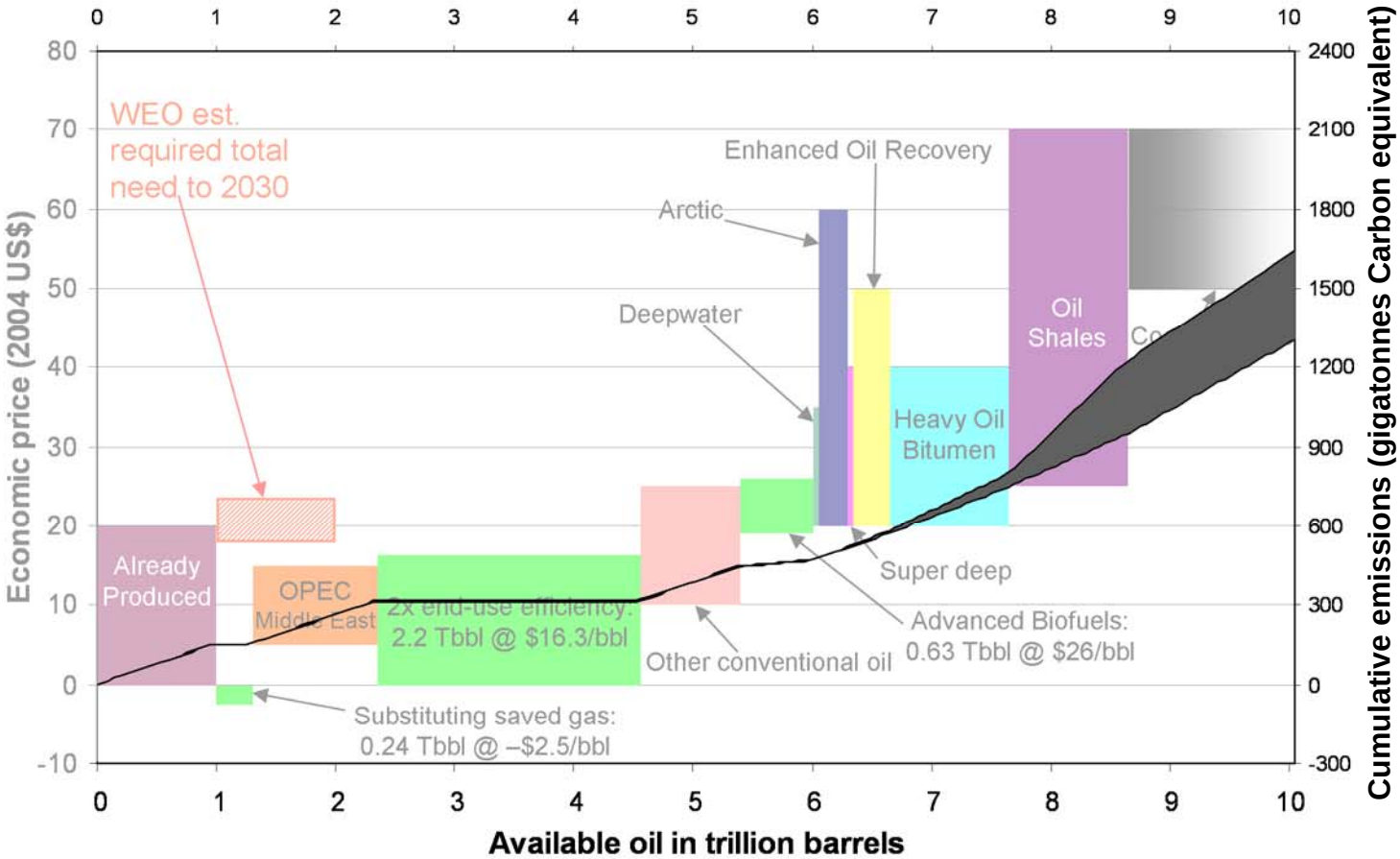


†These substitutions make sense at any relative prices. Depending on future prices, additional such substitutions several- to manyfold larger than shown are also available

*Probably much understated because scaling from U.S. to world should count abundant tropical cane potential; also, the estimate does not include emerging major options like algal oils

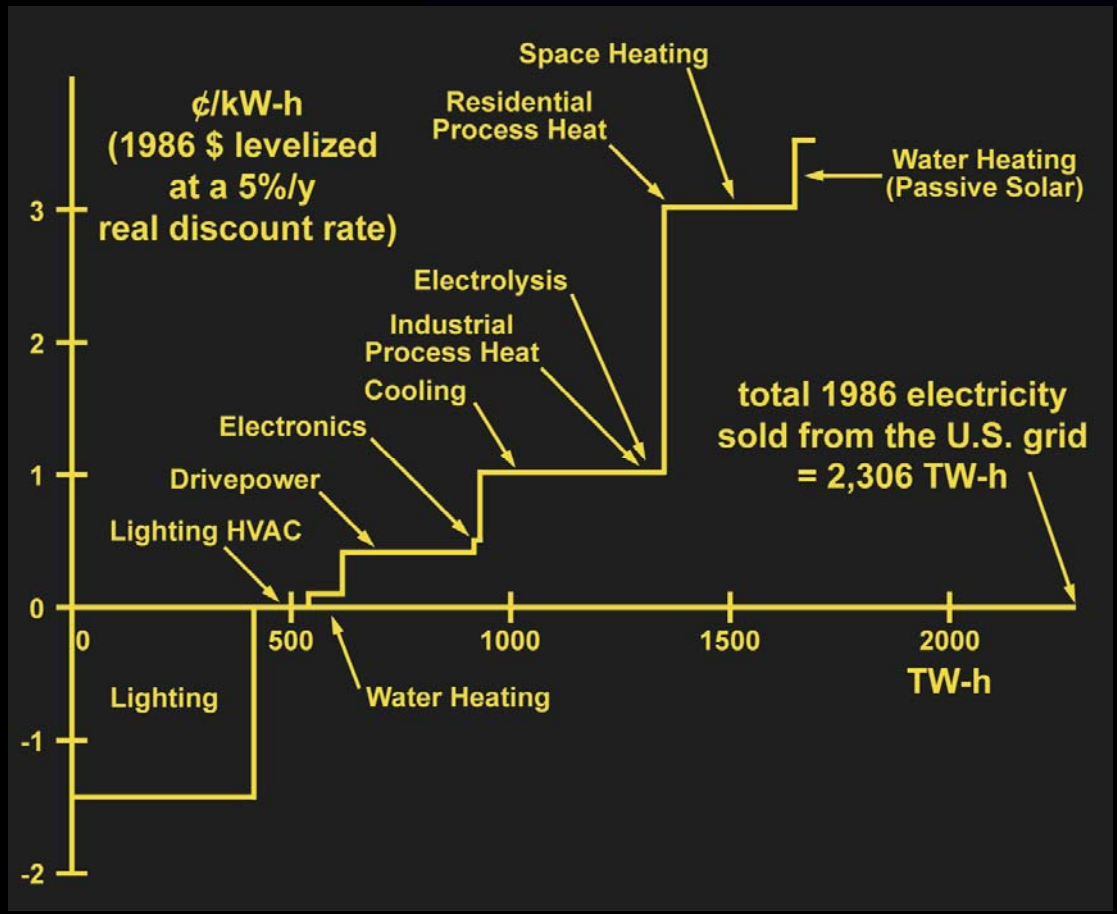
To scale from U.S. alternatives-to-oil potential in Mbbl/d achievable by the 2040s (at average cost $16/bbl in 2004 $: www.oilendgame.com) to world potential over 50 y, multiply the U.S. Mbbl/d × 146,000: 365 d/y × 50 y × 4 (for U.S.→world market size) × 2 (for growth in services provided). Obviously actual resource dynamics are more complex and these multipliers are very rough, so **this result is only illustrative and indicative.**

Stretching oil supply curve by ~3 Tbbl averts >1 trillion tonnes of carbon emissions and tens of trillions of dollars



Nobody can know who's right about peak oil, but it doesn't matter

1989 supply curve for saveable US electricity (*vs.* 1986 frozen efficiency)



Best 1989 commercially available, retrofittable technologies

EPRI found 40–60% saving 2000 potential

Similar S, DK, D, UK…

Now conservative: savings keep getting bigger and cheaper faster than they're being depleted

Measured technical cost and performance data for ~1,000 technologies (RMI 1986–92, 6 vol, 2,509 pp, 5,135 notes)

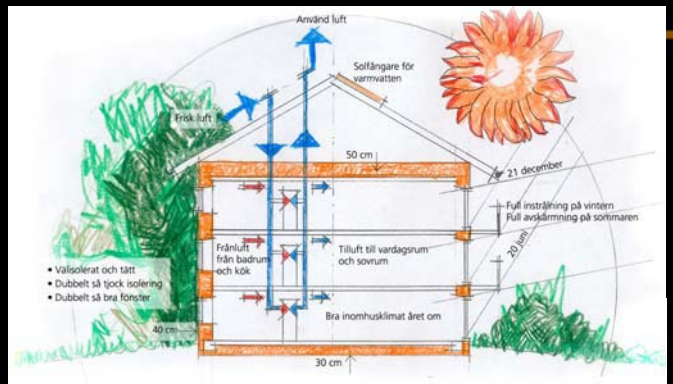
–44 to + 46˚C with no heating/cooling equipment, *less* construction cost

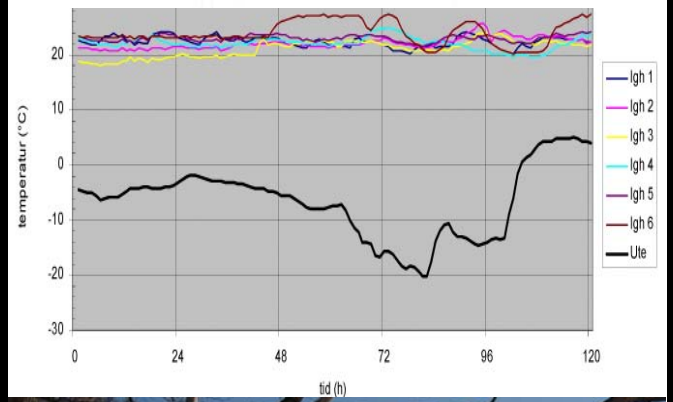
2200 m, frost any day, 39 days' continuous midwinter cloud…yet 28 banana crops with no furnace

Key: integrative design—multiple benefits from single expenditures

- Lovins house / RMI HQ, Snowmass, Colorado, '84
  - Saves 99% of space & water heating energy, 90% of home el. (372 m^2 use ~120 W_{av} costing ~$5/month @ $0.07/kWh)
  - 10-month payback in 1983
- PG&E ACT^2, Davis CA, '94
  - Mature-market cost –$1,800
  - Present-valued maint. –$1,600
  - 82% design saving from best 1992 std., ~90% from US norm
- Prof. Soontorn Boonyatikarn house, Bangkok, Thailand, '96
  - 84% less a/c capacity, ~90% less a/c energy, better comfort
  - No extra construction cost

Houses comfortable with no heating system in Göteborg, same capital cost





- Hundreds of “Passivhus” examples around Göteborg, typically designed by Hans Eek or Christer/Kerstin Nordström
- No extra capital cost

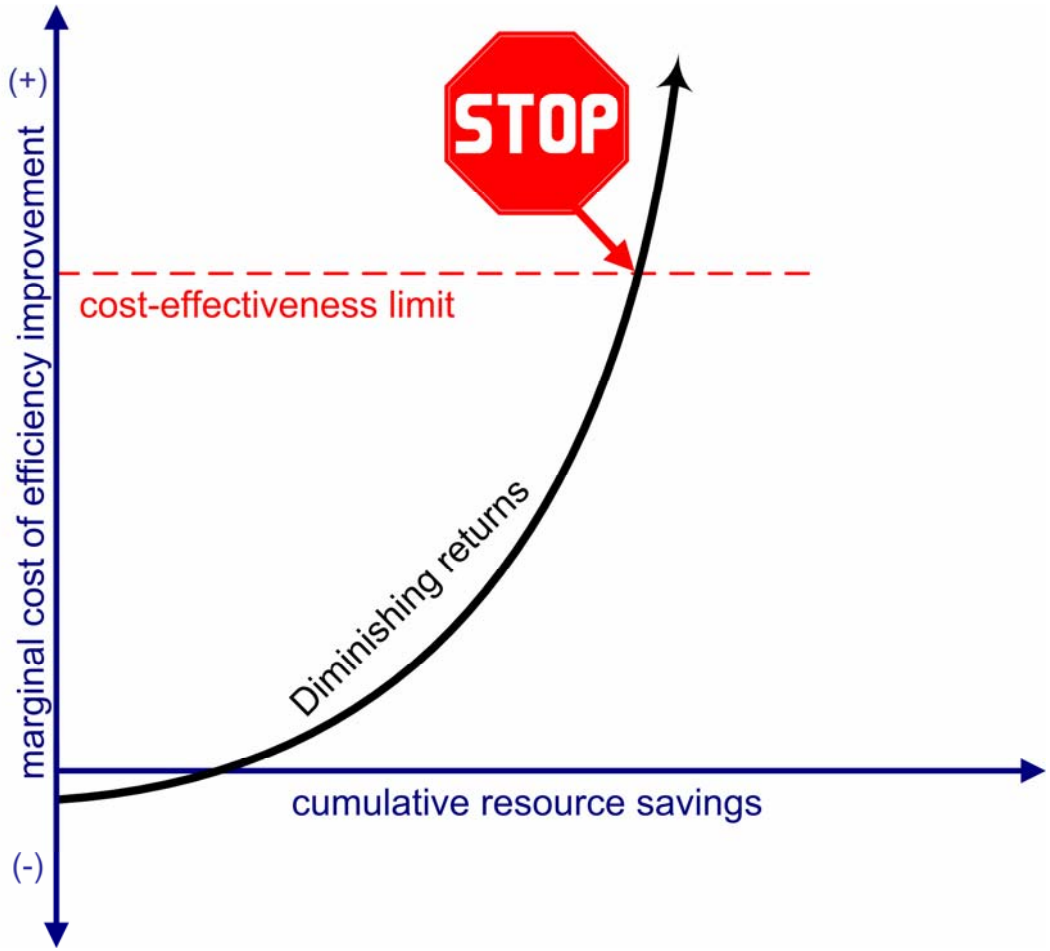
PASSIVHUSEN I LINDÅS

Försäljningspris: ca 2 000 000 SEK

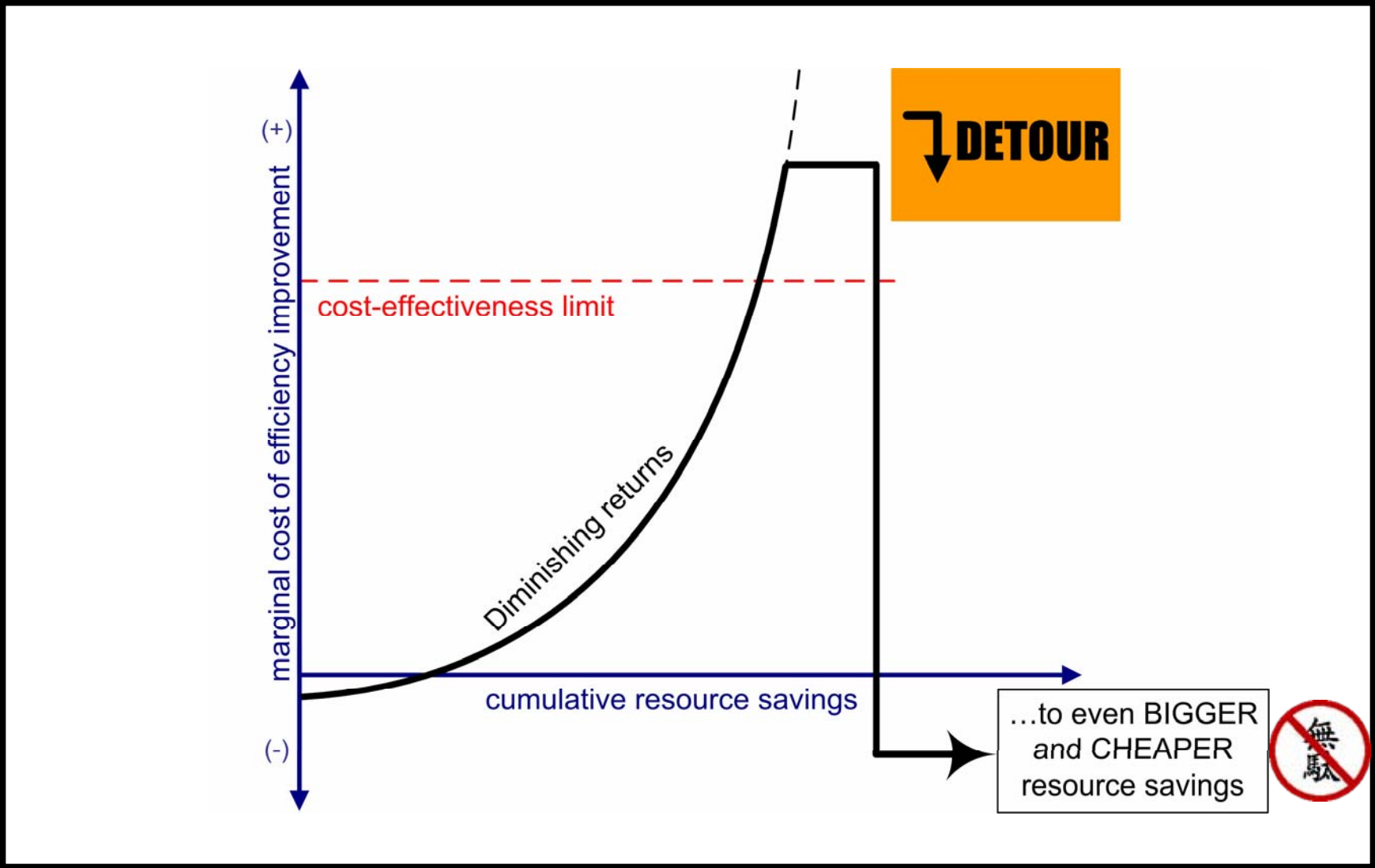
EXTRA KOSTNADER:	**SEK**
Isolering:	**15 – 20 000**
Värmeväxlare (luft – luft)	**10 – 15 000**
Fönster. U=0,85	**15 – 20 000**
SUMMA	**40 – 50 000**
MINUS VÄRMESYSTEM	**– 40 – 50 000**

- Cost-effectively retrofittable

Old design mentality: always diminishing returns...



New design mentality: expanding returns, "tunneling through the cost barrier"



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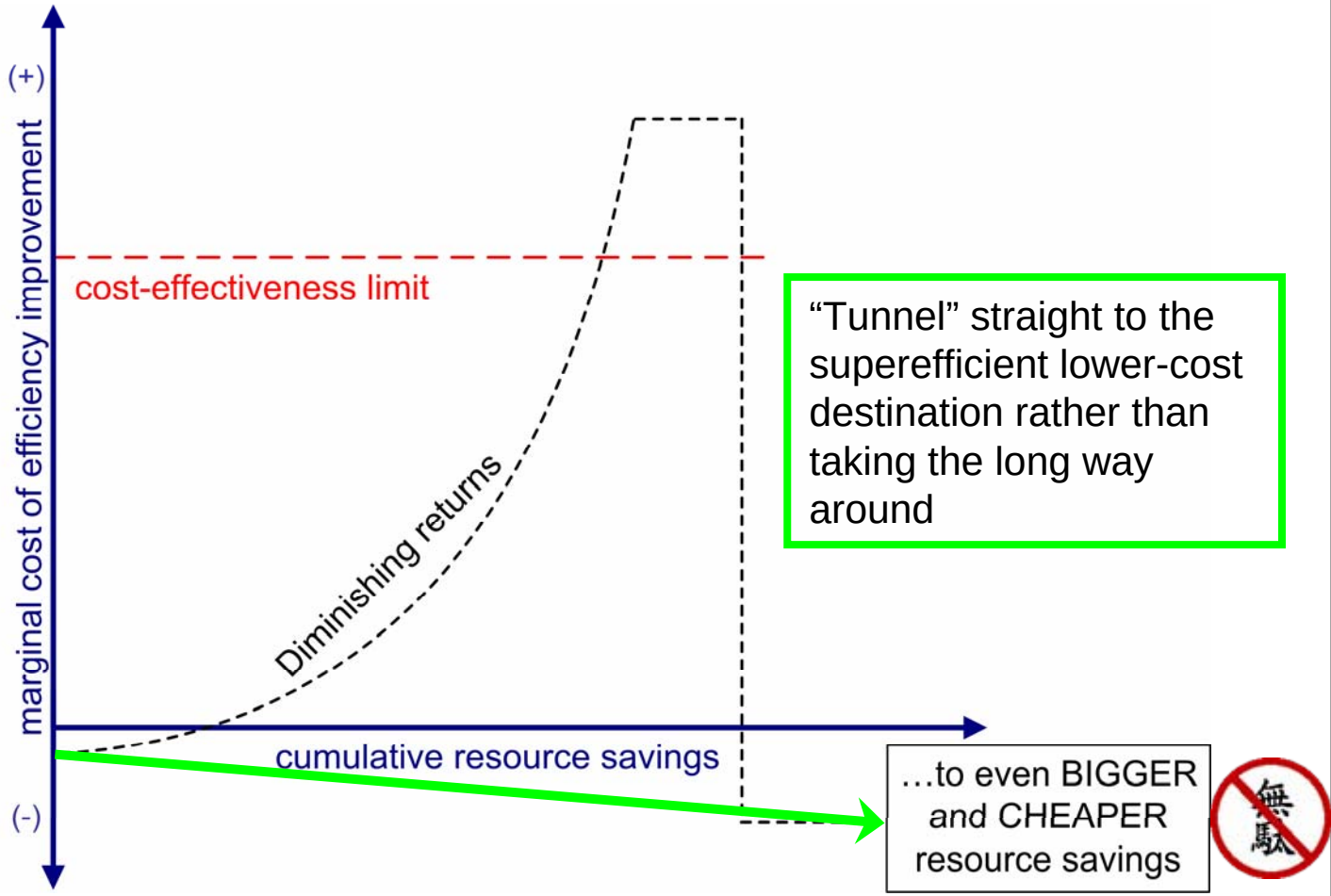


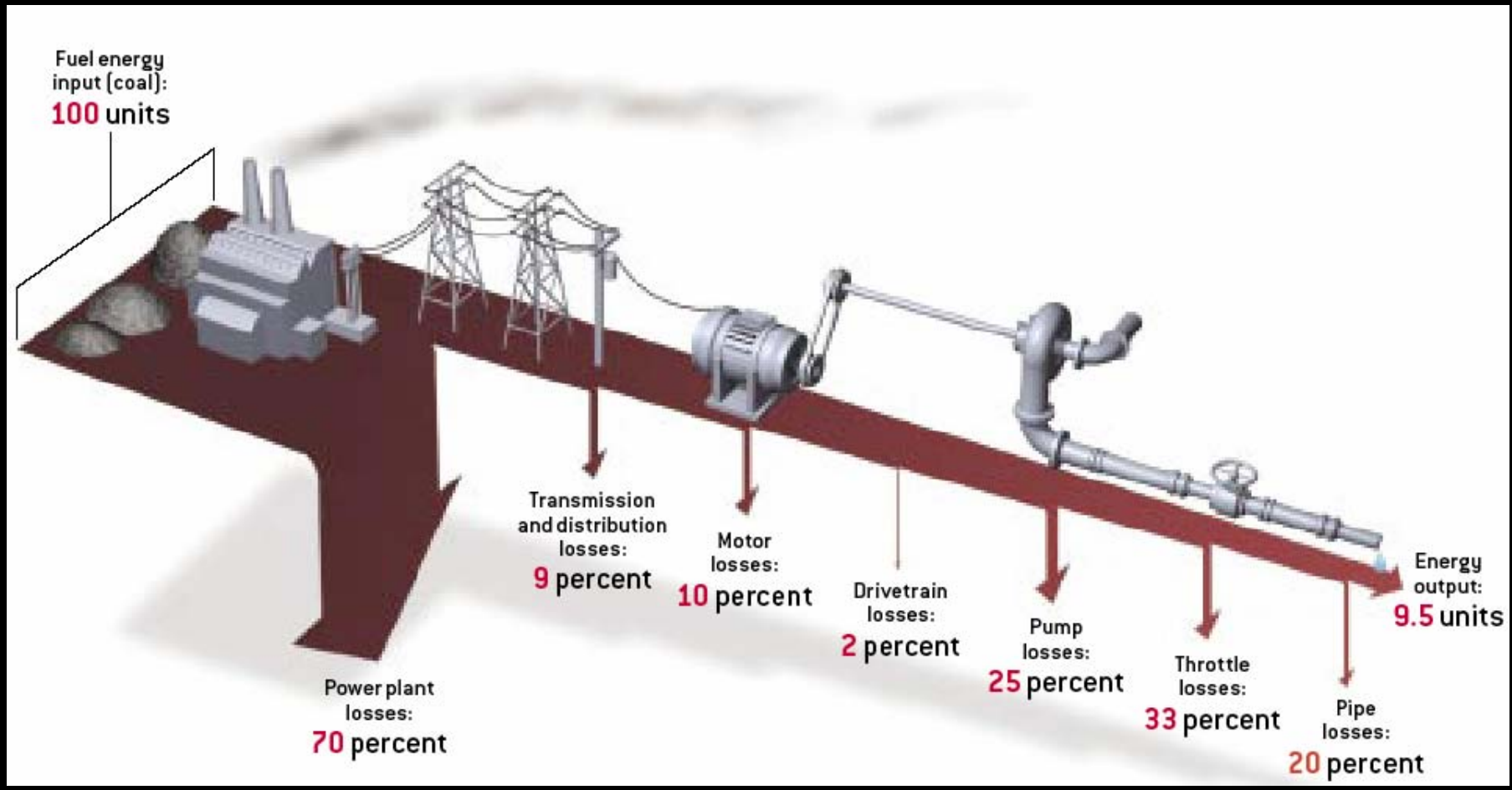
"Tunnel" straight to the superefficient lower-cost destination rather than taking the long way around

To see how, please visit www.rmi.org/stanford

New design mentality

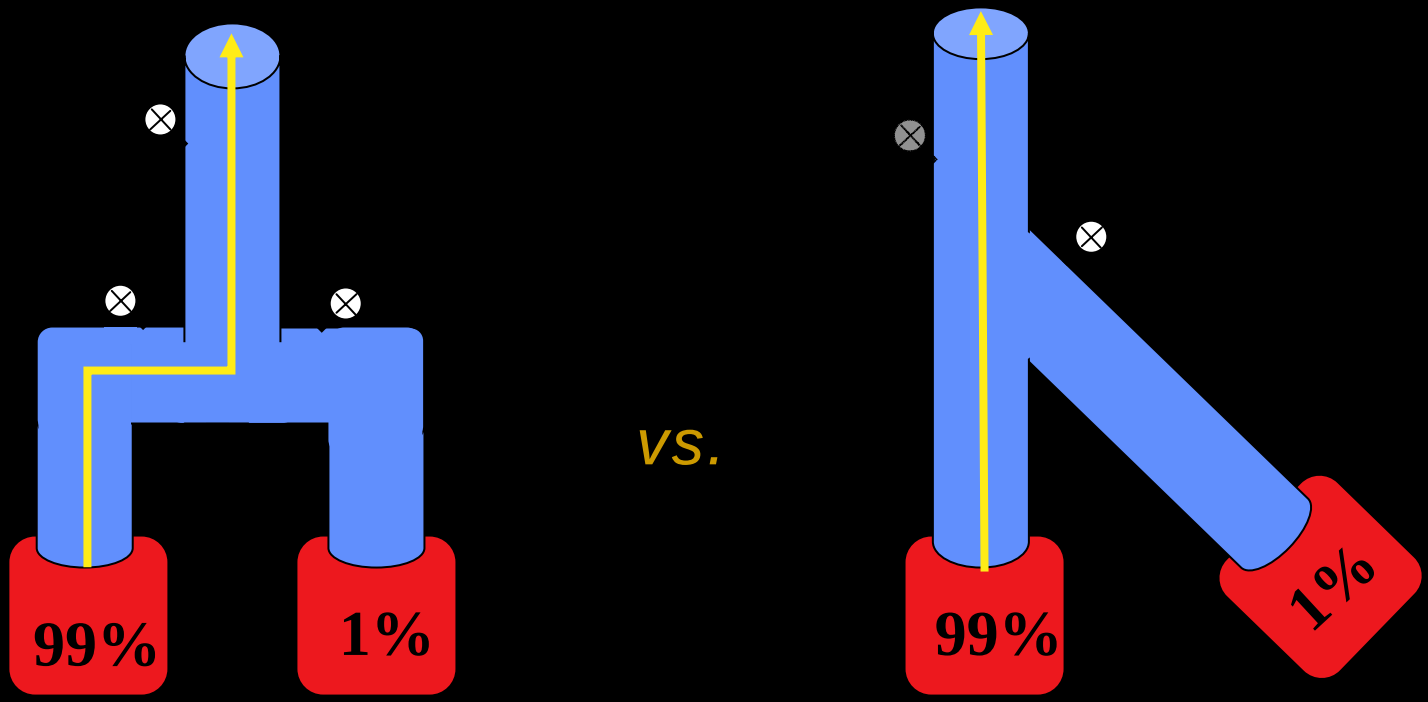
- Pumps and fans use half of motor energy; motors use 3/5 world electricity
- Redesigning a standard (supposedly optimized) industrial pumping loop cut its power from 70.8 to 5.3 kW (–92%), cost less to build, and worked better
- Just by specifying fat, short, straight pipes—not (as usual) thin, long, crooked pipes!
- Even better design could have saved ~98% and cost even *less* to build
- This example is archetypical

Compounding losses…or savings…so start saving at the *downstream* end to save ten times as much energy at the power plant



Also makes upstream equipment smaller, simpler, cheaper

It’s often remarkably simple



Boolean pipe layout

hydraulic pipe layout

High-efficiency pumping / piping retrofit
(Rumsey Engineers, Oakland Museum)

Notice smooth piping design – 45ºs and Ys

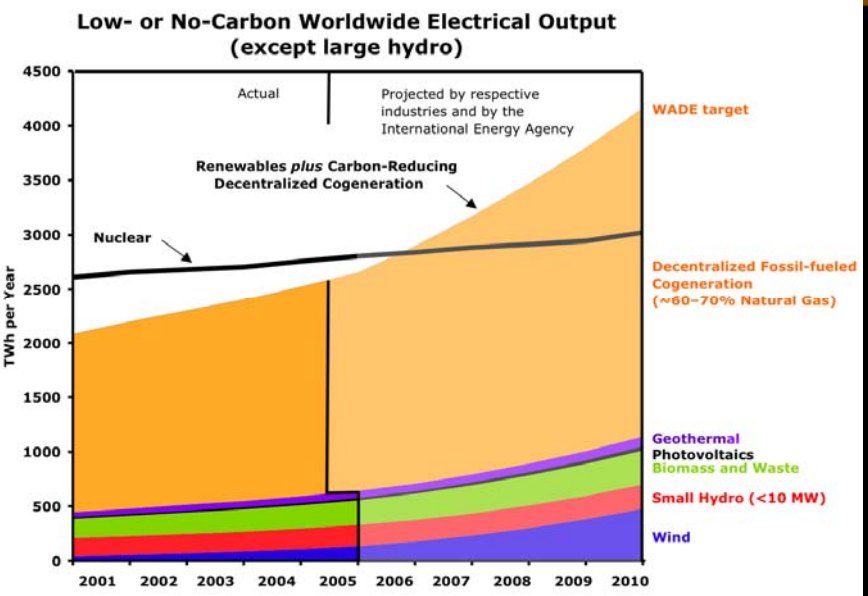
Downsized condenser-water pumps, ~75% energy saving

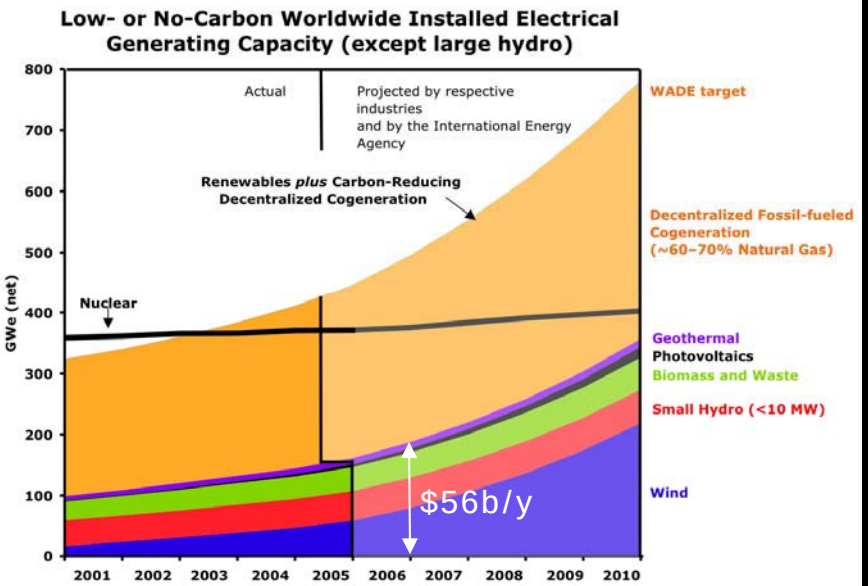
Examples from RMI's industrial practice (~$30b of facilities)

- Save half of motor-system electricity; retrofit payback typically <1 y
- Similar ROIs with 30–50+% retrofit savings of chip-fab HVAC power
- Retrofit very efficient oil refinery, save 42%, ~3-y payback
- Retrofit North Sea oil platform, save 50% el., get the rest from waste
- Retrofit USNavy *Aegis* cruiser's hotel loads, save ~50%, few-y paybacks
- Retrofit huge LNG plant, ≥40% energy savings; ~60%? new, cost less
- Redesign $5b gas-to-liquids plant, –$1b capex, save >50% energy
- Redesign giant platinum mine, 43% energy savings, 2–3-y paybacks
- Redesign new data center, save 89%, cut capex & time, improve uptime
- Redesign next new chip fab, eliminate chillers, save 2/3 el., 1/2 capex
- Redesign supermarket, save 70–90%, better sales, ?lower capex
- Redesign new chemical plant, save ~3/4 of auxiliary el., –10% capex
- Redesign cellulosic ethanol plant, –50% steam, –60% el, –30% capex
- Redesign new 58m yacht, save 96% potable H_2O & 50% el., lower capex
- "Tunneling through the cost barrier" now observed in 29 sectors
- None of this would be possible if original designs had been good
- Needs engineering pedadogy/practice reforms; see www.10xE.org

Electric shock: low-/no-carbon decentralized sources are eclipsing central stations

RMI analysis: www.rmi.org/sitepages/pid171.php#E05-04





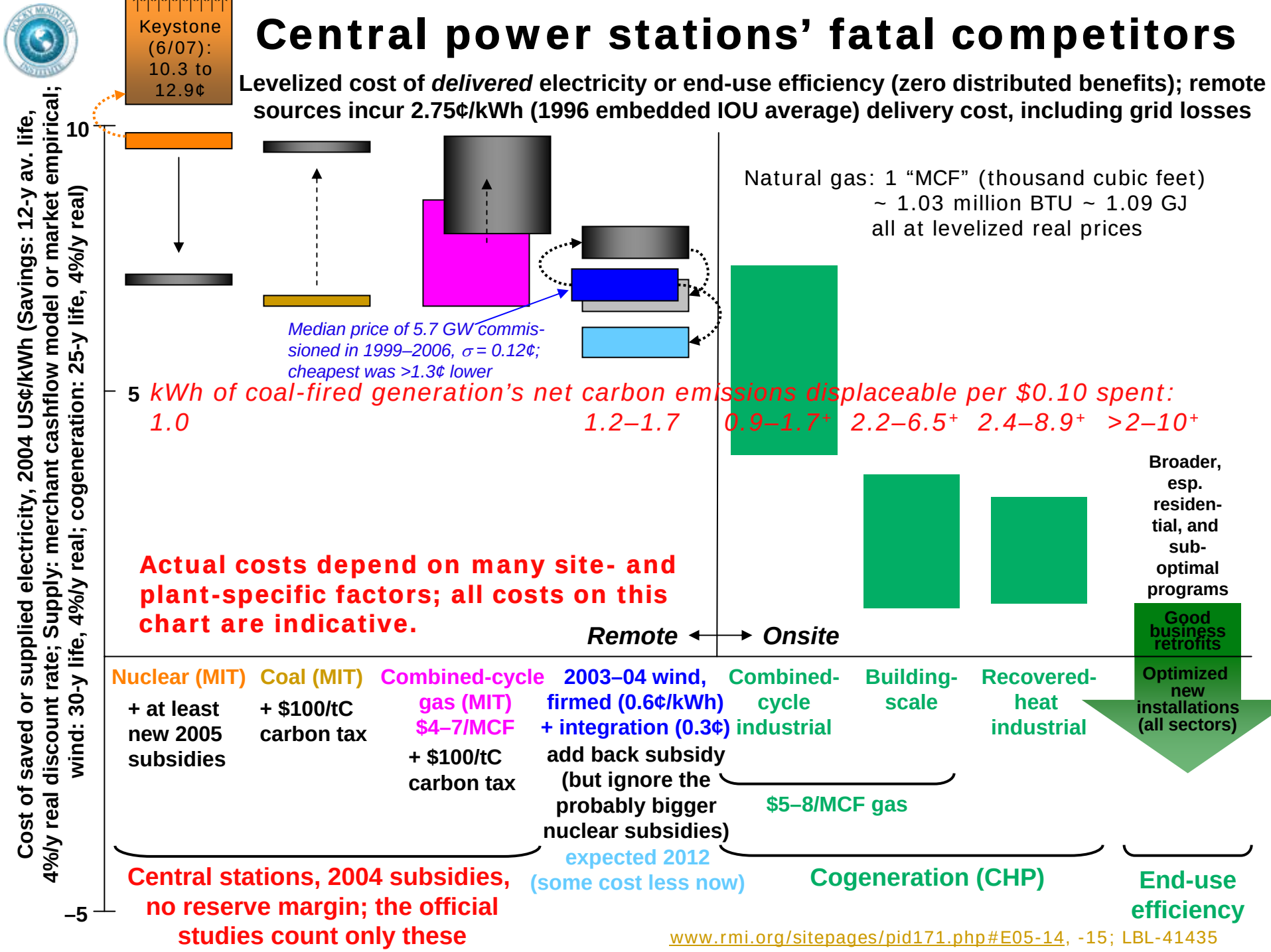
- Two-thirds combined-heat-and-power (cogeneration)*, ~60–70% gas-fired, ≥50% CO_2 reduction

*Gas turbines ≤120 MWe, engines ≤30 MWe, steam turbines only in China

- One-third renewable (including hydropower only up to 10 MW_e)
- In 2005, micropower added 4× as much output and 11× (excl peaking & standby units, 8×) as much capacity as nuclear power added
- *1/6 of el, 1/3 of new el, & rising*
- 1/6 to >1/2 of all electricity in 13 industrial nations
- Negawatts comparable or bigger; central plants have <1/2 of market!
- Micropower is winning due to lower costs & financial risks, so it's financed mainly by private capital (only central planners buy nuclear)

Central power stations' fatal competitors

Levelized cost of *delivered* electricity or end-use efficiency (zero distributed benefits); remote sources incur 2.75¢/kWh (1996 embedded IOU average) delivery cost, including grid losses



www.rmi.org/sitepages/pid171.php#E05-14, -15; LBL-41435

So it's not surprising that worldwide in 2006 …

- New nuclear capacity was smaller than solar PV additions, or 1/10th of windpower additions
- Nuclear retirements exceeded additions, so *net* nuclear capacity fell by 0.5 GW while micropower added ~34 net GW
- Micropower passed nuclear power in total annual electricity production (16% of total)
- Micropower got $56b of private risk capital; nuclear, as always, got zero
- And in China, distributed renewables had 49 GW—7× nuclear capacity—and added 7× more per year

All options face implementation risks; what does market behavior reveal?

- California's 1982–85 fair bidding with roughly equal subsidies elicited, *vs.* 37-GW 1984 load:
  - 23 GW of contracted electric savings acquisitions over the next decade (62% of 1984 peak load)
  - 13 GW of contracted new generating capacity (35% of 1984 load), most of it renewable
  - 8 GW (22%) of additional new generating capacity on firm offer
  - 9 GW of new generating offers arriving per year (25%)
  - Result: glut (143%) forced bidding suspension in April 1985
  - Lesson: real, full competition is more likely to give you too many attractive options than too few!
- Ultimate size of alternatives also dwarfs nuclear's
  - El. end-use efficiency: ~2–3× (EPRI) or 4× nuclear's 20% US share at below its *short*-run marginal delivered cost
  - CHP: industrial alone is comparable to nuclear; + buildings CHP
  - On-/nearshore wind: >2× US & China el., ~6× UK, ~35× global*
  - Other renewables: collectively even larger, PVs almost unlimited
  - Land-use and variability *not* significant issues

*www.stanford.edu/group/efmh/winds/global_winds.html, on- and nearshore sites with annual mean windspeeds ≥6.9 m/s at 80m hub, ~72 TW

Two 1989 climate-strategy cases that scope the world's conditions

- Sweden: Vattenfall, "The Challenge of Choices"
  - Cold, cloudy, far north, heavily industrialized, relatively efficient
  - Half of Swedish el. saveable at 78% lower cost than making more
  - Least-cost strategy (doubled el. end-use eff. + some fuel-switching + environmental dispatch) could achieve forecast 54% GDP growth 1987–2010, shut down nuclear half of el. supply, reduce heat-and-power-sector CO_2 emissions by 1/3, cut el. service cost $1b/y
  - Report (in T B Johansson's *Electricity)* little-known, ignored, valid
- India: Amulya Reddy, roadmap for Karnataka state
  - A little efficiency & natural gas, bagasse CHP, biogas/producer gas, solar water heaters, small hydro—far from comprehensive mix
  - Would achieve far greater and faster economic development
  - Would have 3/5 lower el. demand, 2/3 lower cost, and 99.5% less fossil-fuel CO_2 than utility's official plan (*both* plans were rejected)
- Both: efficiency more than pays for renewables, making major carbon savings better than free
- Today's technologies/designs are far better & cheaper

Five implementation myths

- "It isn't happening—why not?"
  - U.S. E/GDP (1975–2006) fell 48% for energy, 54% for gas, 64% for direct natural gas; total U.S. oil, coal, and energy use *fell* in 2006. Far more *could* happen if we paid attention
- "Solutions must await global agreement"
- "Pricing carbon is the essential first step"
  - Internalizing carbon costs will be valid and helpful, but not necessary, sufficient, nor probably very important (because efficient carbon markets will clear at low or negative prices)
  - *Ability to respond* to price ("barrier-busting") matters more
- "Public policy = taxes, subsidies, and mandates"
  - Other instruments, such as car feebates and utility decoupling-and-shared-savings, are more effective and attractive
- "Public policy is the only, or the strongest, key"
  - Innovative competitive strategy, technology, and design, all from *business* coevolving with civil society, are more dynamic

Implementation reality: Compete to win…via efficiency

- Boeing's crisis in 1997 was like Detroit's today
  - Wrenching changes instituted at BCA, including TPS (*e.g.*, moving assembly); mfg. & costs brought back under control; but what next?
- 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," said Richard L. Aboulafia, a Teal Group aerospace analyst, in 2003
- Boeing's bold, efficiency-led 2004 response: *787 Dreamliner*
  - ≥20% more fuel-efficient than comparable modern aircraft, *same price*
  - 80% advanced composite by volume, 50% by mass ⟶
    - 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 jetliner in history
  - Now rolling out *787*'s radical advances to *all* models (Yellowstone)

- Airbus: Ultra-jumbo *A380*, 2 years late, ~□5b over budget
  - Response? Efficient, composite *A350*—probably too late
- Boeing's breakthrough strategy flipped the sector in 3 years

What are we waiting for?
We are the people we have been waiting for!

"Only puny secrets need protection. Big discoveries are protected by public incredulity."

—Marshall McLuhan

Your move...

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