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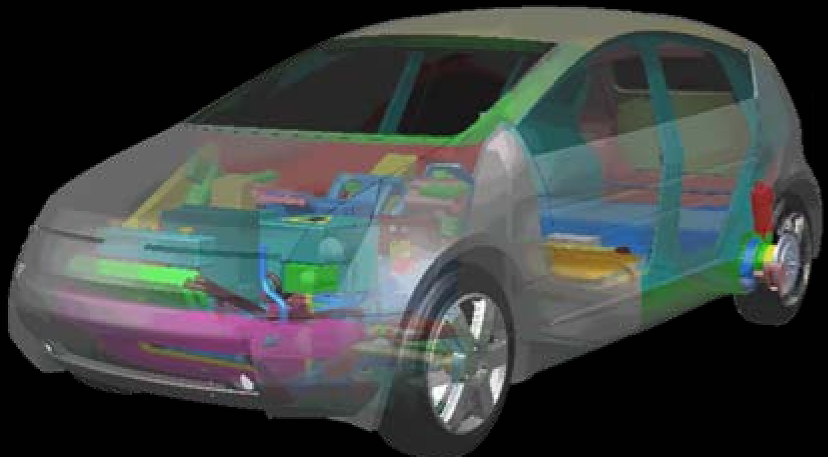
Army Sustainability Lecture Series, Army Environmental Policy Institute
Washington DC, 28 Oct 08

DoD's Strategic Energy Opportunities: More Fight, Less Fuel, Lower Cost, Safer World



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DoD's energy challenge

- The Department's mission is at risk, and huge costs are being paid in blood, treasure, and lost combat effectiveness, due to:
  - Pervasive waste of energy in the battlespace
  - Fixed facilities' dependence on the highly vulnerable electricity grid
- Solutions are available to turn these handicaps into revolutionary gains in capability, at comparable or lower capital cost and at far lower operating cost, without tradeoff or compromise
- Adopting these means to give DoD's forces and facilities two vital new attributes—*endurance* and *resilience*—depends on your attention

“[A]ggressively developing and applying **energy-saving technologies** to military applications would potentially do more to solve the most pressing long-term challenges facing DoD and our national security than any other single investment area.”

— LMI review of *Winning the Oil Endgame*, Jan 05, emphasis added

Independent, transparent, peer-reviewed, uncontested, OSD / ONR-sponsored, Sep 04

For business / mil. leaders

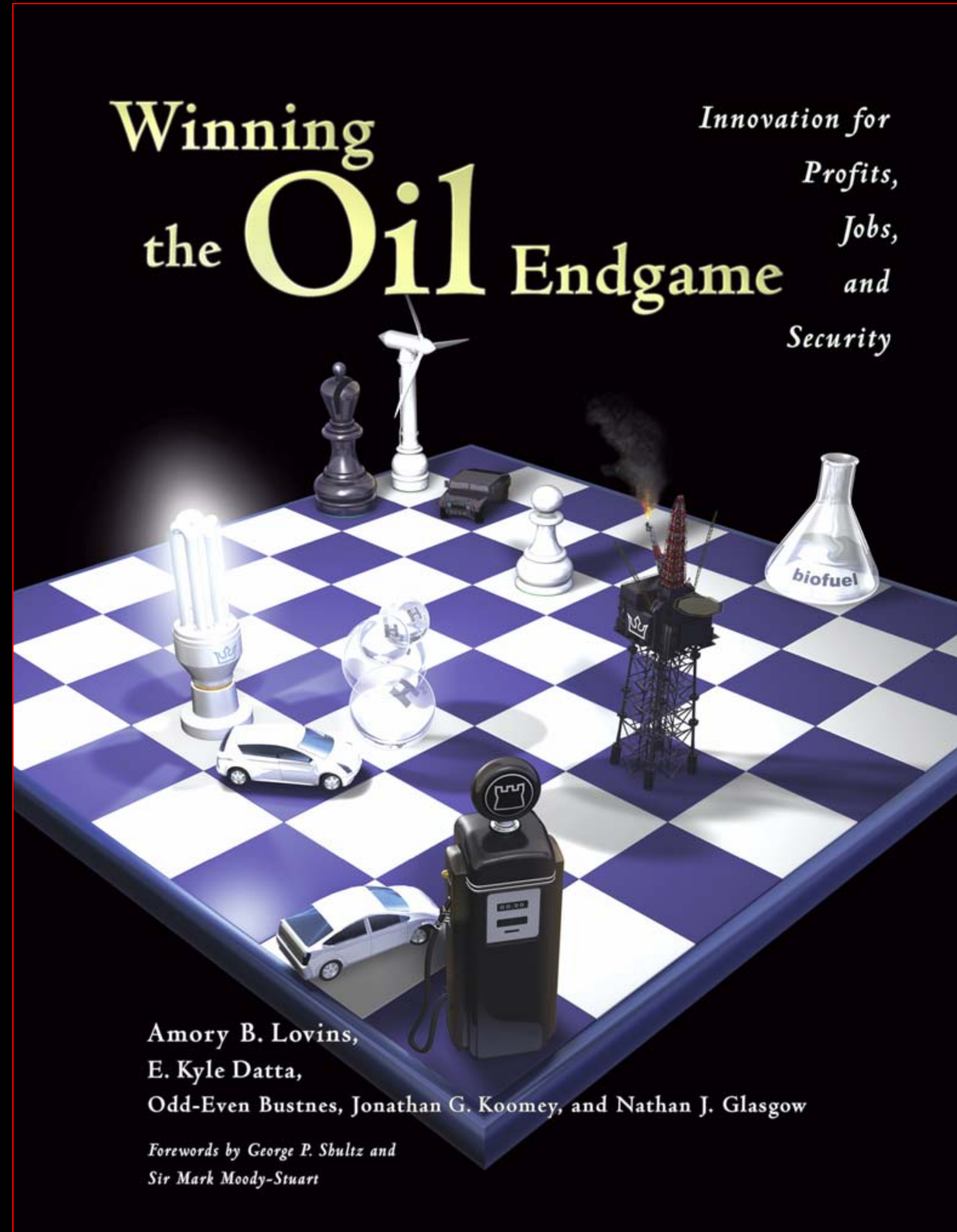
Based on competitive strategy cases for cars, trucks, planes, oil, military

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 others)



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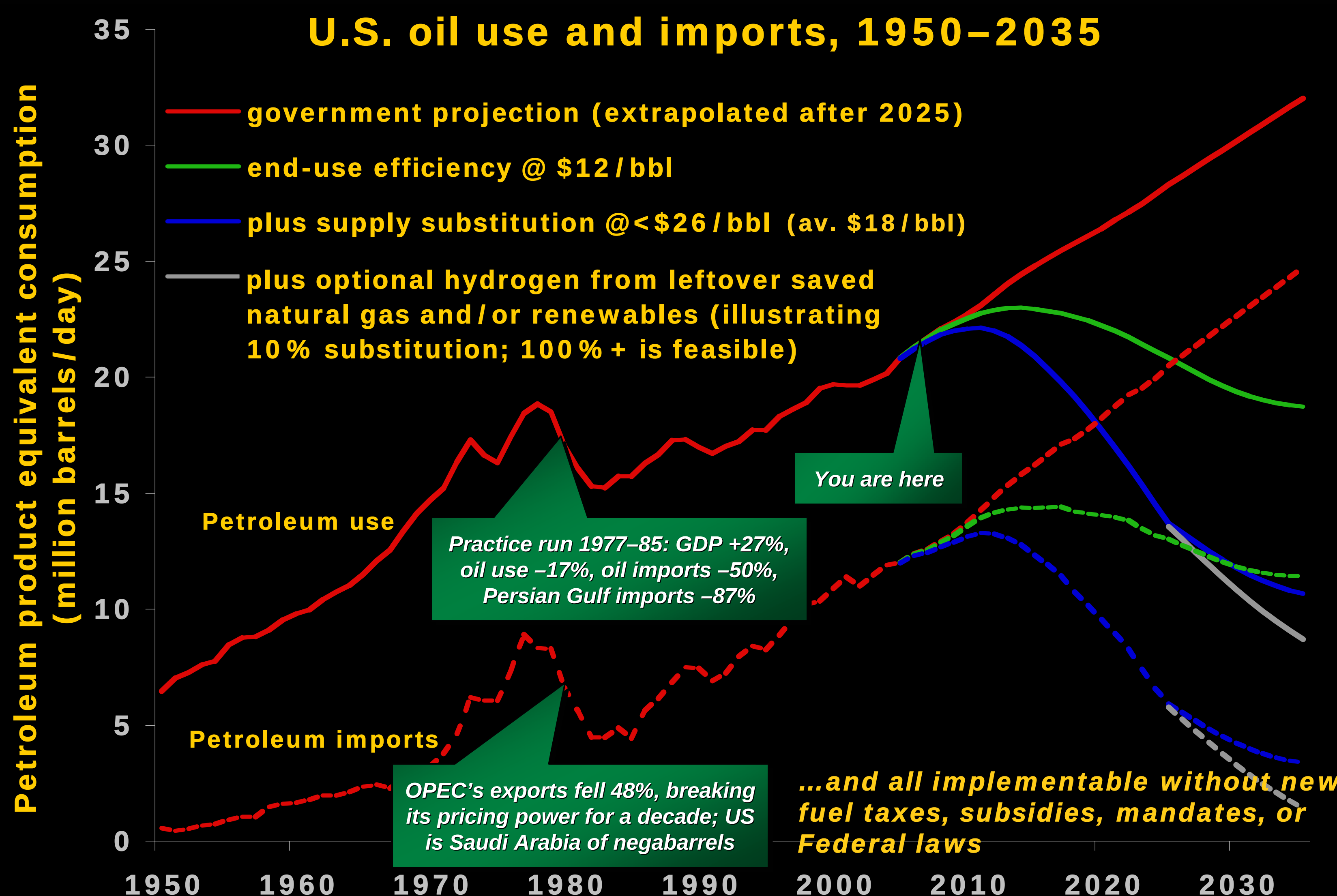
A profitable US transition beyond oil (with best 2004 technologies)



Integrating ultralight, ultra-low-drag, and advanced propulsion triples car, truck, & plane efficiency at low cost

CARS: save 69% at 57¢/gal

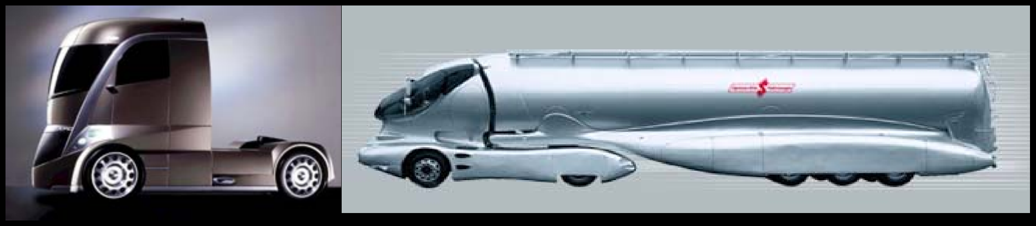
Surprise: ultralighting is ***free*** **—** offset by simpler automaking and 2–3× smaller powertrain!

155 mph, 94 mpg

PLANES: save 20% free, 45–~65% @ ~46¢/gal

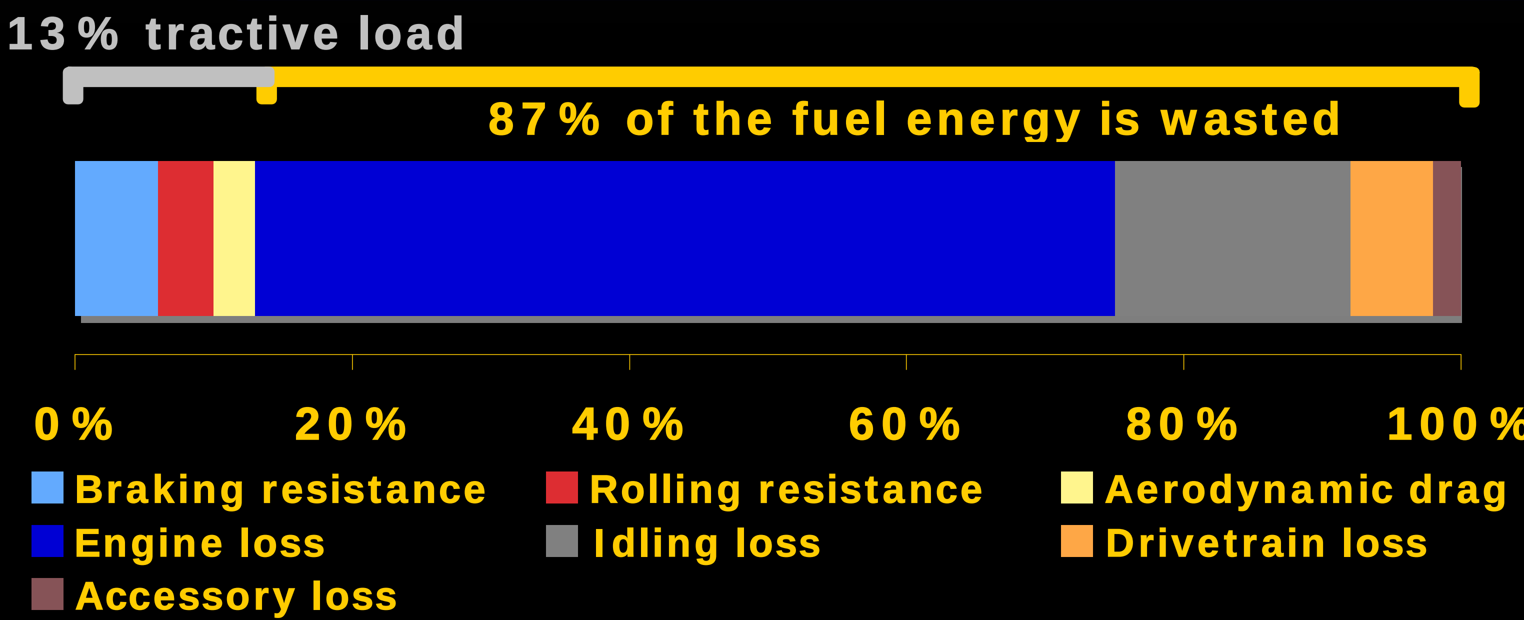
BLDGS/IND: big, cheap savings; often *lower* capex

TRUCKS: save 25% free, 65% @ 25¢/gal



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

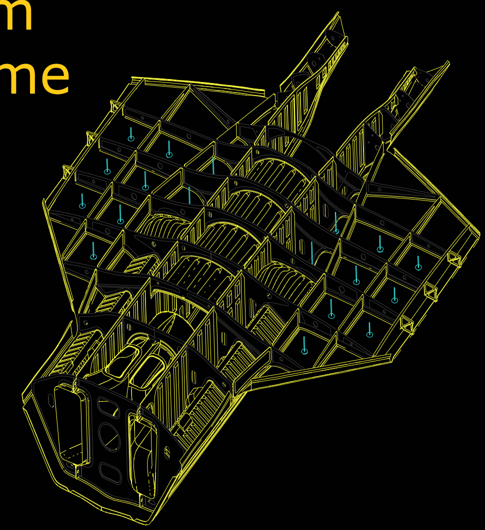
Each day, your car uses ~100× its weight in ancient plants. Where does that fuel energy go?



- 6% accelerates the car; just ~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!**

Migrating innovation from military / aerospace to high-volume vehicles

◊ 1994–96: DARPA/IATA* Skunk Works® team designed an advanced tactical fighter airframe



- made 95% of carbon-fiber composites
- 1/3 lighter than its 72%-metal predecessor
- *but 2/3 cheaper…*
- because designed to be made from carbon, not from metal

*Integrated Technology for Affordability (IATA)

◊ Finding no military customer for something so radical, the team leader left. I hired him to lead the 2000 design of a halved-weight SUV with two Tier Ones, *Intl. J. Veh. Design* **35**(1/2):50–85 (2004), with 22-month payback at US fuel price…

Midsize 5-seat* Revolution *concept crossover SUV
Ultralight (1,889 lb, –53 %) but ultrasafe
0–60 mph in 8.2 s, 114 mpg (H_2)…
or 0–60 mph in 7.1 s, 67 mpg
(gasoline hybrid)

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

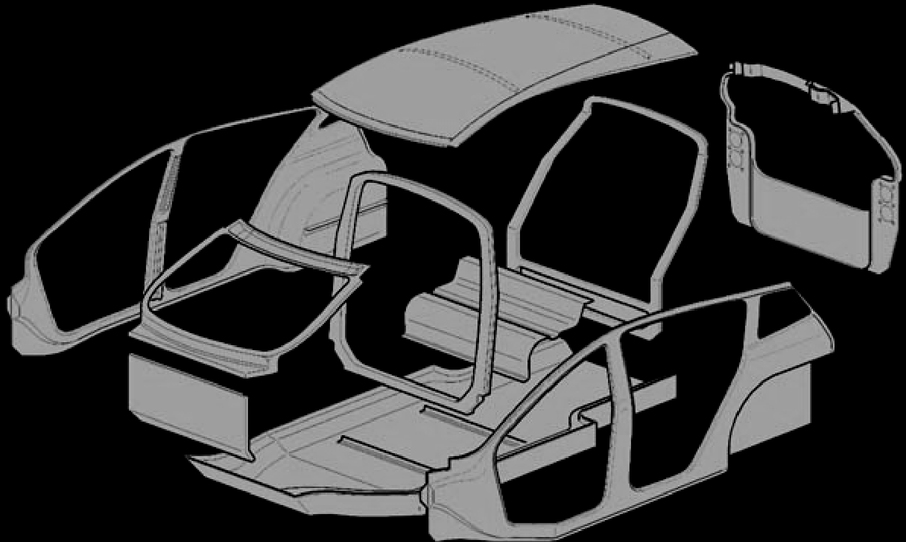
World Technology Award, 2003

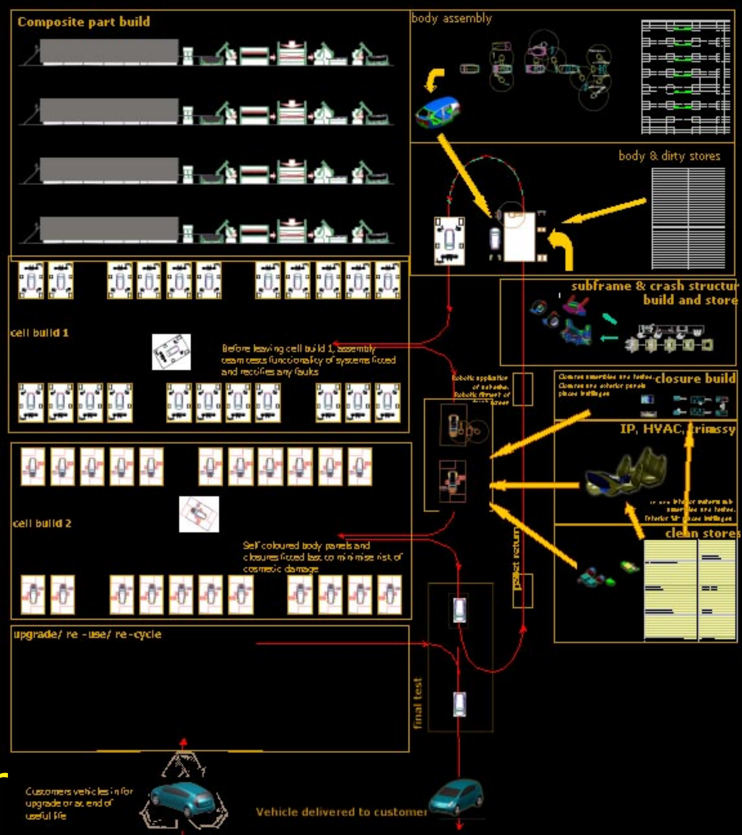
Show car and a complete virtual design (2000), uncompromised, production-costed, manufacturable; gasoline ver. MSRP +$2,511 MSRP bec. hybrid

Radically simplified manufacturing

◊ Mass customization

- *Revolution* designed for 50k/year production volume
- Integration, modular design, and low-cost assembly
- Low tooling and equipment cost





- 14 major structural parts, no hoists
- 14 low-pressure diesets (not ~10^3)
- Self-fixturing, detoleranced in 2 dim.
- No body shop, optional paint shop
- Plant 2/5 less capital/car-y, 2/3 smaller

Ultralight safety confirmed by racecar crash experience

(even with relatively brittle thermosets)

Katherine Legge's 180-mph walk-away *ChampCar* wall crash on 29 Sep 06

Toyota's Hypercar®-class *1/X* concept car (Tokyo Motor Show, 26 Oct 2007)

- 1/2 *Prius* fuel use, similar interior vol. (4 seats)
- 1/3 the weight (420 kg)
- carbon-fiber structure
- 0.5-L flex-fuel engine under rear seat, RWD
- plug-in hybrid-electric (if plain hybrid, 400 kg)

- One day earlier, Toray announced a ¥30b plant to mass-produce carbon-fiber auto parts for Toyota, Nissan,…; in July 2008, similar Honda/Nissan/Toray deal announced too; signals strategic intent
- Nov 2007: Ford announced 113–340-kg weight cuts MY2012–20
- Dec 2007: 15% av. weight cut in all Nissan vehicles by 2015; China formed auto lightweighting alliance targeting –200 kg 20*10*

WTOE 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 the 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
  - RMI's two transformational projects and "feebate" promotion are helping
  - Competition, at a fundamental level and at a pace last seen in the 1920s, will change automakers' managers or their minds, whichever comes first

DoD's soft underbelly: fuel and fuel logistics

- In WWII, heavy steel forces "floated to victory on a sea of oil," and 6/7^ths^ of oil to defeat Axis came from Texas; today, warfighting is ~16× more energy-intensive, and Texas is a net importer of oil
- Logistics consumes roughly half of DoD's **personnel** and a third of DoD's **budget**
- ~70% of **tons** moved when the Army deploys are fuel
- About half of **casualties** in theater are now associated with convoys—whole divisions hauling oil, more divisions trying to guard them (often including helicopter cover)
- Yet *most of the fuel those convoys deliver is wasted*, because when we require, design, and acquire the things that use the fuel, we assume that *fuel logistics is free* and *invulnerable*; it is emphatically neither

Is this trip necessary?




One inefficient 5-ton a/c uses ~1 gal/h of genset fuel. Truck's 68-barrel cargo can cool 120 uninsulated tents for 24 h. This 3-mile convoy invites attack. (Photos aren't all in the same place.)

- COL Dan Nolan (USA Ret.) on convoys: "We can up-gun or down-truck. The best way to defeat an IED is…don't be there." Manx force: no tail 
- In above example, the task (comfort) can probably be done with no oil. No gensets, no convoys, no problem. Turn tail into trigger-pullers. Multiply force. Grow stronger by eating our own tail. 
- Of Clausewitz's three conditions for success in war—government decision, military capacity, and the will of the people—current adversaries are attacking mainly the third, but are figuring out that the second is fragile too. How soon will they bring that tactic to CONUS? COL Nolan: "We are in crisis now, and if we don't fix it, we'll be in catastrophe in five years."
- The "endurance" strategic vector is at least as vital for stability as for combat ops (they now have comparable priority: DoDD Memo 3000.05, §4.1), because stability ops may need even more persistence, dispersion, and affordability

Many *non*combat gas-guzzlers too

Today's Top 10 Battlefield Fuel Users

SWA scenario using current Equipment Usage Profile data

Of the top 10 Army battlefield fuel users, only #5 and #10 are combat platforms

1. Truck Tractor: Line Haul C/S 50000 GVWR 6X4 M915
2. Helicopter Utility: UH-60L
3. Truck Tractor: MTV W/E
4. Truck Tractor: Heavy Equipment Transporter (HET)
5. *Tank Combat Full Tracked: 120MM Gun M1A2* ← Shooter
6. Helicopter Cargo Transport: CH-47D
7. Decontaminating Apparatus: PWR DRVN LT WT
8. Truck Utility: Cargo/Troop Carrier 1 1/4 Ton 4X4 W/E (HMMWV)
9. Water Heater: Mounted Ration
10. *Helicopter: Attack AH-64D* ← Shooter

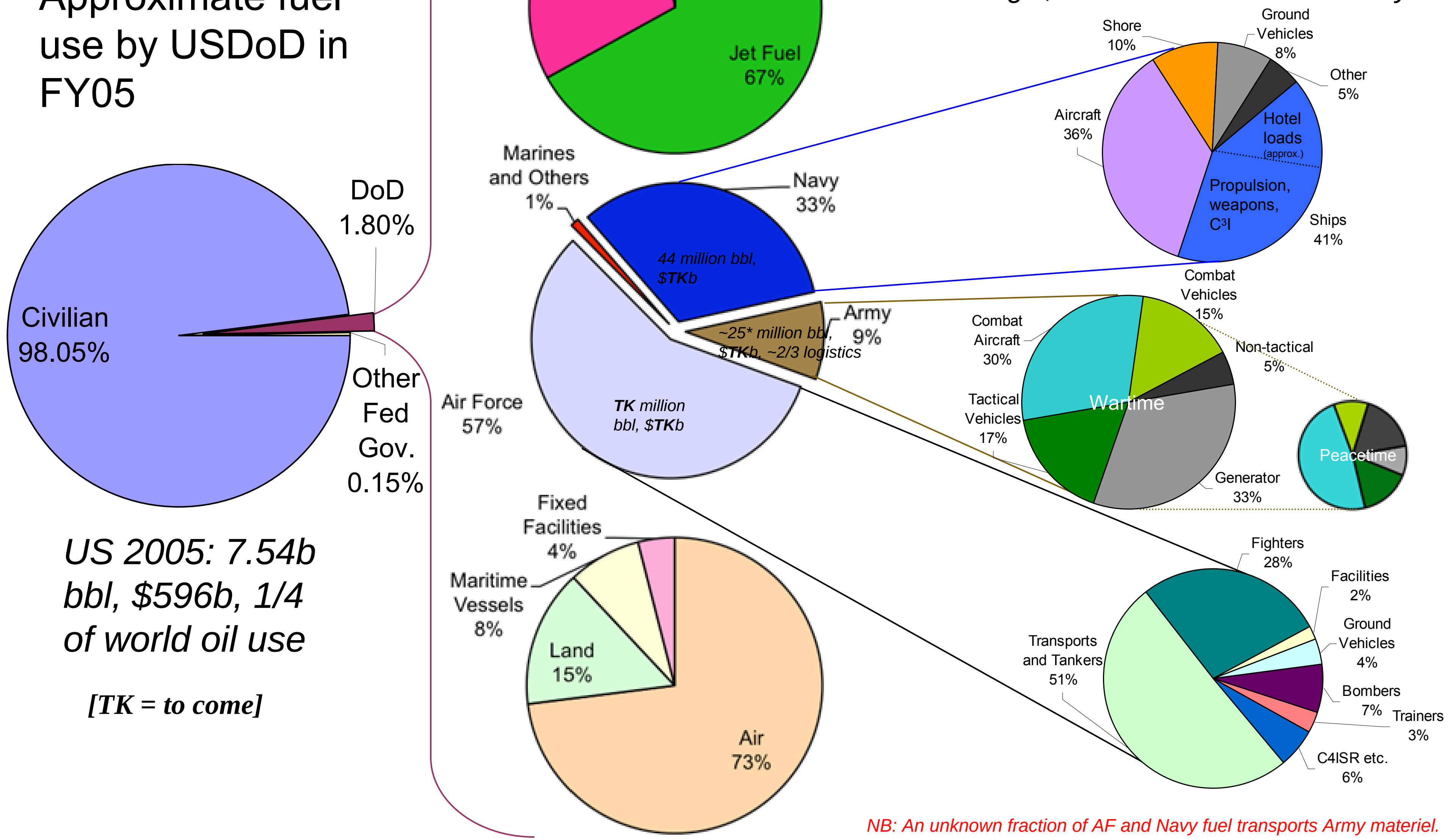
Source: CASCOM study for 2001 DSB using FASTALS for SWA.

Fuel savings: major warfighting, logistics, and budget benefits

- Force **protector**: far fewer sitting-duck convoys
- Force **multiplier**: trigger-pullers can win battles without the deadly distraction of protecting fuel
- Force **enabler**: unprecedented persistence (dwell), agility, mobility, maneuver, range, reliability, and autonomy—at low cost, so many small units can cover large areas—needed for asymmetrical, demassed, elusive, remote, irregular adversaries
- Can unlock vast transformational gains (multi-divisional tail-to-tooth realignment, 10s of b$/y)
- Biggest win: catalyze leap-ahead civilian tech transition that can *eliminate* U.S. oil use by 2040s, leveraging military S&T as we did with the Internet, GPS, and chip and jet-engine industries

Approximate fuel use by USDoD in FY05

DoD's apparent fuel cost [FY06: ~$12.5b] is a modest fraction of true fully-burdened delivered *fuel cost; the added delivery costs are mainly for the 9% of AF fuel delivered aerially for >$49/gal, and for forward fuel to Army*



US 2005: 7.54b bbl, $596b, 1/4 of world oil use

[TK = to come]

NB: An unknown fraction of AF and Navy fuel transports Army materiel. Oil used by contractors to which DoD has outsourced work is unknown.

US Defense Science Board Energy Strategy Task Force

Former SECDEF/SECEN/SECTREAS/DCI James R. Schlesinger
and GEN Mike Carns (USAF Ret), Co-Chairs

More Fight—Less Fuel

www.acq.osd.mil/dsb/reports/2008-02-ESTF.pdf

Unofficial slides reflecting my own personal views
(consistent with the Task Force's briefs & discussions)

Terms of Reference

- Identify opportunities to reduce fuel demand by deployed forces and assess cost, operational and force structure effects
- Identify opportunities to deploy renewable and alternative energy sources for facilities and deployed forces
- Identify institutional barriers to achieving this transition

Key Findings

- Two primary energy risks to DoD
  - **Unnecessarily high and growing operational fuel demand increases mission risk**
  - **Critical missions at fixed installations are at unacceptable risk from extended power loss**
- DoD lacks the strategy, policies, metrics, information, and governance structure necessary to properly manage its energy risks
- There are technologies available now to make DoD systems more energy efficient, but they are undervalued, slowing their implementation and resulting in inadequate S&T investments
- There are many opportunities to reduce energy demand by changing wasteful operational practices and procedures

The rest of the story

- There *is* a clear and present crisis in national and theater energy security, but it's not about oil; rather, *electrical* vulnerabilities have been blocking stabilization in Iraq (micropower proved a key counterinsurgency tactic), are becoming acute in Afghanistan, and could take down DoD's operating capability and the US economy
- Reliable, affordable oil supply is a gathering storm for the world and US, but not specifically for DoD, which will remain able to get the mobility fuels it needs
- Rather, DoD's oil issue is that the costly burdens imposed by using oil inefficiently also weaken combat effectiveness
- Conversely, DoD can radically boost combat effectiveness *and* fuel efficiency at reasonable or reduced up-front cost
- Thus exploiting two new strategic vectors—**resilience** and **endurance**—can turn DoD's energy risks into revolutionary gains in warfighting capability and national security

Two missing strategic vectors can turn energy threats into decisive advantages

- ***Resilience*** combines efficient energy use with more diverse, dispersed, renewable supply—turning big energy supply failures (by accident or malice) from inevitable to near-impossible
- ***Endurance*** turns radically improved energy efficiency and autonomous supply into manyfold greater range and dwell — hence affordable dominance, requiring little or no fuel logistics, in persistent, dispersed, and remote operations, while enhancing overmatch in more traditional operations
- These two new vectors are as urgent, vital, and fundamental as **speed**, **stealth**, **precision**, and **networking**
- Without them, exploitation of electricity and fuel vulnerability (already critical in OIF/OEF) could soon come to CONUS
- But with them, DoD can gain far more effective forces and a safer world—generally at reduced budgetary cost and risk

“Amory’s petting zoo” from DSB 08: dramatic gains in combat effectiveness *and* energy efficiency are widely available, *e.g.*:

(scaled-down wind-tunnel model)

BWB quiet aircraft: range & payload × ~2, sorties ÷ 5–10, fuel ÷ 5–9 (Σ 2–4)

SensorCraft (C⁴ISR): 50-h loiter, sorties ÷ 18, fuel ÷ >30, cost ÷ 2

VAATE engines: loiter × 2, fuel – 25–40%, far less maintenance, often lower capital cost

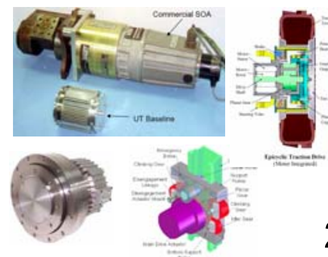
Optimum Speed Tilt Rotor (OSTR): range × 5–6, speed × 3, quiet, fuel ÷ 5–6

Re-engine *M1* with modern diesel, range × ≥2, fuel ÷ 3–4

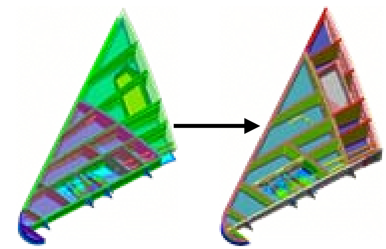
More lethal, highly IED-resistant, stable *HMMVV* replacement, weight ÷ 3, fuel ÷ >3 (up-armored *HMMVV* ~4 mpg)

Hotel-load retrofits could save ~40–50% of onboard electricity (thus saving ~1/6 of the Navy’s non-aviation fuel)

FOB uses 95% of gen-set fuel to cool desert; could be ~0 with same or better comfort

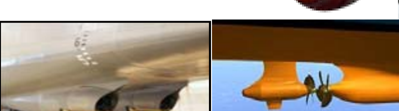


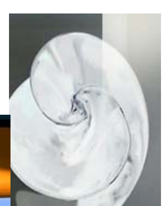
Actuators: per-formance × 10, fault tolerance × 4, size & mass ÷ 3–10



25% lighter, 30% cheaper advanced composite structures; aircraft can have ~95% fewer parts, weigh ≥1/3 less, cost less

Advanced propulsors can save much noise and fuel





Rugged, 2.5-W PC, $150, solar + back-up crank

A zero-net-energy building (it’s been done in –44˚ to 46˚C at lower cost)

240-Gflops supercomputer, ultrareliable with no cooling at 31˚C, lifecycle cost ÷ 3–4

Where to find winners: prospecting

1. The most total *fuel* can be saved in aircraft: Since aircraft use 73% of DoD oil, a 35% saving in aircraft would equal the total fuel use by all land and maritime vehicles plus facilities
   - Fortunately, 35% is conservative because 60% of Heavy Fixed Wing inventory (which uses 61% of AF aviation fuel) uses 50–60-year-old designs, and nearly all Vertical Lift fleet is 30–50-year-old configurations and derivatives
   - Heavy Fixed Wing fleet can halve fuel use by practical geometrically compounded improvement in aero, materials, systems, and propulsion including shift to integrated-wing-body configurations; in vertical lift, OSTR saves 5–6×
2. The greatest gains in *combat effectiveness* will come from fuel-efficient ground forces (land and vertical-lift platforms, land warriors, FOBs)
3. Savings *downstream*, near the spear-tip, save the most total fuel: delivering 1 liter to Army speartip consumes ~1.4 *extra* liters in logistics
4. Savings in aerially refueled aircraft and forward-deployed ground forces save the most *delivery cost* and thus *realignable support assets*

Progress is emerging

"Effectively immediately, it is DoD policy to include the fully burdened cost of delivered energy in trade-off analyses conducted for all tactical systems with end items that create a demand for energy and to improve the energy efficiency of those systems, consistent with mission requirements and cost effectiveness." —USD(AT&L) memo 10 April 2007

Pilot Programs established to refine methodology

- Joint Light Tactical Vehicle (JLTV) (MS B mid 2007)
- CG(X)—Maritime Air and Missile Defense of Joint Forces alternative ship concepts AoA (MS B mid 2007)
- Next Generation Long-Range Strike (MS B FY11)

In Aug 06, too, JROC established the energy KPP in CJCSI 3170, though implementation is slow so far

But NDAA 08 mandated Fully Burdened Cost of Fuel methodology and Energy KPPs…and DoD is starting to organize energy leadership

Now we need to focus on some even deeper issues DSB discovered…

PA&E's Army fuel cost: what's in/out?

2006$/gallon	**DoD historic norm: $2-odd**	**Army briefs to DSB 01: $15 (in CONUS in peacetime); up to hundreds of $ if far beyond FEBA**	**PA&E Nov 06 av. JP-8 est.: $5.62** (to DSB 29 Nov 06)	**fully burdened delivered cost: to be assessed**
DESC direct cost (refined product, delivered in bulk to Service customer at global-average location with no protection cost) + notional carbon adder	✓ ($2.53 Jun 06; F07 will be $0.23 lower)	✓	✓ (PA&E found & is working a nearly 2× uncertainty in Army's FY06 fuel usage—a warning of data problems, probably due to fuzzy Service/contractor boundaries)	✓
Placeholder market CO_2 cost	✗	✗	✓ (10¢/gal)	✓
Trucks to deliver to FOB and thence into platform	✗	✓ (details unreported)	✓ (but only the two most heavily used types: 1,593 *M978* @ $5k/y + 1,291 *M969* @ $4.3k/y; others?)	✓ (should include fully burdened end-to-end life-cycle cost of ownership of all physical fuel-delivery assets)
POL personnel (those actually doing POL tasks, whether POL specialists or not)	✗	✓ (~FY99: Army delivered 300Mgal with 20k Active @ $100k/y + 40k Reserve @ $30k/y; update both; +19% to 06$)	✓ (FY06 Army used 490Mgal with 16k Active @ $55k/y [FY05] + 15k Reserve @ $17k/y; where are contractors/AF/MC…?	✓ (check headcounts—DESC says much theater POL is now interService or outsourced—and 2× lower POL personnel cost/head)
Vehicle & logistics support, base fuel dir.+indir. infrastr.	✗	?	? (only to the extent included in the trucks' average O&S cost)	✓
Force protection (incl. air escort, MP pump guards,…)	✗	??	✗	✓
Lifecycle support pyramids and rota-tional multipliers to force structure for all	✗	??	✗	✓
Adjust for theft & attrition	✗	✗	✗	✓
AF & Navy lift cost	✗	✗	✗	✓

Examining DoD energy use reveals a hidden fallacy

- What the requirements/acquisition system currently calls "capability" is really *theoretical performance of "tooth" alone* at the platform or system level… *omitting the tail* needed to produce capability
- Tail takes money, people, and materiel that detract from tooth
- True net capability, *constrained by sustainment*, is thus the gross capability (performance) of a platform or system *times its "effectiveness factor"—its ratio of effect to effort*:

  Effectiveness Factor = Tooth / (Tooth + Tail)

  Also, in an actual budget, Tooth = (Resources – Tail), so:

  Effectiveness Factor = (Resources – Tail) / Resources

  Effectiveness factor ranges from zero (with infinite tail) to one (with zero tail). If tail > 0, *true net capability is always less than theoretical (tail-less) gross performance; but DoD consistently confuses these two metrics, and so misallocates resources*

  - Buying more tooth that comes with more (but invisible) tail may achieve little, no, or negative net gain in true capability; we often seem to do this
  - But dramatically trimming tail can create revolutionary net-capability gains *and* free up support personnel, equipment, and budget for realignment

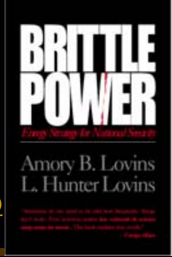
The electric grid needs resilience—efficient, diverse, dispersed, renewable—and that's *cheaper* anyway!

10 Aug 96: 4M blacked out in 9 states in 35 seconds

- ~98–99% of U.S. outages start in the grid
- The Federal response to regional black-outs (build more and bigger power plants and power lines) will make blackouts *more* widespread and frequent
- Some good Federal support for inherently resilient systems, but the policy framework still strongly favors big and brittle
- DoD can and must lead change

14–15 Aug 03: 50M in area that lost 71 GW in 9 seconds, but some islanded systems kept the lights on

The brittle electricity grid



Brittle Power: Energy Strategy for National Security, RMI report to DoD, 1981, www.rmi.org/sitepages/pid533.php

- Vital to run all *other* energy systems too: no power means little oil and gas
- Very capital-intensive, very long lead times, technologically unforgiving
- Central plants/grids are inherently vulnerable to simple, devastating attacks
  - Continuous and exact synchrony required over huge areas
  - This needs long power lines (easily cut with a rifle), comms, and vulnerable transformers etc.—often with no spares, and taking 1–2 y to manufacture and import
  - New threats to grid are grave and urgent (DSB Task Force 08, classified App. 8: brief via Gueta Mezzetti 202 256 6716)
- These vulnerabilities are too inherent to fix, so DoD facilities must rapidly get resilient power supplies

The brittle grid threatens DoD's mission continuity—urgent fixes are needed

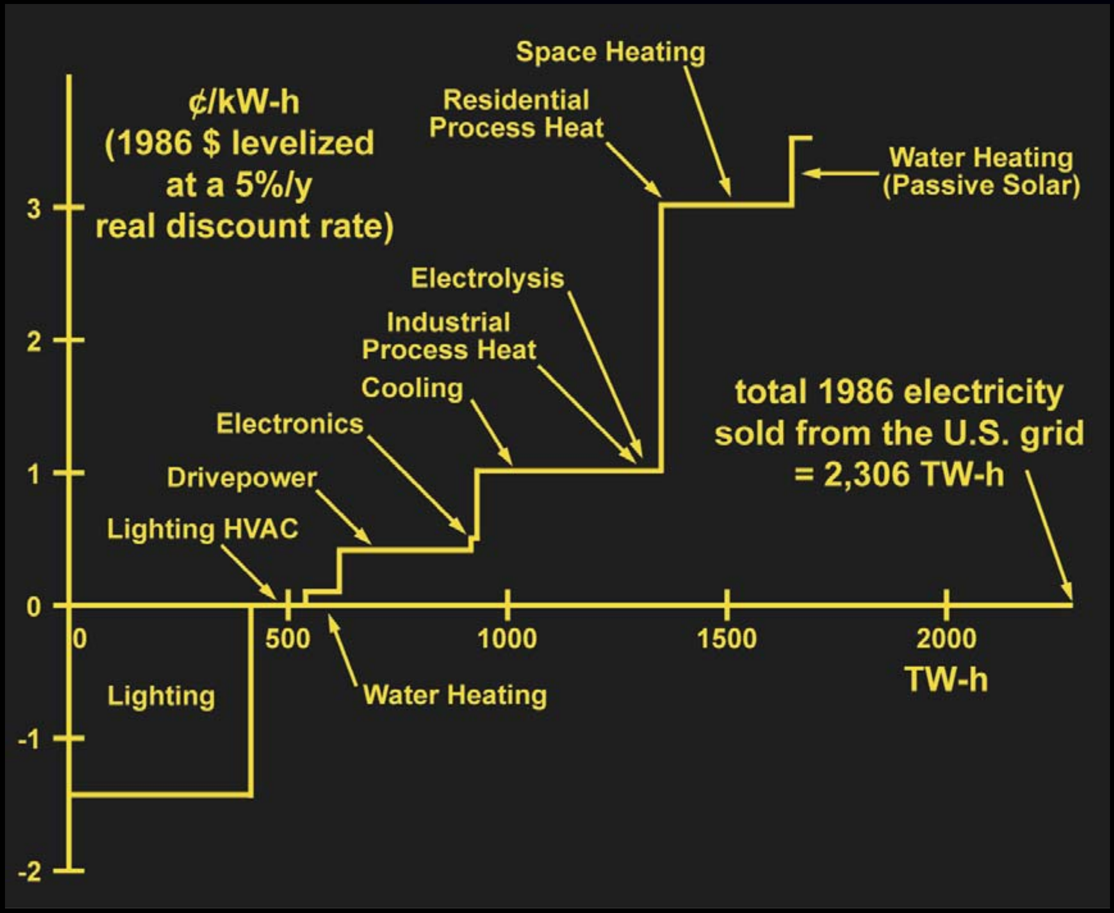
- DoD, though the world's #1 buyer of renewable energy, is at least 98% reliant on the brittle electric grid, so it must quickly make bases' power supplies resilient and mainly renewable
  - Of 584 CONUS bases, ~90% have good supply options onsite or nearby, mostly renewable, and most of their electricity can readily be renewable; could achieve zero daily net energy need for facilities/ops/ground vehicles, full independence in hunker-down mode (no grid), then power export to nearby communities and to nucleate grid blackstart
  - So DoD bases' energy independence would collaterally enable national electric grid resilience—and probably only DoD can move as decisively as the threat warrants
  - OCONUS potential for austere-FOB energy independence is even larger because avoidable delivered energy costs are higher
- DSB Task Force 08 strongly recommended implementing existing policy (DoDI 1470.11 §5.2.3) so bases switch to onsite, self-contained power for critical functions, DoD-facilities-based micro-grids, and netted area microgrids for extended strategic islanding, all with efficient end-use

Designing for resilience (1981–84)…

"An inherently resilient system should include many relatively small, fine-grained elements, dispersed in space, each having a low cost of failure. These substitutible components should be richly interconnected by short, redundant links…Failed components or links should be promptly detected, isolated, and repaired. Components need to be so organized that each element can interconnect with the rest at will but stand alone at need, and that each successive level of function is little affected by failures or substitutions at a subordinate level. Systems should be designed so that any failures are slow and graceful. Components, finally, should be understandable, maintainable, reproducible at a variety of scales, capable of rapid evolution, and societally compatible."

Summarized from Chapter 13, "Designing for Resilience," A.B. & L.H. Lovins, Brittle Power: Energy Strategy for National Security, *Brick House 1982, RMI 2001, reposted at www.rmi.org*

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



Best 1989 commercially available, retrofittable technologies

Similar S, DK, D, UK…

EPRI found 40–60% saving 2000 potential

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)

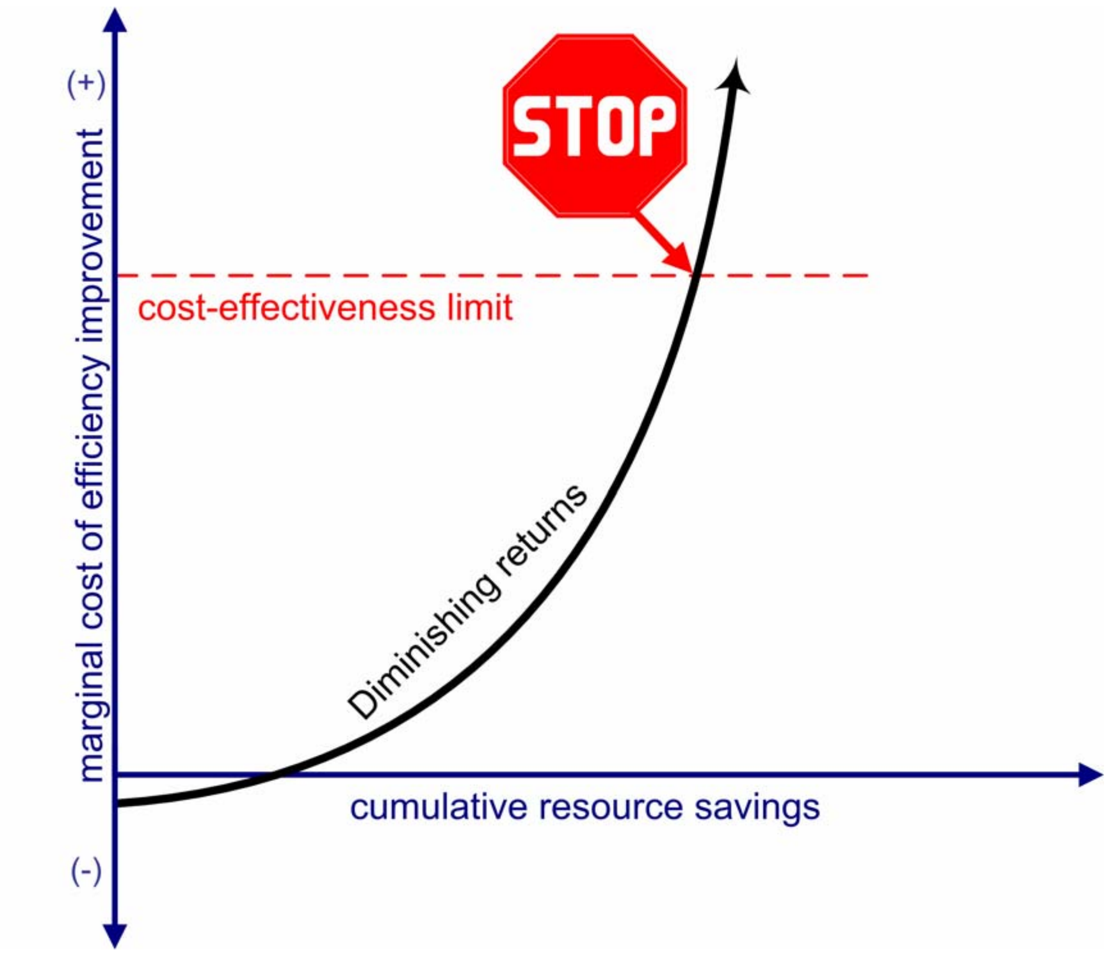
−47 to +115°F with no heating/cooling equipment, *less* construction cost: Can your base housing do this? Why not?

7100′, frost any day, 39 days′ continuous midwinter cloud…yet 28 banana crops with no furnace

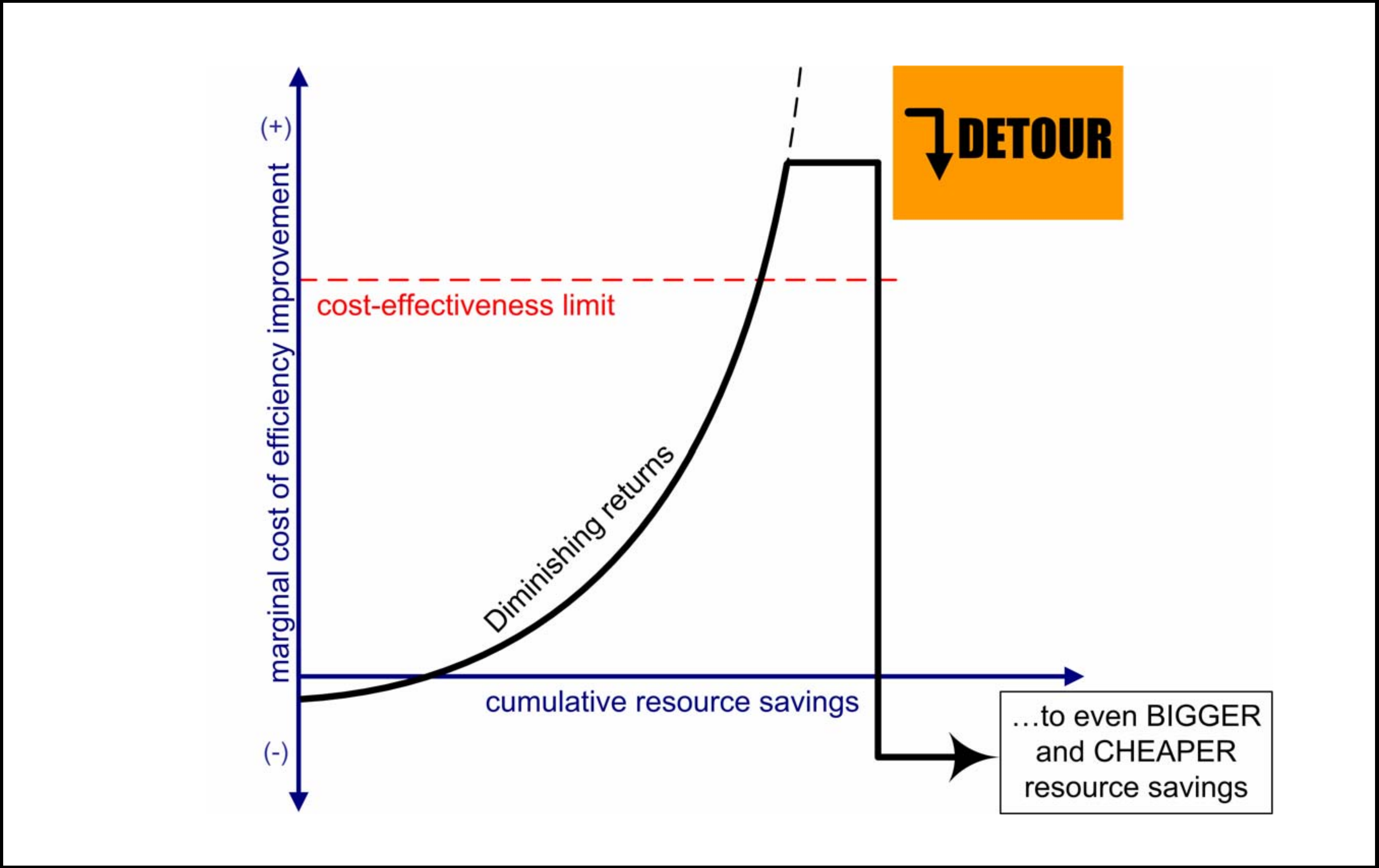
Key: integrative design—multiple benefits from single expenditures

- Lovins house / RMI HQ, Snowmass, Colorado, ’84
  - Saves 99% of space & water heating energy, 90% of home el. (4,000 ft^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

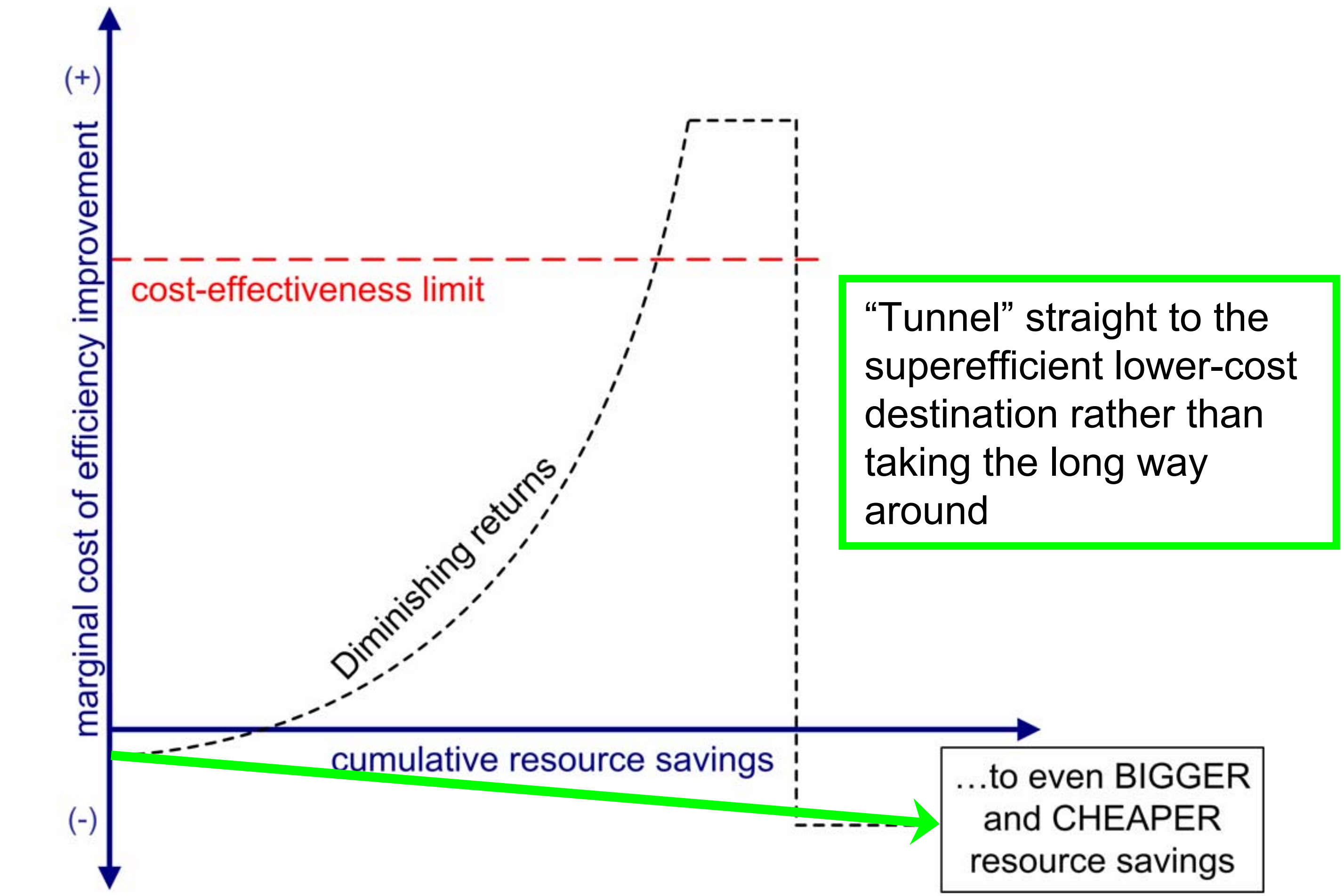
Old design mentality: always diminishing returns…



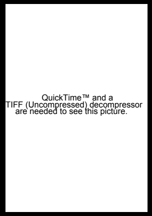
New design mentality: expanding returns, "tunneling through the cost barrier"



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



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



Cost can be negative even for *retrofits* of big buildings

- 200,000-ft^2, 20-year-old curtainwall office near Chicago (hot & humid summer, very cold winter)
- Dark-glass window units' edge-seals were failing
- Replace not with similar but with superwindows
  - Let in nearly 6× more light, 0.9× as much unwanted heat, reduce heat loss and noise by 3–4×, cost 78¢ more per ft^2 of glass
  - Add deep daylighting, plus very efficient lights (0.3 W/ft^2) and office equipment (0.2 W/ft^2); peak cooling load drops by 77%
- Replace big old cooling system with a new one 4× smaller, 3.8× more efficient, $0.2 million cheaper
- That capital saving pays for all the extra costs
- 75% energy saving—*cheaper* than usual renovation

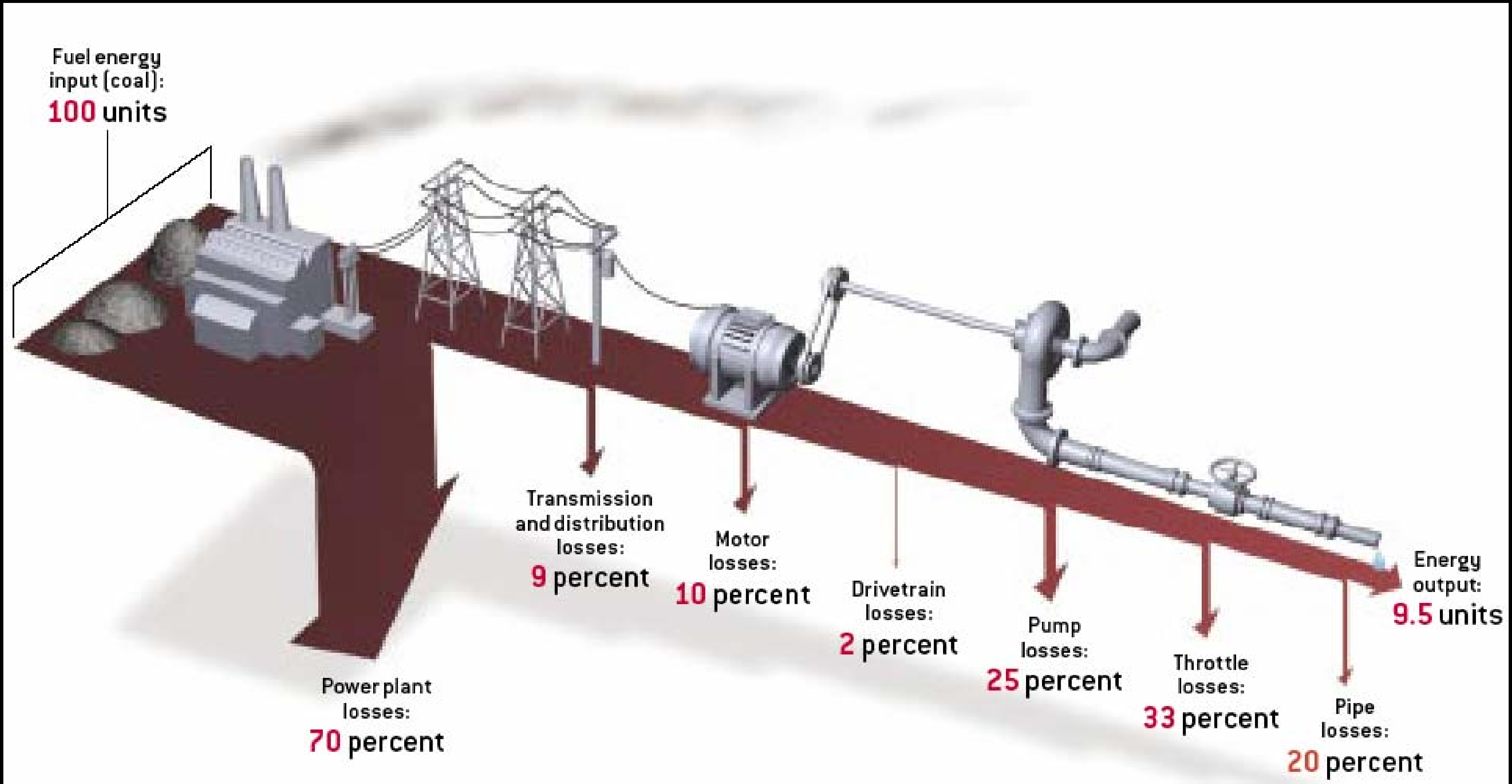
Retrofitting New York City's 2.8-milliion-ft² Empire State Building (2009)

- Will save 38% of energy use, with a 3-year payback and increased value
- Integrative design yields 2–3× the savings normally cost-effective
- Remanufacturing 6,500 windows onsite (!) into superwindows cuts their winter heat loss by ≥2/3 and their unwanted heat gain by 1/2
- That plus better lights and office equipment cuts cooling loads by 1/3
- Old chillers can then be reduced and renovated, not replaced and expan-ded—saving capital that helps pay for all the other improvements
- Designed for scalable replication

New design mentality makes very big energy savings cheaper than small ones

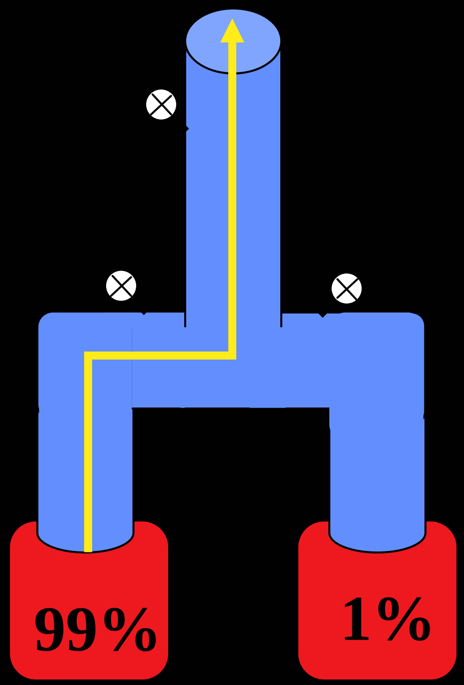
- Redesigning a standard (supposedly optimized) industrial pumping loop cut its power from 95 to 7 hp (–92%), cost less to build, and worked better
  - Just by fat short straight pipes, not thin long crooked pipes
  - Should have saved ~98% and paid even less!

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

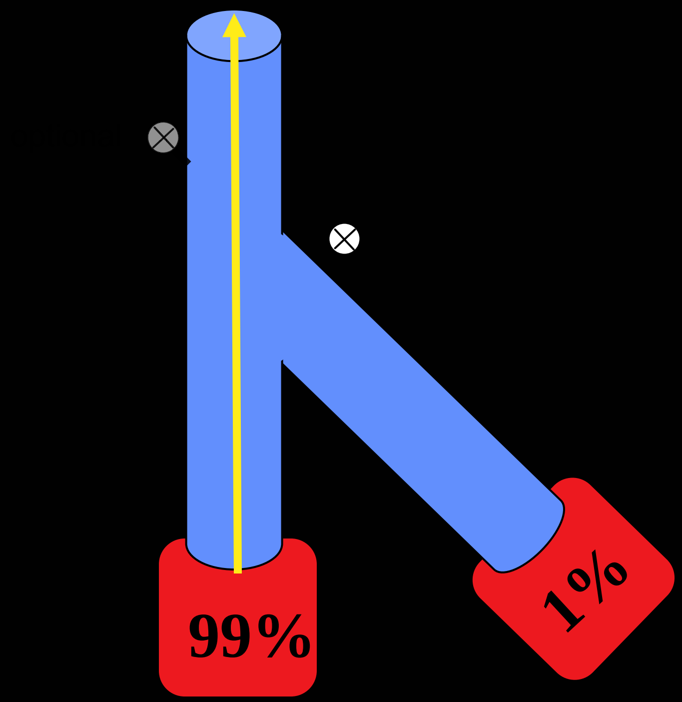


Also makes upstream equipment smaller, simpler, cheaper

Then minimize friction



vs.

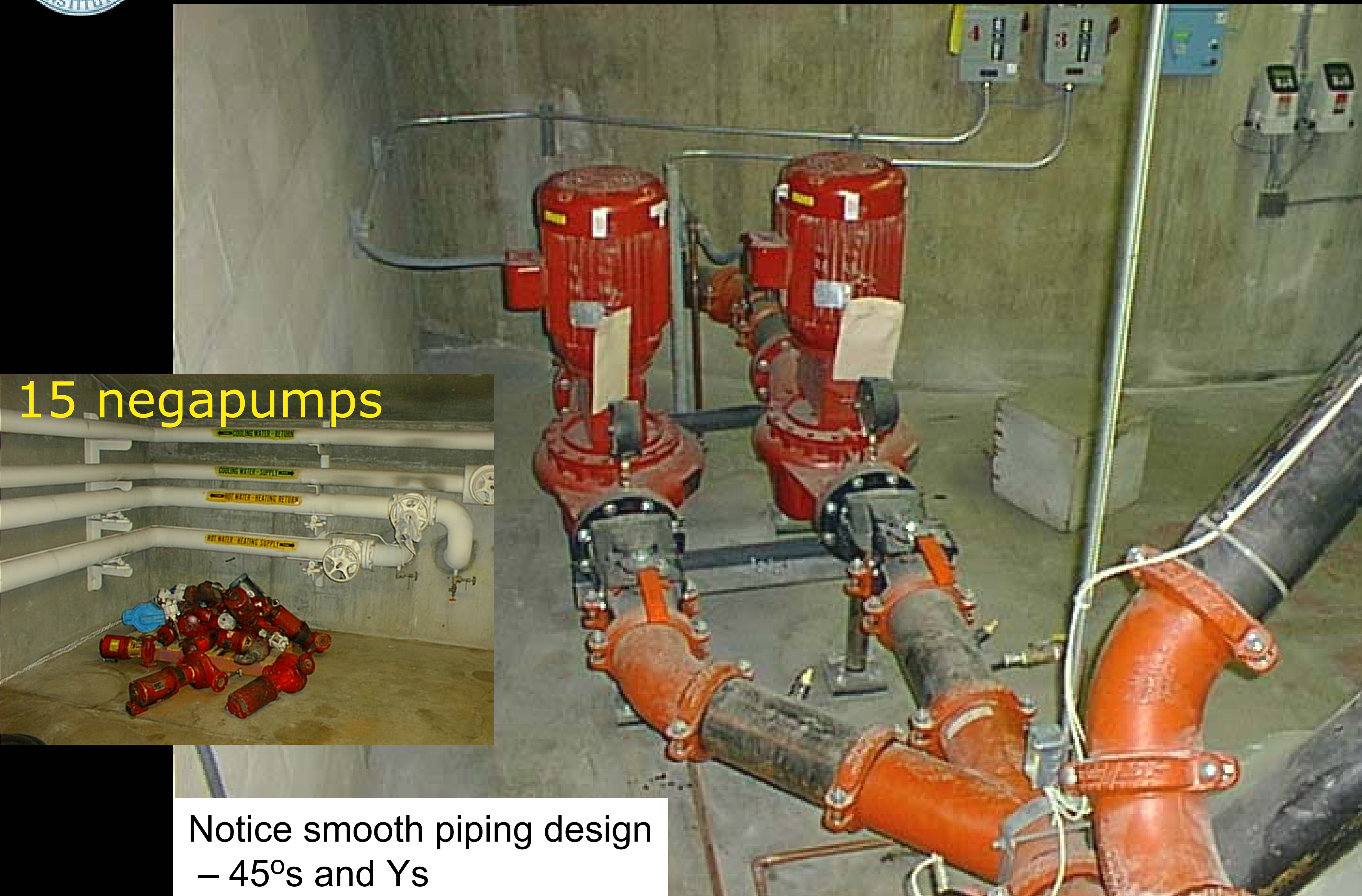


Boolean pipe layout

hydraulic pipe layout

High-efficiency pumping / piping retrofit

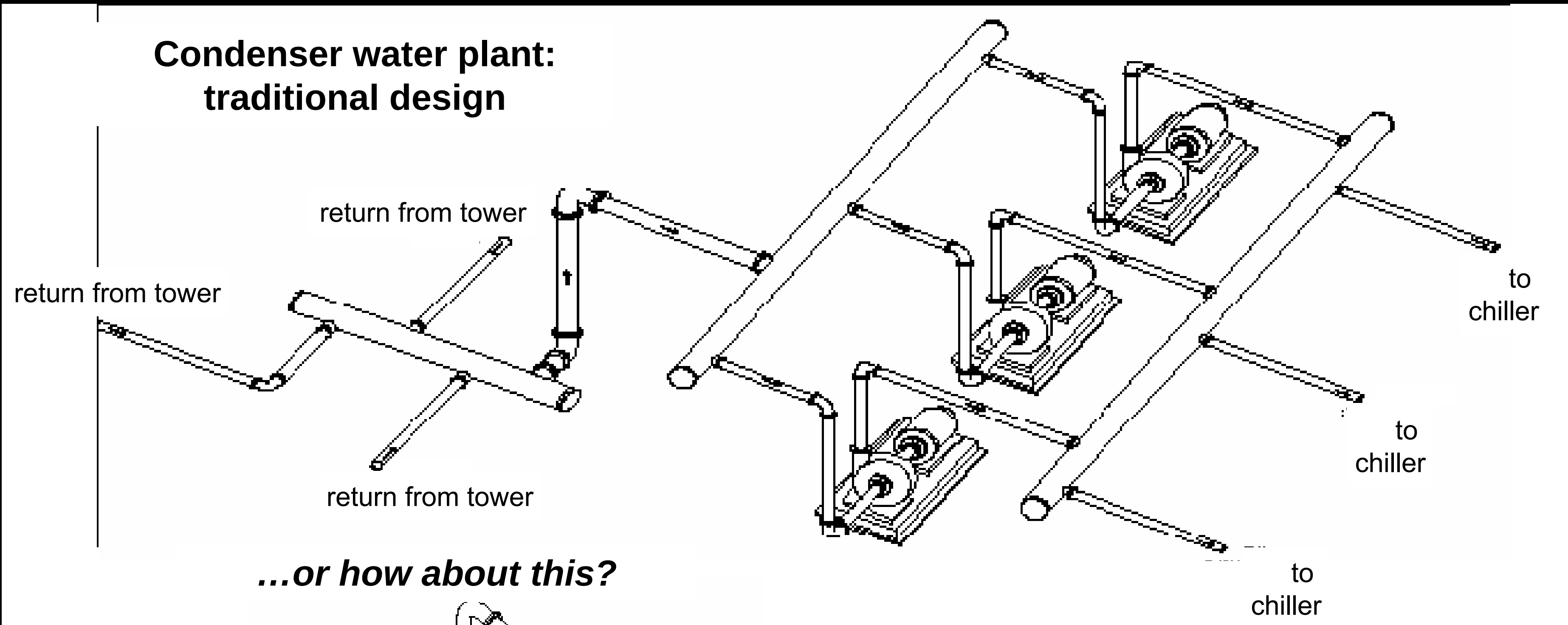
(Rumsey Engineers, Oakland Museum)



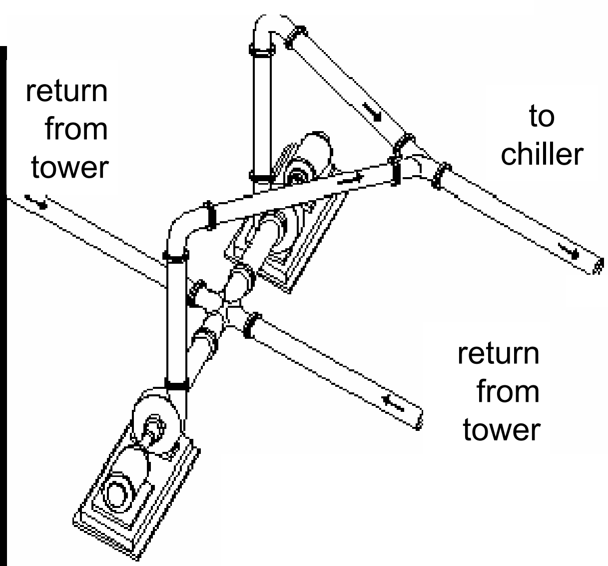
Notice smooth piping design
– 45°s and Ys

downsized CW pumps, ~75% pumping energy saving

Which of these layouts has less capex & energy use?



…or how about this?

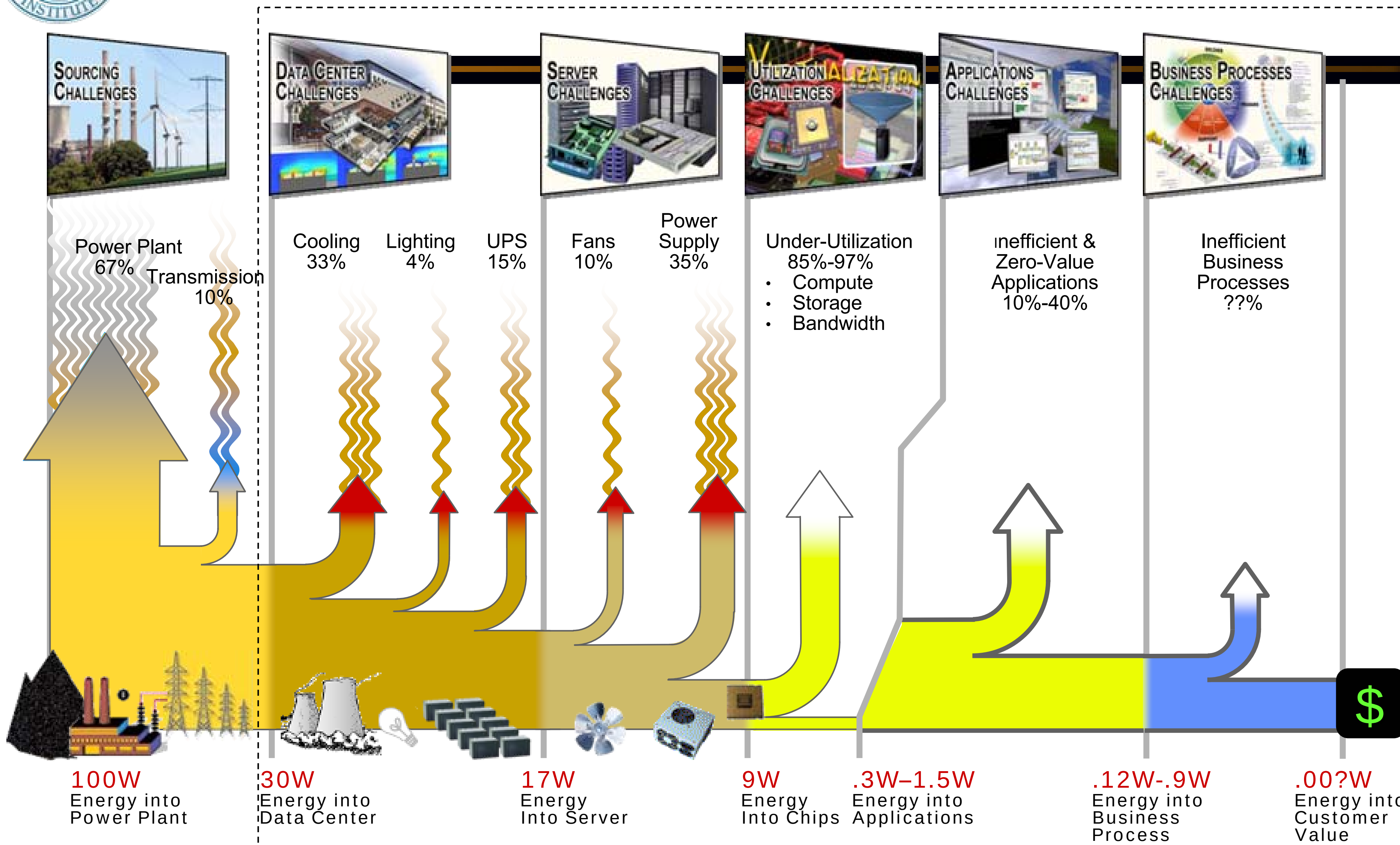


- Less space, weight, friction, energy
- Fewer parts, smaller pumps and motors, less installation labor
- Less O&M, higher uptime

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

- Retrofit eight chip fabs, save 30–50+% of HVAC energy, ~2-y paybacks
- Retrofit very efficient oil refinery, save 42%, ~3-y payback
- Retrofit North Sea oil platform, save 50% el., get the rest from waste
- Retrofit huge LNG plant, ≥40% energy savings; ~60% new, cost less
- Retrofit giant platinum mine, 43% energy savings, 2–3-y payback
- Redesign new mine, save 100% of fossil fuel (it's powered by gravity)
- Redesign $5b gas-to-liquids plant, save >50% energy and 20% capex
- Redesign next new chip fab, eliminate chillers, save 2/3 el. & 1/2 capex
- Redesign new data ctr, save 75–95%, cut capex & time, improve uptime
- 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
- Retrofits save ~30–60% w/2–3-y payback; new, ~40–90% w/less 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 (RMI's plot for the nonviolent overthrow of bad engineering)

>100× energy leverage in a data center



←then cut utility losses by ~50%→

←…then cut support overhead by 90%→

←…then cut IT equipment's internal losses by 75%… →

←First debloat software and ensure that every computation cycle is needed →

Low-/no-carbon distributed generators, too, are rapidly eclipsing central stations

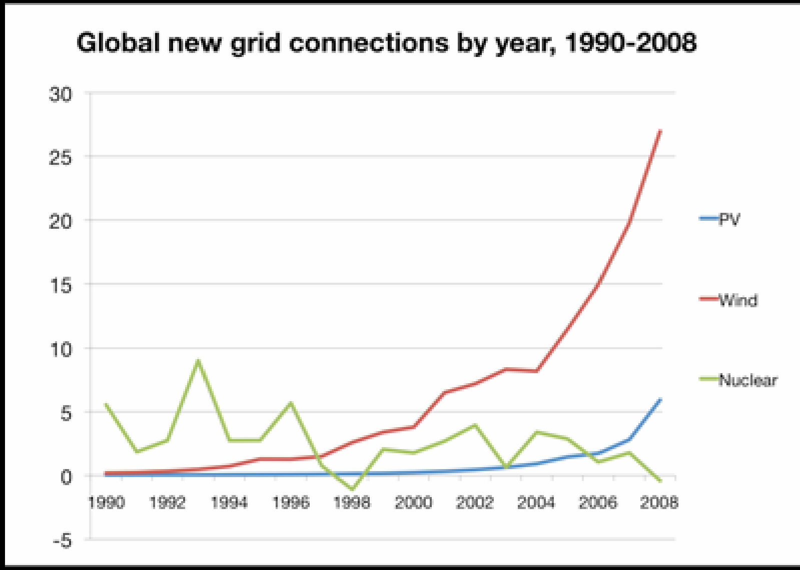
RMI analysis: www.rmi.org/sitepages/pid171.php#E05-04

Wind

- Micropower in 2006 delivered *1/6 of global electricity, 1/3 of new electricity*, 1/6 to >1/2 of all electricity in a dozen industrial nations (*vs.* US ~7%)
- Negawatts look comparable or bigger, so central plants have <1/2 of market!
- Micropower is winning due to lower costs and financial risks, so it's financed mainly by private capital—$100b/y in '08 for distributed renewables, while nuclear got zero equity as usual

Global nuclear additions are dwindling while renewables soar

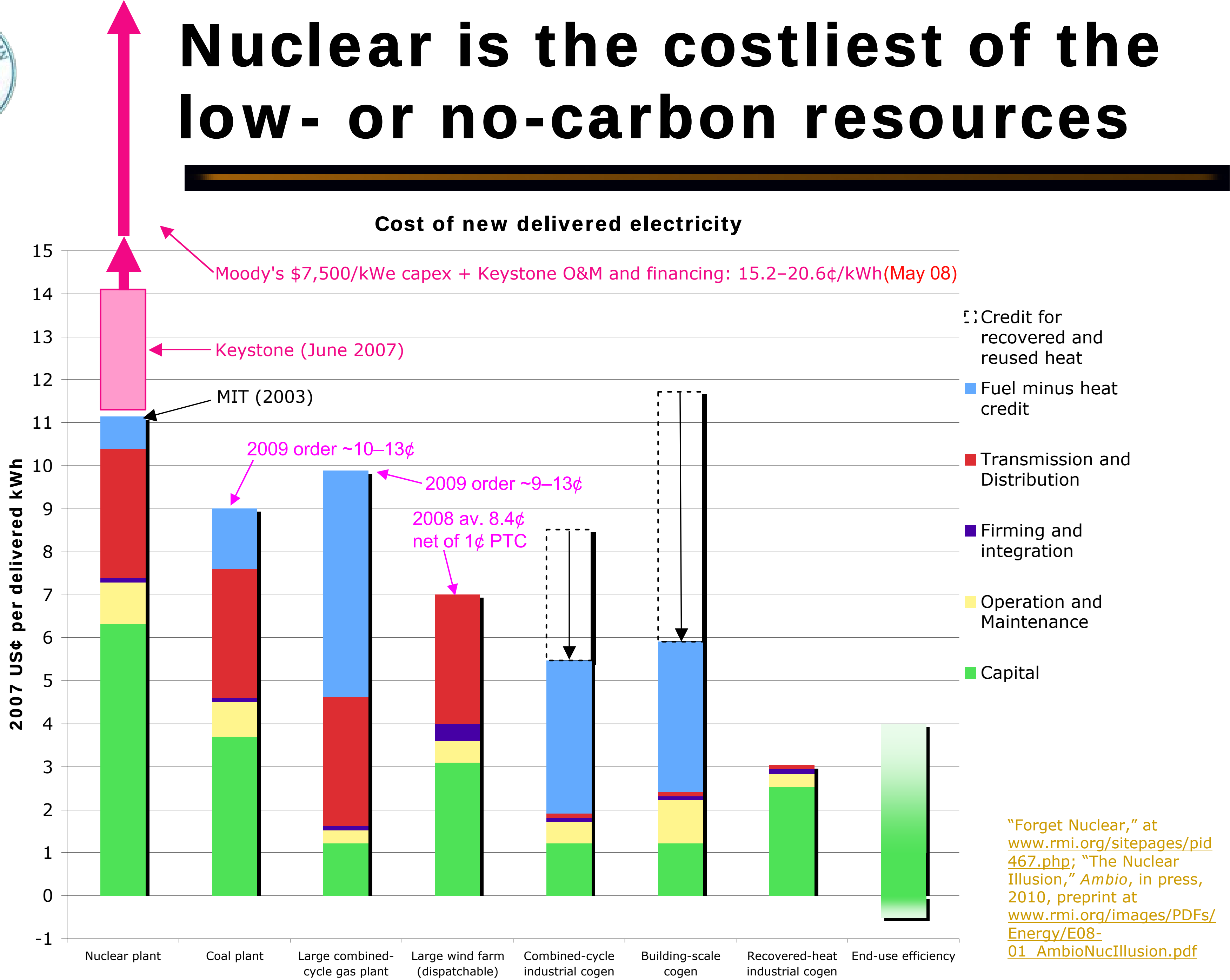
- Global nuclear retirements (L) would need heroic construction pace to keep up with >2015 (impossible to do so earlier)
- Nuclear "renaissance" (lower L) is barely perceptible in construction starts so far
- While nuclear additions grind to a halt (lower R)—*e.g.*, zero for the past 2 years—distributed renewables are surging ahead, adding 40 GW in 2008 alone



Where's the "nuclear renaissance"?

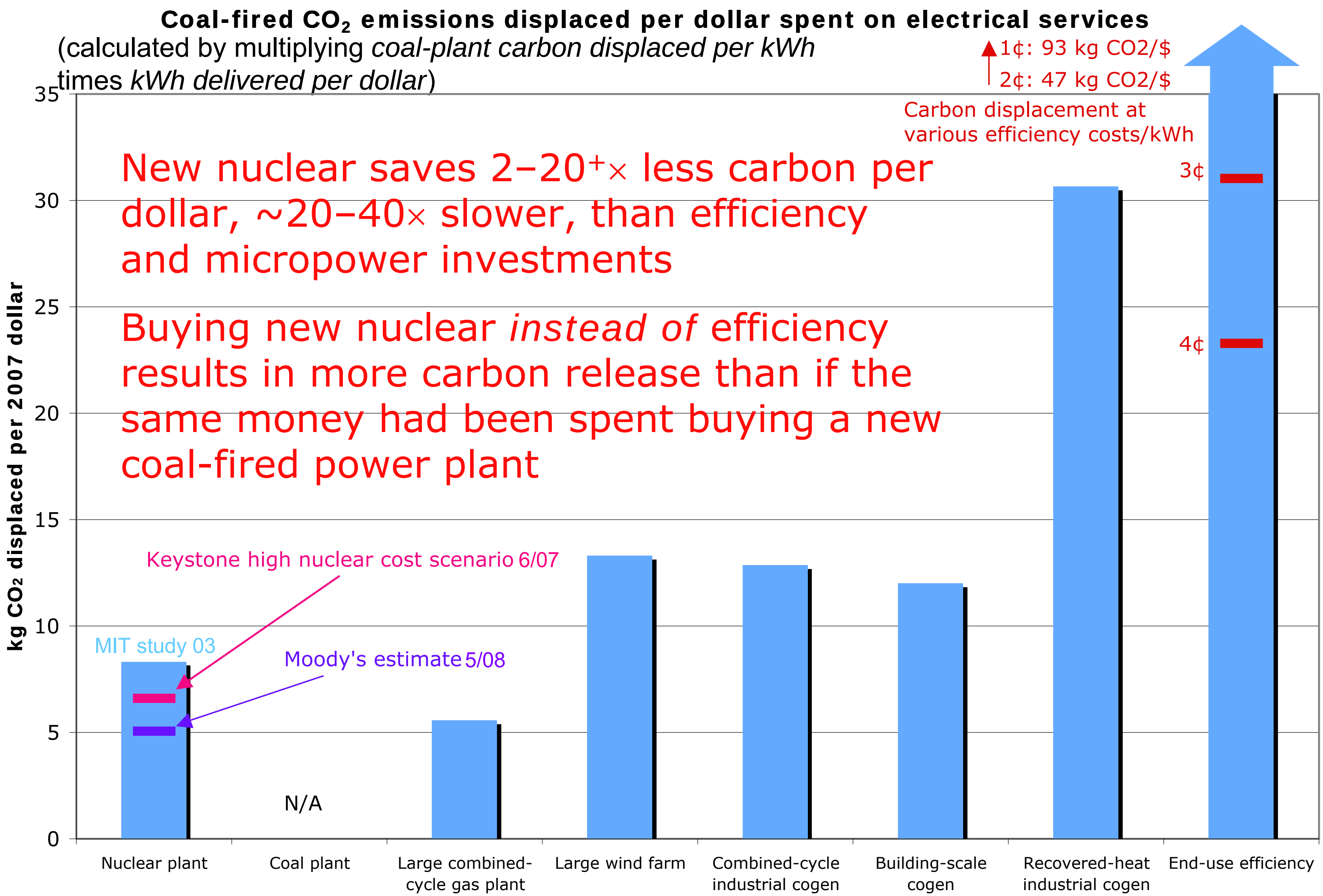
- In Aug 05–Aug 08, with the most robust capital markets and nuclear politics in history, new U.S. nuclear subsidies rivaling or exceeding total con-struction cost elicited *zero* equity for 33 projects
- Of the 52 reactors said by the IAEA to be "under construction" at 1 Aug 09, 13 have been "under construction" for >20 y; 24 have no official start date; half are late; 36 are in China, India, Russia, or S Korea; all 52 are centrally planned; none are normal competitive free-market purchases
- Nuclear capacity fell 1.6 GW in 2008. Further falls are inevitable at least through 2015 and can be only temporarily stabilized thereafter, even with huge building efforts and global license extensions (the average operating plant is now 25 y old)

Nuclear is the costliest of the low- or no-carbon resources



"Forget Nuclear," at www.rmi.org/sitepages/pid467.php; "The Nuclear Illusion," *Ambio*, in press, 2010, preprint at www.rmi.org/images/PDFs/Energy/E08-01_AmbioNucIllusion.pdf

Cheapest *and* lowest-carbon sources save the most C per $



Percentage of U.S. coal-fired electricity that can be saved or displaced by…

- Using electricity as efficiently as the average of the top ten states: ~62%
- Using electricity fully cost-effectively: >100%
- Building the 300 GW of windpower stuck in the interconnection queue: >50%
- Building cost-effective windpower in available U.S. sites: >400%
- Building untapped industrial cogeneration: ~40% (not counting the large potential in buildings)
- Putting photovoltaics on 7% of U.S. structures: >200%
- Plus lots of other renewables…
- All (except some PVs briefly) beat new coal; the first two beat *operating* old coal

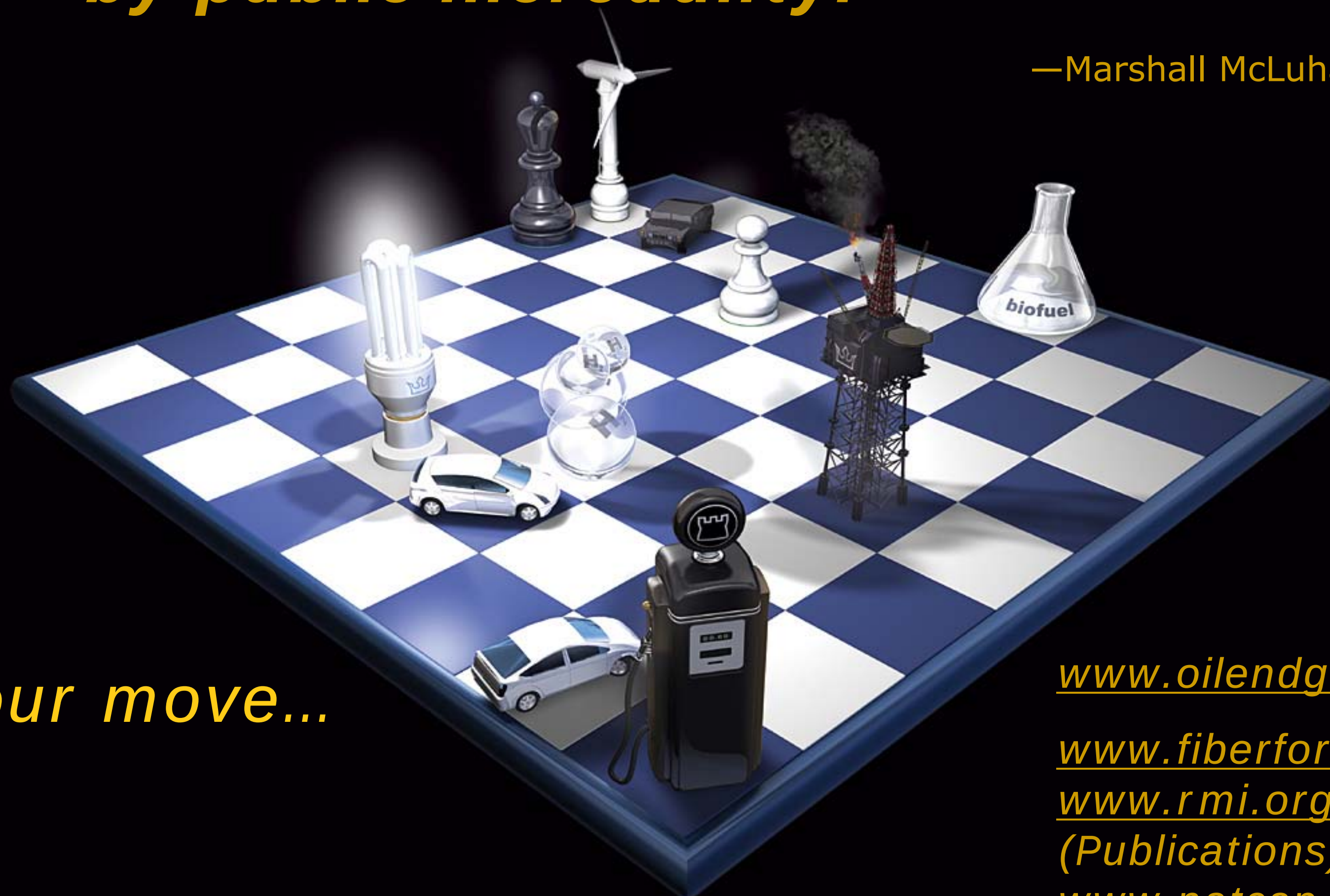
Negawatts/renewables synergy: Bundling PVs with end-use efficiency—a recent example, widely applicable

- Santa Rita Jail, Alameda County, California, 2002–3
- PowerLight 1.18 MW_p project, 1.46 GWh/y, ~3 acres of PVs
- Integrated with Cool Roof and ESCO efficiency retrofit (lighting, HVAC, controls, 1 GWh/y)
- Energy management optimizes use of PV output
- Dramatic (~0.7 MW_p) load cut
- Gross project cost $9 million
- State incentives $5 million
- Gross savings $15 million/25 y
- IRR >10%/y (Cty. hurdle rate)
- Works for PVs, so should work better for cheaper distrib. gen.

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…

www.oilendgame.com, www.fiberforge.com, www.rmi.org (Publications), www.natcap.org