# A Sustainable Energy Future for Vermont and New England: Aiming Higher, Mobilizing Faster

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# *Energy security for dangerous times*

- *I'll summarize, then update, definitive 1981 Pentagon study* **Brittle Power: Energy Strategy for National Security** *(A. & H. Lovins, 500 pp., 1200 refs.), reposted, www.rmi.org; Woolsey/Moorer intro.*
- *It showed that domestic energy infrastructure is often fatally vulnerable to disruption (by accident or malice)—often even more so than imported oil*
- *An* **in***vulnerable energy system is feasible, costs less, works better, is favored in the market but not by much US policy*

# *Misdefining energy security*

- ***Two oil shocks, and today's Mideast instability, have understandably but excessively focused attention on cutoffs of oil imports***
- ***Not just political risk: "One aircraft, or even two people in dinghies, could probably shut down 85% of Saudi oil exports for up to 3 y ([to remake] key components for the loading terminals [CIA later said 2 y]) [and repeat the attack] once the damage was repaired."***
- ***But most of the 78% of U.S. energy use that*** **isn't** ***imported oil, and most of the 95% that isn't Gulf oil, can be cut off at least as easily, but faster, for longer, and in larger pieces***

## *Inherently vulnerable system architecture*

- *Complexity—sometimes beyond full understanding (big electric grids)*
- *Control and synchronism requirements*
- *Reliance on vulnerable telecoms & IT*
- *Hazardous fuels, often in or near cities*
  - *Standard fuel-oil delivery truck ~0.3 kiloton*
  - *Fueled 757/767 at speed ~0.8 kiloton total*
  - *Typical LNG marine tanker ~0.7 megaton*
- *Inflexibility of fuels and equipment*
- *Interdependence of most energy systems*
- *Specialized equipment & labor needs*
- *Difficulty of repair, paucity of spare parts*

# *Examples: natural gas (1981)*

- *One Louisiana plant processes 3.5% of U.S. gas, equivalent to >20 $GW_t$*
- *~84% of U.S. interstate gas flowed from or through Louisiana*
- ***A few people could shut off, for ¡ 1 y, 3/4 of the gas and oil supplies to eastern US in one night without leaving Louisiana***
- *Algerian extremists in 2001 threaten to blow up their main gas pipe to S. Europe*
- *Head of a major US oil production firm: "With a hundred pounds of dynamite, distributed among about eight places, I could cripple the country"*

# *North Slope oil: fattest terrorist target?*

- ***ANWR oil would raise TAPS flow to US refineries above current Strait-of-Hormuz rate***
  - ***But TAPS is easier to cut off for longer, harder to fix, has no alternative route, is indefensible***
  - ***800 miles, >1/2 aboveground and accessible***
  - ***Already sabotaged; incompetently bombed twice; shot at >50×; 10/2000 near-miss at Valdez***
  - ***Engineer caught by luck, 2 y ago, 4 mo. before blowing up 3 key pts w/14 sophisticated bombs: amiable bungler compared to 11 Sept. attackers***
  - ***Can be unrepairable in winter, when 9 Mbbl of hot oil, in 5–7 days, can turn into big Chapstick if key pumping stns. or N/S-end facilities are hit***
  - ***4 Oct 2001: 1 Mbbl/d shut 60 h by one rifle bullet***

# *TAPS is also getting geriatric*

- ***Even if not attacked, TAPS is unreliable***
  - ***24 y old now, ~32+ at putative ANWR start, approaching centenary as ANWR ran out***
  - ***Accelerating corrosion, mishaps, maintenance problems—most recently, for the 7th year in a row, 22 Sept 2001 planned shutdown had sloppy restart, overpressuring the line and causing spills in 3 pumping stations***
  - ***Serious permafrost concerns as tundra thaws***
- ***Some in industry believe within 5–10 y, maintenance costs will be unaffordable***
- ***Probably no economic oil there anyway***
- ***Core of the Homeland Energy Security Bill***

# *Power grids are worse*

- *Blackouts are instant and propagating*
- *No storage, vulnerable controls/telecoms*
- *Many key spare-parts vulnerabilities: consider recent Auckland NZ experience*
- *Bulk transmission vulnerable to rifle fire*
- *Nuclear facilities: 1-GW operating reactor >15 GCi (~2,000 Hiroshimas' fallout) + heat and mech./chem. energy facilitating release comparable to a MT groundburst*
  - *Cut onsite & offsite power, and core melts*
  - *1-kT bomb 1 km away probably melts core*
  - *Widebody jet or certain standoff attacks can release virtually the full core inventory*
  - *Seriously contaminate ~$10^5$ $km^2$ for ~$10^{2–3}$ y*
  - *NRC just announced all sites are secure*

# *Alas, in the past 20 years…*

- ***Little has changed, little for the better***
- **Brittle Power** ***findings were confirmed by CSIS, LANL,…, including classified work***
- ***Modest hardening of some of the softest sites...but adversaries will shop around***
- ***Federal energy policy for most of the period, including today, emphasizes the most vulnerable options, and seldom affords a fair opportunity to the resilient ones that can make the system efficient, diverse, dispersed, and renewable***
- ***So is DOE undercutting DoD's mission?***

# *The good news: resilience is cheaper*

- ***Energy insecurity—from Gulf* or *domestic infrastructure—is not necessary***
- ***It isn't even economic: inherently resilient alternatives work better & cost less***
- *Thus the "insurance premium" against energy vulnerability is negative—it'd put several trillion dollars back in Americans' pockets over the next 20 y*
- *Design lessons from biology and engineering suggest ~20 principles of resilient design whose systematic use can make major failures impossible*

# *Designing for resilience*

- ***Fine-grained, modular structure***
- ***Early fault detection***
- ***Redundancy and substitutability***
- ***Optional interconnection***
- ***Diversity***
- ***Standardization***
- ***Dispersion***
- ***Hierarchical embedding***
- ***Stability***
- ***Simplicity***
- ***Limited demands on social stability***
- ***Accessibility/vernacularity***

Summarized from Chapter 13, “Designing for Resilience,” A.B. & L.H. Lovins, *Brittle Power: Energy Strategy for National Security*, Brick House 1982, RMI 2001

# *Efficiency gives most "bounce per buck"*

- ***Fastest, cheapest way to replace the most vulnerable supplies—it cut U.S. oil use 15% and Gulf imports by 87% in just six years (1979–85) while GDP grew 16%***
- ***Most potent way to break OPEC's power***
- ***Those failures it can't prevent, it makes slower, more graceful/fixable, less severe***
- ***Buys time to improvise substitutes, and stretches the job they can do***
  - ***67-mpg light-vehicle fleet stretches oil stocks ~3×; half-filled tanks can run 3 weeks (a dispersed, delivered, refined-product SPR); wellhead-to-car buffers could last for months, buying precious time to mend or improvise around what's broken***
  - ***Electric efficiency stretches distributed resources***

# *Oil savings can be greatly accelerated*

- *Off >$100/bbl Gulf oil (2.5 Mbbl/d = 1.15 Mbbl/d gasoline) = light vehs. +2.7 mpg*
- *Don't just wait—mobilize the resource*
  - *Accelerated-scrappage feebates turn over fleet quickly, help economy & environment*
  - *Feebates for heavy trucks, buses, aircraft too*
  - *Accelerate auto/aircraft industries' transition*
  - *Encourage early $H_2$ infrastructure: miniature gas reformers cost ~50%* **less** *per car than maintaining* **existing gasoline** *infrastructure*
  - *Access- & mobility-based business models*
- *Barrier-busting tops the policy agenda*
- *Break airport gate and slot monopolies*
- *Stop subsidizing and mandating sprawl*

# A 5×-efficiency midsize SUV already designed


**An illustrative, uncompromised, manufacturable, production-costed concept car (11/2000) developed for a few million dollars in 8 months by Hypercar, Inc. (www.hypercar.com), with attributes never before combined in a single vehicle**

- 5 big adults, up to 69 $ft^3$ of cargo
- Hauls 1,013 lb up a 44% grade
- 1,889-lb curb (47% Lexus RX300)
- Head-on wall crash @ 35 mph doesn't damage passenger cell
- Head-on collision with a car twice its mass, each @ 30 mph, meets U.S. occupant protection stds. for fixed-barrier crash @ 30 mph
- 0–60 mph in 8.2 seconds
- 99 mpg-equivalent (5 times RX300)
- 330 mi on 7.5 lb of safe 5-kpsi $H_2$
- 55 mph on < normal a/c energy
- Zero-emission (hot water)
- Sporty, all-wheel digital traction
- Ultrareliable; flexible, wireless diagnostics/upgrades/tuneups
- 200k-mile warranty—no dent/rust
- Competitive cost expected
- Decisive manufacturing advantage—1/10th capital, parts, assembly

# *Hypercar℠ vehicles will ultimately…*

- *save 8 Mbbl/d (= 1 Saudi Arabian output) in US; worldwide, as much oil as OPEC sells*
- *decouple driving from climate and smog*
- *permit a rapid, profitable hydrogen transition*
- *become immense electricity generators: cars are parked ~96% of the time, so a full US fleet of 220 million light vehicles, @ 20–45 kW, wd total 4–10 TW — 6–12× today's gen. capacity*

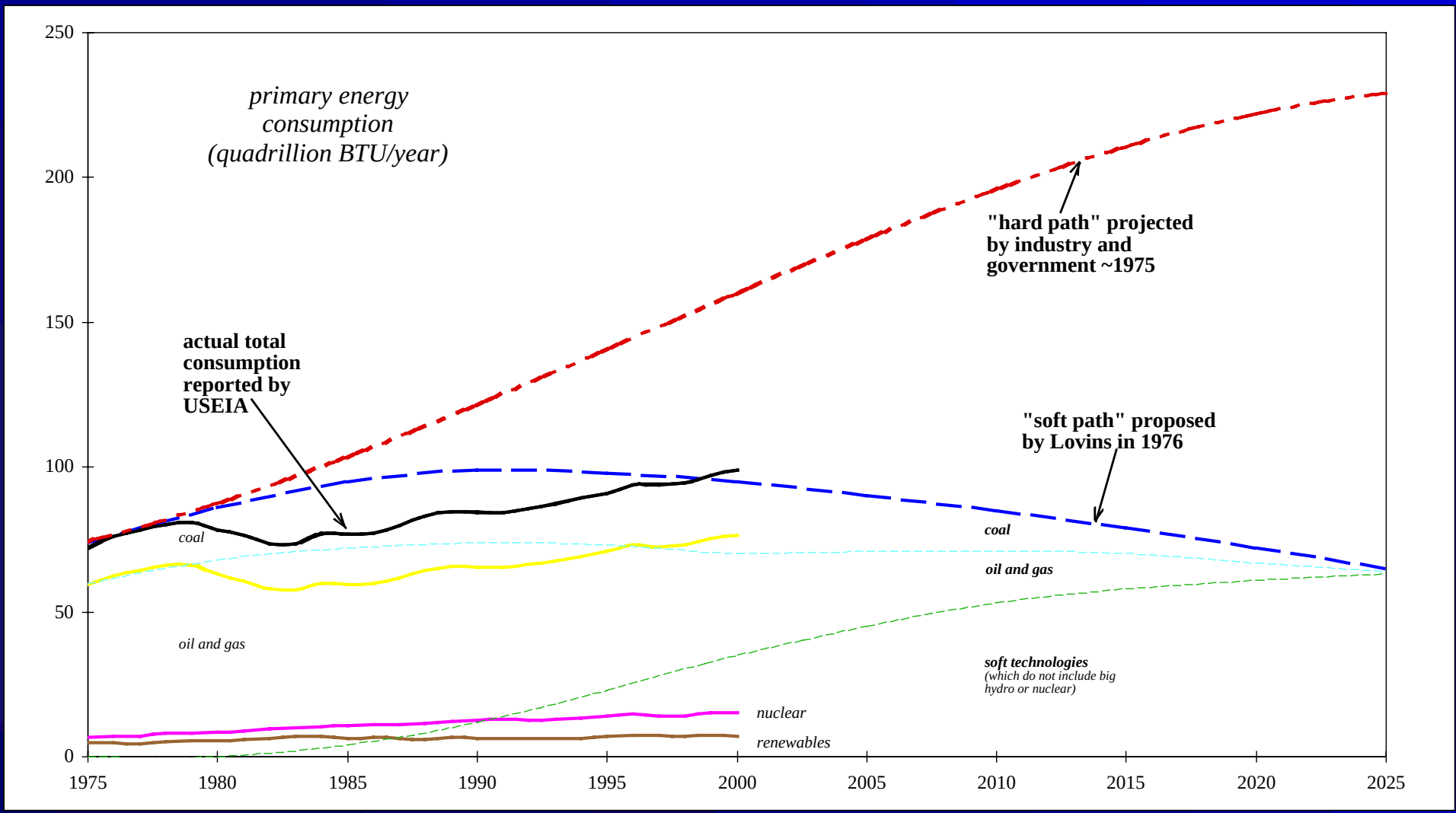
***WHEN? Within current planning horizons!***

- *~$10 billion committed during 1993–2000*
- *Hypercars could enter production in ~5 y, dominate in ~10 (www.rmi.org/sitepages/pid414.asp)*
- *The old way of making cars — and electricity — could be toast in 20 y…a nat'l. advantage*

# *Note unusual features…*

- *Uncompromised cars at comparable cost — no tradeoffs, no extra costs (CDs)*
- *They'll sell because they're better, not because they're clean and efficient*
- *No oil price, fuel tax, climate regulation, mandate, or subsidy needed — an "end-run" around the 20-year policy gridlock*
- *Business model rests solely on value to the customer and competitive advantage to the manufacturer*
- *Quick entry, formidable new entrants*
- *Hard to stop; basic work in public domain*

# US energy use/$ GDP already cut 40%, to very nearly the 1976 “Soft Energy Path”

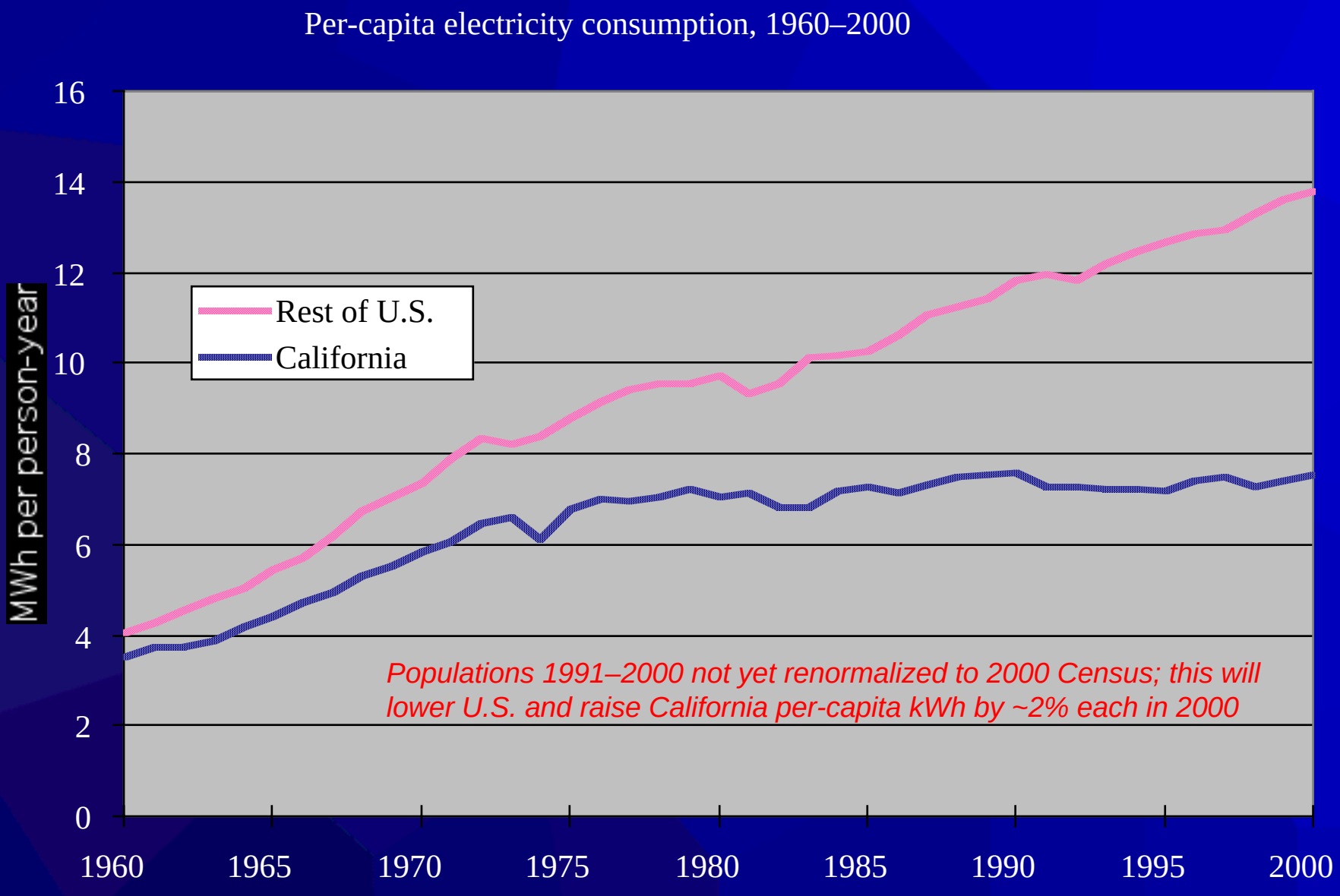


# *Reduced US E/GDP 1975–2000 was:*

- *The nation's largest energy "supply," providing 40% of 2000 energy services*
- *The fastest-growing US "source"*
- *>5 times US domestic crude-oil output*
- *3 times total US net oil imports*
- *6 times net oil imports from OPEC*
- *13 times net imports from Persian Gulf*

*The US in 2000 got twice as much GDP from each barrel of oil as in 1975. Yet this barely scratched the surface of available and very profitable oil productivity. (Electric efficiency is in its infancy; CA leads.)*

# California: policy really does work



***US has saved $200 billion/year in energy costs since 1973—but still wastes $300 billion a year***

- ***Power-plant-fuel to incandescent-light efficiency: 3%***
- ***Efficiency with which a modern 29-mpg car converts fuel energy into driver motion: <1%***

***US power plant waste heat = total Japanese energy use***

***Even Japan's economy is <10% as energy-efficient as physics permits***

# *Recent building examples*

- *Grow bananas with no furnace at –47¢F (RMI); comfort without air-conditioning at +115°F (PG&E ACT²); both cost less to build*
- *90% household el. saving (~$5/month · 4k ft²), 99% space- & water-ht. saving, 10-mo. paybk.*
- *90% a/c saving in new Bangkok house, 0 cost*
- *Big office buildings: 75–90% less energy, ~3–5% less capital, 6 months faster, superior comfort & market performance*
- *75% energy savings retrofittable in Chicago office tower, costs same as renovation*
- *97% a/c saving retrofit design in CA office*

# Rocky Mountain Institute

- *At 7100' nr. Aspen*
- *"Winter and July"*
- *Integrated design*
- *Superinsulated*
- *Thermally passive*
- *Air heat recovery*
- *95% daylit*
- *50% water saving*
- *Very efficient lighting & equip't.*

***Grow bananas with no furnace at –47°F***

***<u>Savings (1983 tech.):</u>***

- *90% in home el.*
- *99% in space & water heating*
- *10-month payback*
- *Market-avg. cost*

# *PG&E ACT² House*

***Davis, California***

***- Comfort without air conditioning at +113°F***
***- Mature-market building cost $1800 lower***
***- Present-valued maintenance cost $1600 less***
***- Design energy savings ~82% below California Title 24 standard***
***- Last 7 improvements justified only by savings of energy*** plus ***capital cost (last 1.5 T of a/c), not of energy alone***
***- Saved 3/4 of wall wood***
***- Later done at 115¢F too***

# *Renovating a 200k-ft² office*

- *20-y-old curtainwall, near Chicago*
- *Failing seals require reglazing*
- *Superwindows + efficient lights & plug loads cut cooling from 750 t to 173 t*
- *4x smaller, 4x more efficient HVAC costs $200k less than renovating old one*
- *That $200k pays for everything else*
- *Design would save 75% of energy, or $1.10/ft²-y; much better comfort; –5 to +9 month payback (though they didn't do it!)*
- *Tech details available: **www.esource.com***
- *Cheap capital too: **www.ipmvp.org***

# *Integrated office design*

- *RMI led design for Hines and Gensler*
- *Tightly integrated state-of-the-shelf choices*
  - *Deep daylighting, superefficient direct/indirect lighting, very efficient plug loads and HVAC*
  - *Underfloor displacement ventilation*
  - *No or almost no dropped ceiling*
  - *Tuned superwindows, careful shading/mass*
  - *Optimized structural bays and surface optics*

# *Integrated office results*

- *Energy cut by about 50% without influence over tenant light/plug loads, or ¡ 75% with it*
- *6 storeys in 75' lowrise limit,higher ceilings*
- *Superlative lighting, acoustic, thermal, & air quality; each worker controls temperature*
- *Typically ~6–16% higher labor productivity*
- *Reconfiguration costs almost eliminated*
- *Higher space efficiency*
- *Same or slightly lower capital cost*
- *Simpler construction, six months faster*

# *A Few Industrial Examples*

- *Saving 1/2 of industrial drivepower (3/8 of industrial el.) typically retrofittable with 35 measures @ ~100–200%/y aftertax return*
- *Same ROIs recently found for retrofitting chip-fab chiller/fan systems (save 50+%)*
- *Microfluidics, dematerialization/longevity*
- *Southwire (biggest US independent maker of rod/wire/cable) cut BTU/lb 1/2 in 6 years*
- *DuPont plans to boost energy productivity at least 6%/y in this decade, after saving 1/2*
- *Dow/Louisiana got >200%/y ROI retrofitting $110M/y of simple energy savings*
- *New chem plant cd save ~3/4 el., ~1/10 cap.*

# *The energy efficiency solution*

- *Here and now, not a decade away*
- *Reserves expanding w/new technology*
- *Rapidly, equitably deployable in market*
- *No dry holes, volatile prices, cutoffs*
- *Exercises more market power than OPEC*
- *Enhances relative importance of less vulnerable and more diversified sources*
- *Improves environment, protects climate*
- *Creates net jobs everywhere and for all*
- *Improves profits and competitiveness*
- *Very advantageous at any energy price*
- *Seemingly invisible/unimportant to some*

# *Electric efficiency is very cheap*

- *Vast literature documents sophisticated, rigorous measurement and evaluation*
- *Costs and savings accurately predictable*
- *Historic US* **av.** *cost utilities ~2¢/kWh*
  - *SCE's DSM portfolio 1991–94: 2.6→1.2¢/kWh (av. 1.7) despite relatively costly res'l. efforts*
- *Well-designed progs. often far cheaper*
  - **E.g.,** *NYSERDA review of >200 programs by 58 utilities –'88: dozens cost 0.4–1.1¢/kWh*
  - *>20 utilities' comm'l./ind'l. programs cost ¡ 1¢/kWh, the best <0.5¢/kWh ('88 $); median was ¡ 1¢ for eight major types of programs*
  - *Transaction costs often tiny (SCE 1984: 0.065¢ res'l, 0.031¢ other — ~1% of tariff)*

# *A closer look at one DSM example*

- ***Southern California Edison Company, serving 9 million customers in 50k mi²***
- ***Self-evaluation reported saving ~1.09 $GW_p$ (over the next 10 y)* just in 1983 — *equivalent to 8.6% of '83 peak load***
  - ***~45% from utility programs with average utility cost of 0.32¢/kWh for efficiency and $31/kW_p$ for load management***
  - ***~55% from State, mainly appl./bldg.stds.***
  - ***SCE could have done those itself,* e.g., *via seller rebates & bldg. feebates***
- ***Similar results in 1984; savings today could be even bigger and cheaper***

# *Efficiency can work quickly*

- *In 1983–85, 10 million people served by Southern California Edison Co. were cutting its 10-y-ahead forecast peak load by 8½%* per year*, at ~1% of marginal supply cost*
- *In 1990, NEES got 90% of a small-business retrofit pilot program's market in 2 months*
- *PG&E got 25% of its 1990 new-commercial-construction market in 3 months, raised its 1991 target, and got it all during 1–9 January*
- *New delivery methods are even better — not just marketing negawatts but making markets* in *negawatts, thus maximizing competition*

# *A new wave of US energy efficiency*

- *1979–86: real GDP +20%, pri. energy –5%*
- *1986 price crash, "period of stagnation"*
- *Calif. led in el. eff.: –10 $GW_p$ by early '90s… and in 1–2Q01, undid 5–10 y of load growth*
- *1996–2000: U.S. neared record for speed of cutting primary energy/GDP (–3.2%/ y)*
  - *Despite record-low / falling prices 1996–99*
  - *Significant structural change, but mostly technical gains in end-use efficiency*
  - *Driven by competition, fashion, side-benefits*
- *Savings keep getting bigger and cheaper*
- *No sector or use lacks huge potential*

# *Future negawatts can be even cheaper*

- *Better technologies, more ubiquitous*
- *Volume production, competitive prices*
- *More streamlined delivery methods*
- *Better marketing, especially in bundles and using valuable side-benefits*
- *Much better insight into how to turn obstacles into business opportunities*
- *Greater customer awareness / eagerness*
- *Continuing innovation expands technical potential faster than it's being exploited*
- *Now add breakthrough design integration*

## *How much electricity can be saved?*

- *Late-1980s technologies could save 3/4 of Danish buildings' el., or 1/2 of Sweden's total el., at $0.016/kWh ('86 $), and 4/5 of German home el. with ~40%/y aftertax ROI (incl. minor fuel-switching)*
- *Similar findings worldwide 1979–97*
- *Full retrofit of best mid-1980s technologies could save ~3/4 of US electricity at an average '86 cost of ~$0.006/kWh*
- *This RMI finding is broadly consistent with EPRI's (the differences are almost all methodological, not substantive)*
- *That's with >13-y-old technology/design*

# *Then add sustainable, resilient supplies*

- ***Wind and PVs are fastest-growing sources; global wind adding 5 GW/y (nuclear added 3 GW/y in 1990s); wind can outcompete coal; fuel cells, $H_2$ transition coming fast***
- ***Important new cellulose-to-biofuel options***
  - ***Must integrate with sustainable farms/forests***
- ***Proven implementation techniques***
  - ***Sacramento muni replaced failed nuclear plant with eff. + clean portfolio; big financial win***
  - ***Pay distribution utils. to cut bills, not sell kWh***
  - ***Local initiatives: see last ch. of* Brittle Power**

# *Distributed generation can compete*

- *Gas-turbine cogen/trigen delivers a few $MW_e$ at ~$0.005–0.02/kWh net ($\eta$ ~ 0.90)*
- *~27%-efficient 30- or 60-$kW_e$ natural-gas microturbines; engine generators*
- *A recent microturbine retrofit design would give a 1-y payback against $0.055/kWh utility power ($\eta$ ~ 0.92) in a 1.5-million-$ft^2$ US office/lab complex*
- *Windpower profitable in good sites (now $0.030–0.032/kWh w/o subsidy); $0.026/kWh expected in 2002 (@ av. 5.6–6 m/s); practical potential ~1.5–4$\times$ global el. use*

# *Distributed generation can add up*

- *Supply-side bidding in >26 US states yielded av. 8× desired capacity in 1–2 y*
- *Even more opportunities today as microturbines and fuel cells start to enter the market, windpower becomes cheap, and PVs become routinely mortgage-financed as part of house*
- *Enabling all owners, kinds, and sizes of generators to compete fairly can turn power shortages into gluts—surprisingly quickly*
- *The sobering example of California...*

# *The sobering saga of California's 1980s shortage-to-glut transition*

- *In 1984, CA had a ~37-GW peak load*
- *Had committed 12 and was buying another 7 GW of demand-side resources through '94 (~10 were ultimately procured, ~9 lost)*
- *By 3/85, had 20.3 GW of independent generation, mostly renewable, on firm offer, 57% of it online or contracted and being built—plus another 9 GW* **per year***!*
- *By 4/17/85, when the CPUC suspended most new small-power contracts, 13.1 GW was already under contract and another 8+ GW was in negotiation*

# *California's shortage-to-glut saga (2)*

- *Thus, had this boom continued through 1985, those dispersed generators, averaging only 12 MW and with lead times ranging from months to a few years, could have displaced all 27 GW of thermal plants in California*
- *The transition from scarcity to glut took only two years—yet well after it ended, at least 24 other states and provinces were still seeking to sell CA their surpluses simultaneously*
- *CA and US now seek to reproduce this experiment; the same results can be expected as fast DSM (& dxd. gen.) outrun slow supply*
- *A very bad movie—we needn't see it again*

# *What's the Right Size for Generation?*

- *Optimal scale should be a market choice*
- *So the rules must let all scales compete*
  - *Simple, transparent interconnection rules*
    - *Net metering desirable; time-of-use both ways*
    - *Ensure safety without burdensome obstacles*
      - *New Mexico's brief example: compliance with Underwriters' Laboratory, National Electric Code, and IEEE standards is sufficient and automatically acceptable*
      - *Texas, New York are "pre-qualifying" equipment*
  - *Ensure no obstacles to thermal integration*
  - *Modernize $H_2$ installation, use, safety rules*
- *No take-or-pay protection for sunk costs*

# *Some basic questions*

- ***Short-run social value for el. is ¡ $10^2\times$ its long-run production cost***
  - ***El. costs ~1% of GDP, but blackout stops most prod'n.***
  - ***Threat of blackout raises market price to 10–100$\times$ cost***
  - ***High capacity/price elasticity $\rightarrow$ profitable withholding***
  - ***Market price limited only by FERC, or customer assets***
  - ***Contracts then convert short- into long-term rents, little of which get reinvested in CA electricity supply***
- ***So if we base price on value, not cost, are we prepared for ¡ $10^2\times$ price jumps?***
- ***Don't the resulting losses dwarf claimed in-efficiencies of a well-regulated monopoly?***
  - ***Regulated, even state-owned el. looks relatively efficient!***

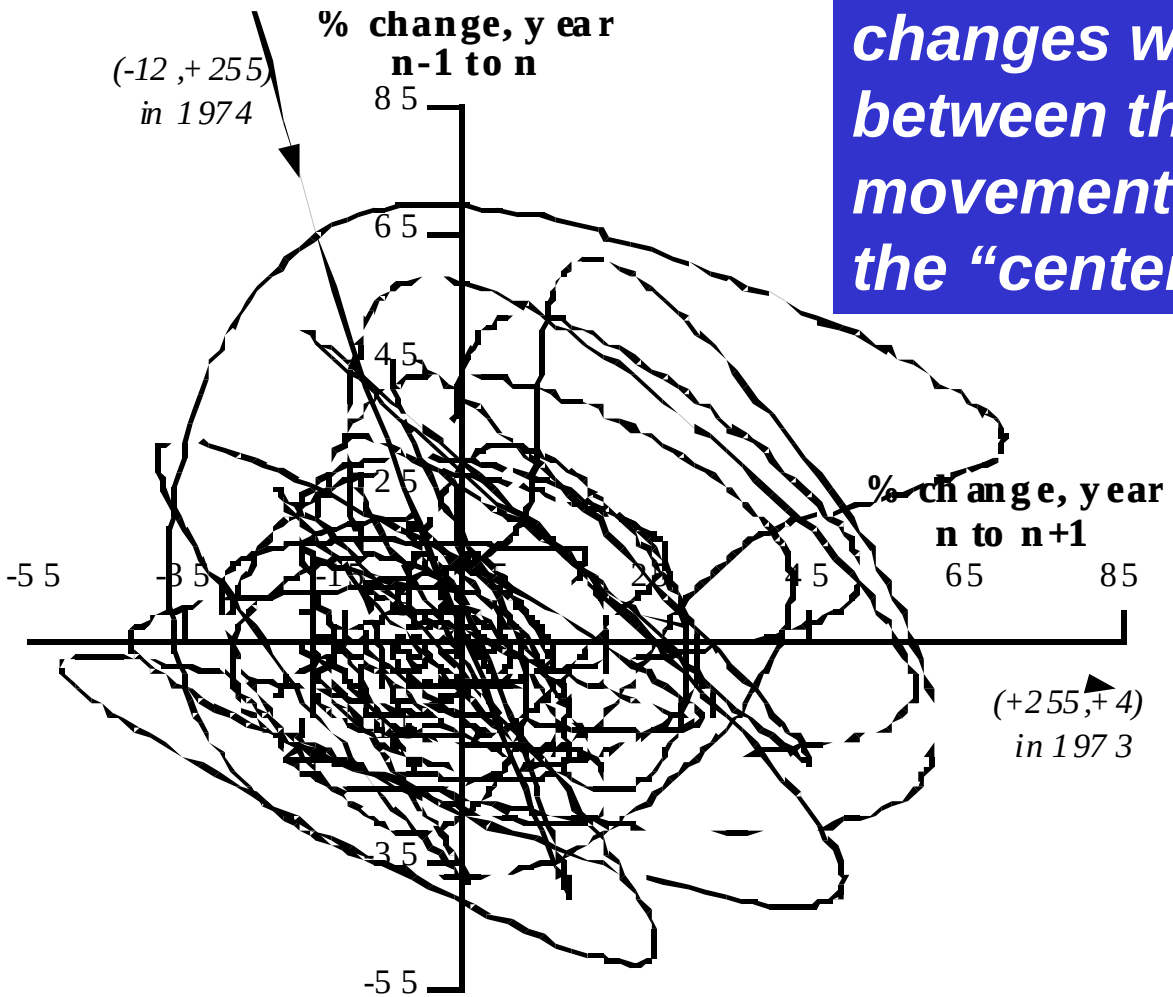
# *Big underlying issues remain*

- *Why must competition be retail too?*
  - *Wholesale competition, which was already in place, captures nearly all the same benefits without most of the risks*
- *Do we believe in a least-cost portfolio of resources, or will we continue to slight the demand side and invest in supply?*
  - *Even EPRI, which should know better, presents DSM only as an emergency response, not as a major portfolio element or a systematic competitor against supply*
- *Will we continue to bail out bad buys?*
- *Why do we tolerate such poor reportage?*

# *Conventional policy instruments for turning ideas and goals into actions*

- ***Regulation***
  - ***Standards, mandates, results (Kyoto),…***
- ***Innovation + laissez-faire***
  - ***RD&D, "golden carrots", targeted devel't.***
  - ***Labeling, information, and public education***
  - ***Liberalization, "competitive" restructuring***
- ***Taxes and prices***
  - ***Energy, carbon, and other Pigouvian taxes***
  - ***Tariffs and tariff structures***
- ***These all work; choice is a matter of taste***

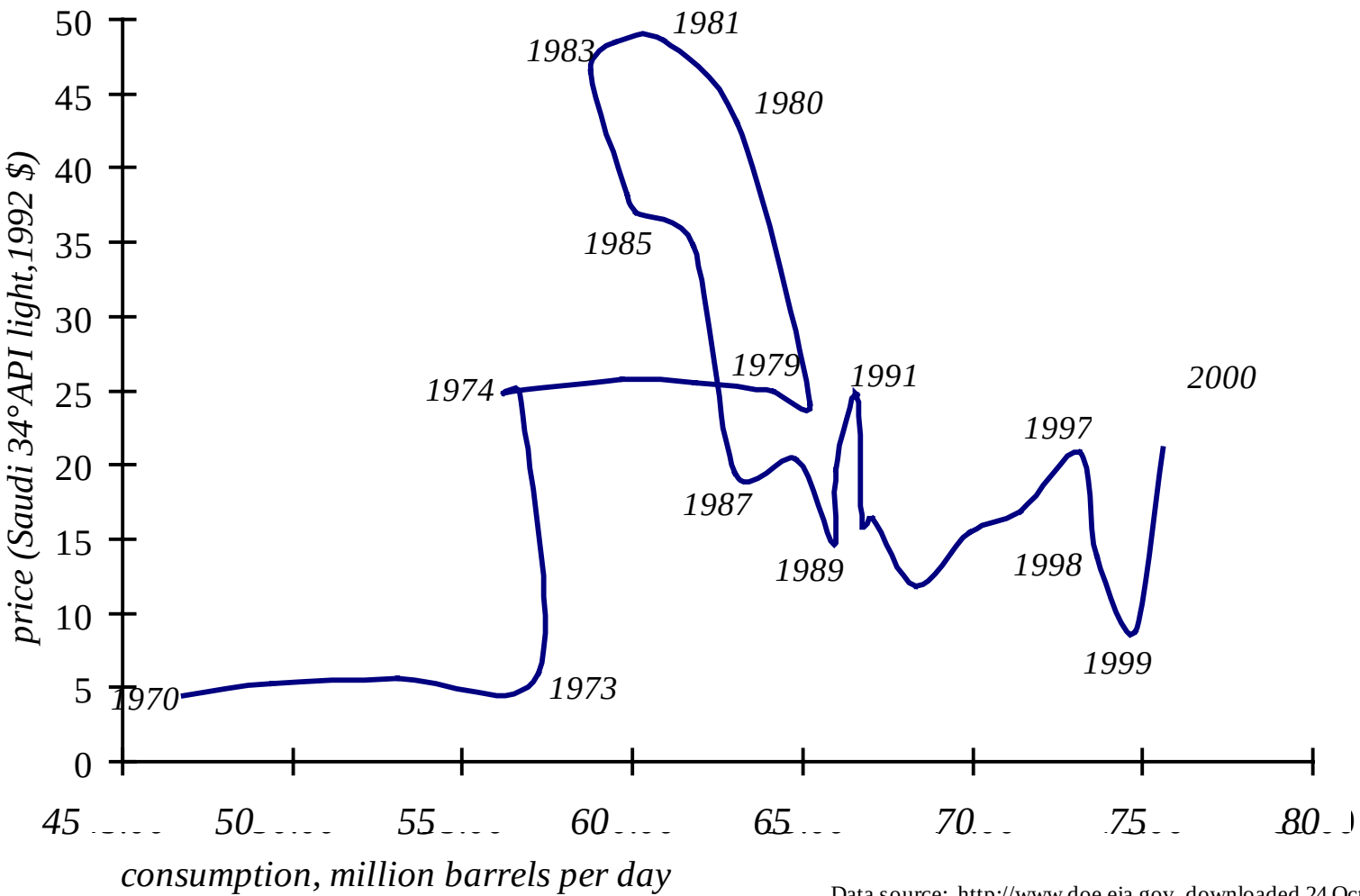
# The Brownian Random Walk of World Real Oil Price, 1881–1993




*Year-to-year percentage price changes with a one-year lag between the axes. If the price movements showed a trend, the "center of gravity" would favor a particular quadrant. All that happened after 1973 is that volatility trebled; changes stayed perfectly random, just as for any other commodity.*

*Graph devised by H.R. Holt, USDOE*

# Market surprise: world crude-oil real price vs. oil consumption, 1970–2000




Data source: http://www.doe.eia.gov, downloaded 24 October 2000

# *What drives energy savings?*

- ***Prices do matter, and should be correct, but ability to respond can matter more***
  - ***Seattle in 1990–96 paid half Chicago's electricity price, yet saved $kW_p$ 12× as fast and kWh 3,640× as fast, due to utility differences***
- ***Price is only one of many ways to get attention: e.g., US E/GDP 1996–00 fell 3.2%/y during record-low & falling prices***
- ***Prices without barrier-busting do little***
  - ***DuPont's European factories are as inefficient as US ones despite long exposure to prices 2× as high***

# *Price may well become less important*

- *On the demand side, end-use efficiency will be bought mainly for qualitatively improved services (joint products)*
- *On the supply side, distributed and renewable resources will be bought mainly for distributed benefits*
- *Outcomes will therefore become de-creasingly predictable from economics*
- *Disruptive technologies may be driven by factors other than price and regulation*
- *In any case, price should reflect ecologic-al tax-shifting (from goods to bads)*

***Conventional policy instruments are not the only ones and may not be the most effective. Here are eight more. Change...***

1. ***Ability to respond to price***
2. ***What competes, what is rewarded***
3. ***What benefits are marketed and sought***
4. ***Technologies* vs. *negatechnologies***
5. ***How designers think***
6. ***How quickly we deploy***
7. ***How business is done***
8. ***What drives underlying demand for energy services***

# *1. Ability to respond to price*

- ***60–80 specific market failures of 8 types:***
  ***Capital misallocation, value-chain risks, organizational and informational failures, regulatory failures, perverse incentives, false or absent price signals, absent markets***
- ***Proven methods can turn each of these obstacles into lucrative business opps.****
- ***"Barrier-busting" to create that alchemy should top the public policy agenda***

***Pp. 11–20, "Climate: Making Sense* and *Making Money," RMI, 11/97, free download, www.rmi.org/images/other/C-ClimateMSMM.pdf**

# *2. What competes, what is rewarded*

- ***Efficiency should compete fairly and comprehensively with supply in all administrative and market processes***
- ***Energy distributors should be rewarded for reducing customers' bills, not for selling more energy***
  - ***Decoupling + shared savings (9, now 2, U.S. states; widely adaptable methods)***
- ***Designers should be rewarded for savings achieved, not expenditures***
- ***Rules should be neutral as to scale and ownership — just count results***

# *What Should Be Rewarded?*

- ***The classical method of forming retail el. prices is preoccupied with the* price of kWh (tariffs) *and ignores the* cost of electrical services (bills)**
- ***It rewards distribution companies for selling more electricity, and penalizes them for reducing customers' bills***
- ***Thus its commodity mentality rewards just the opposite of what society wants!***
- ***Fixing this defect is* the *most important possible reform in the power sector***

# *What Should Be Rewarded? (continued)*

- *Necessary reforms have been demonstrated in ~9 of the United States; the top experts (RAP) can offer advice on how*
- *Typically done in two linked steps*
  - *Decouple profits from kWh sales*
  - *Share profits from reducing customers' bills*
- *Aligns customer and shareholder goals*
- *Rewards least cost (economic efficiency)*
- *Transforms utility culture*
- *Crucial to economic development goals*

# *What Should Be Rewarded (Example)*

- ***In 1992, the largest investor-owned US utility (PG&E) invested >$170M to help customers save electricity more cheaply than it could be made, even in old plants***
  - ***Created nearly $400M present-value saving***
  - ***Customers got 89% as lower bills***
  - ***Shareholders got 11% as higher profits***
  - ***Both had an incentive to achieve savings***
  - ***Utility received its 2d-biggest profit item (>$40M) at no cost and at no risk***
  - ***What utility dept. is best for your career?***

# 3. What benefits are marketed & sought

- Side-benefits are often worth ¡ 10× more than direct energy savings
  - ~6–16% higher labor productivity from better visual, acoustic, & thermal comfort
  - Big gains in industrial output/quality, +40% sales in well-daylit stores, 20–26% faster learning in well-daylit schools,...
- Integration with other goals: Curitiba
- Distributed benefits: ~125 effects often raise economic value of distributed electric resources by ~10×
- Breakthrough performance: Hypercar℠

# *Order-of-magnitude typical value increase from distributed benefits*

- ***Financial-economics** benefits: often nearing ~10× renewables, ~3–5× others*
- ***Electrical-engineering** benefits: normally ~2–3×, far more if the distribution grid is congested or if premium power reliability/quality is required*
- ***Miscellaneous** benefits: often around 2×, more with thermal integration*
- *Externalities: indeterminate but may be important; not quantified here*
- *Result: PVs often cost-effective* **now**

# *Four Times Square, NYC*
## (Condé-Nast Building)

- *1.6 million ft$^2$; 47 stories*
- *non-toxic, low-energy materials*
- *50% energy savings/m$^2$ despite doubled ventilation rates*
- *Gas absorption chillers*
- *Fuel cells*
- *Integral PV in spandrels on S & W elevations*
- *Ultrareliable power helped recruit premium tenants at premium rents*
- *Fiber-optic signage (signage required at lower floor(s))*
- *Experiment in Performance Based Fees rewarding savings, not costs*
- *Market average construction cost*

# *4. Technologies vs. negatechnologies*

- *We customarily deploy more efficient devices*
- *We too seldom buy and scrap the old, very inefficient devices*
  - *They're often worth more dead than alive*
  - *Take them out back and shoot them*
  - *Offer "bounties" to "hunters"*
- *We do not track, label, stigmatize, or penalize trade in inefficient devices*
  - *"Negative technology transfer"*
  - *Retards global development*

# 5. How designers think

- *Almost all technical systems have been designed by optimizing components for single benefits (pessimizing the system)*
- *Designing by optimizing whole systems for multiple benefits typically yields dramatic resource savings at lower costs*
- *"Tunneling through the cost barrier" now demonstrated in buildings, fan/pump/hot-water/HVAC/motor/lighting systems, computer design, other technical systems*


# *Edwin Land*

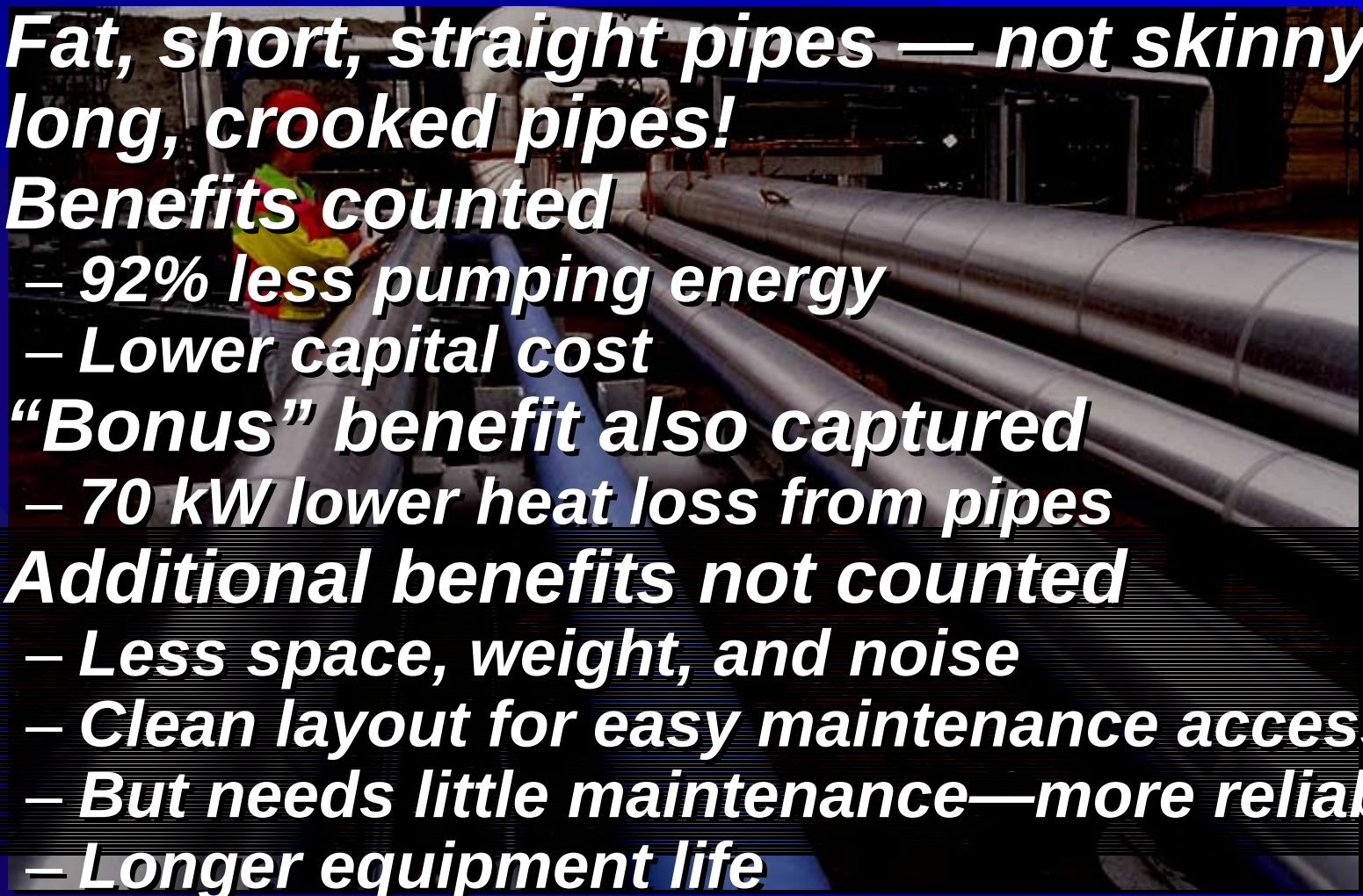
Invention is
"… a sudden
cessation of
stupidity"

# *New design mentality, an example:*

- *Jan Schilham's redesign of a supposedly optimized standard industrial pumping loop cut power from 95 to 7 hp (–92%), cost less to build, and worked better*

*No new technology*

# No new technologies, just two design changes



- Fat, short, straight pipes — not skinny, long, crooked pipes!
- Benefits counted
  - 92% less pumping energy
  - Lower capital cost
- "Bonus" benefit also captured
  - 70 kW lower heat loss from pipes
- Additional benefits not counted
  - Less space, weight, and noise
  - Clean layout for easy maintenance access
  - But needs little maintenance—more reliable
  - Longer equipment life

# *Why this example matters*

- ***Pumps are the biggest use of motors***
- ***Motors use 3/5 of the world's electricity***
- ***Every unit of flow or friction saved in the pipes saves ~10 units of fuel, cost, and pollution at the thermal power plant***
- ***This is an archetype for whole-system redesign: optimizing whole systems for multiple benefits, not individual components for single benefits, typically raises efficiency ~3–10×, reduces capital cost, and improves performance***

# *6. How quickly we deploy*

- *Why assume routine turnover of stocks?*
- *We seldom consider accelerated scrap-page,* e.g. *incentivized by car feebates*
- *We seldom implement mass retrofits*
  - *VT Efficiency wasn't even set up to retrofit!*
- *We seldom even coordinate* e.g. *building superoutsulation with routine façade renovation or HVAC installation/renewal*
- *Rely more on "vernacular" technologies, as fast as mobile phones / informatics?*
- *"Ready, fire, aim"; "just do it, keep trying"; leadership* vs. *management*

# *7. How business is done (beyond structural changes from E-commerce)*

- *Industrial capitalism treats only money and goods; but natural capitalism also productively uses and reinvests in people and nature, thus making far more profit*
- *Being rapidly adopted (www.natcap.org)*
- *Integrates radical resource productivity, closed-loop nontoxic production, a "so-lutions economy" business model that rewards both (profiting from doing more & better with less for longer—like www.mo-bility.ch), and reinvestment in nat. capital*
- *Profound implications for demand*

## *Capitalism: productive use of and reinvestment in capital (but what is capital?)*

1. ***Money*** *— financial capital*
2. ***Goods*** *— physical or manufactured capital, such as buildings & equipment*
3. ***People*** *— human capital (culture, community)*
4. ***Nature*** *— natural capital yielding resources and ecosystem services*

*Without natural capital there is no life and therefore no economic activity*

***First Industrial Revolution:***

***People are scarce and nature is abundant — increase labor productivity***

***Next Industrial Revolution:***

***People are abundant and nature is scarce — increase resource productivity***

# *Principles of Natural Capitalism*

1. ***Radically increased resource productivity***
2. ***Biomimicry: closed loops, no waste, no toxicity***
3. ***"Solutions economy": shift from producing goods to creating flow of value and service, rewarding both provider and customer for following steps 1 and 2***
4. ***Reinvest in natural capital***

***Hundreds of cases in book at www.natcap.org***

# *8. What drives underlying demand for energy services*

- *Population*
- *Affluence and its metric(s)*
- *Distributional (in)equity*
- *Hedonic / functional efficiency (how much human happiness / satisfaction come from each unit of energy services delivered)*
- *“Homo œconomicus” / “vanity”*
- *Markets make a great servant, a bad master, and a worse religion*
- *Meeting nonmaterial needs by non-material means*

***So if we have at least ten ways to deploy savings, not just two...***

***Can’t we become efficient much faster by combining most or all of this rich menu of options?***

# *Ten tools work better than two*

- *Rich menu, many flavors, fast-evolving*
- *Diversified portfolio*
  - *Better fits diverse needs & circumstances*
  - *Reduces risk from something's not working*
  - *More ways to end-run around blockages*
- *Try all; accelerate what works best*
- *Trans-ideological—very market-oriented*
- *Engages more varieties of actors*
- *More vernacular, less dependent on big or specialized institutions…just go do it*
- *More fun, especially in a small State*

# *Local implementation: 27 years ago…*

- ***L.A. 1974, oil embargo: Mayor Bradley's blue-ribbon panel wrote a plan in 6 days***
- ***Two-phase energy reduction per sector, stiff penalties; few activities proscribed***
  - ***Strong publicity, overwhelming response***
    - ***Phase One: res'l, comm'l, ind'l targeted 10, 20, 10% savings respectively; saved 18, 28, 10%***
    - ***City's energy use fell 17% in 2 mo (12% targeted)***
    - ***11% citywide saving just in the first four days***
  - ***Penalties never needed, later suspended***
  - ***Electricity use stayed below '73 level to '76***
- ***Basis for Energy/L.A. Action Plan, 1982***

# *Local implementation: lessons...*

- ***Large numbers of people can be motivated to act by an obvious community need***
- ***Giving citizens credit for maturity is often rewarded;* e.g., *in 1973–74+ oil crisis:***
  - ***Nova Scotia gave every household a check for a few hundred C$ to spend on weatherization***
  - ***Decided policing spending wasn't worthwhile***
  - ***Most of the money was well spent—half the houses were weatherized in the first year***
  - ***Some other Provinces later did better; CHIP***
- ***Reward self-interest: New Orleans schools***

# *Local implementation: Dade Cty, FL*

- *1973 oil crisis, chaotic Federal response*
- *County set up its own energy mgmt office*
- *By ~1981, Metro-Dade Cty had >70 progs*
- *Saved millions of tax dollars: 4600 Cty vehicles' acctg controls (saved >13Mgal)*
- *County-wide reporting of energy use/savs*
- *Local energy resources identified*
- *Many programs & policies developed*
- *Energy efficiency for community ec devel't*
- *Strong capabilities & contingency plans integrated with eff/renewables for preventn*
- *Trained other local officials statewide*

# *Local implementation: fun contests*

- *~1980, 6 New England states & 5 Maritime Provinces competed to save energy*
  - *Very short-term—curtailment, not efficiency*
  - *Monterey, MA, launched w/Main St parade*
    - *3-day effort encouraged by numerous social events*
    - *Coordinator & volunteers made it the leading topic*
    - *A volunteer hand-sewed 1,200 special yellow flags*
    - *Utility tried to take baseline readings, but demand had already fallen 15% in the previous few months*
    - *Additional savings achieved: 15.6%*
    - *Lost to St. Stephens, NB, with 17.5%*
  - *Now...$CO_2$ contest (Christchurch / Newcastle)?*

# *Local implementation: crisis response*

- *Crystal City, TX, 1977—natural-gas shutoff*
  - *Emergency weatherization, mesquite stoves, $85 homemade solar water heaters*
  - *Many "stopgaps" still in use many years later*
- *San Luis Valley, CO/NM—firewood denial*
  - *Very poor, traditional Hispanic, cold/sunny*
  - *Arnie & Maria Valdéz taught solar greenhouse*
    - *Average <$200 each, mostly scrounged materials*
    - *Hands-on workshops, "barnraisings," emulation*
    - *>800 greenhouses in a few years: 2/5 of houses + solar mortuary, Post Office, Baskin & Robbins,…*
  - *Growing season 3→12 mo.; better family life*
  - *"We were too poor to use anything but solar"*

# *Local implementation: mobilization*

- *Minneapolis/St. Paul, MN, 1980*
  - *Mayor announced with maximum fanfare*
  - *Raise energy consciousness, collect data*
  - *Give people information on opps. & $ savings*
  - *Surveys sent to 1500 homes/small businesses*
    - *92% of building occupants contacted; great data*
  - *City Hall closed 3 days; most city workers & many others volunteered (3,000 in all), biz too*
  - *A year later, free Caulkmobile still active*
  - *Energy Park, zoning changes for eff./rens.*
  - *City Energy Resource Center (city + utils.), 1-stop financing, 7% loans repayable on sale*

# *Local implementation: whole package*

- *Minneapolis raised $2.75M through local banks to start training/financing weather'n*
  - *Gas co. handled billing paperwork, gave 10% incentive bonus (up to $100)*
  - *Ten-year loan cost 1 % pt over City's capital*
  - *Planned 1982 $700M bond-underwriter sale*
  - *Trained organizers in each ~60-block area find an "inviter" on each block to spread the word*
  - *All-day Saturday workshop in each 5–10-block area: AM instruction, self-audit your home, come back by lunchtime with list of needed materials (~$40), get free from gas co., install (supported by a roving "house doctor")*
  - *~50% participation—important social event*
  - *5,000 blocks to be weatherized ~1980–85*

# *Local implementation: mobilization*

- ***Fitchburg, MA, backed by ACTION* et al.**
  - *500 volunteers in central 3 months of program*
  - *Trained to help neighbors implement low-/no-cost household improvements*
    - *60% of the 14,000 households participated*
    - *Av. materials & salaries cost $19 per retrofit kit*
    - *Each weatherized household diffused to two more, greatly reducing average cost per household*
  - *Average retrofit saved $73 in the first winter —$146 (14% of heating oil) with kit*
- ***At least 20 other communities successfully adopted this model; some added solar***
- ***Reinforce with retrofit-on-sale ordinances***

# *Local implementation: neat tricks*

- *Tupperware® party → housewarming party*
- *Share savings w/local libraries & churches*
- *Block meetings to discuss energy opps.*
- *Diffuse knowledge quickly by existing nets*
- *Ad-agency & marketing execs to volunteer*
- *Tech resources: JPL's alt. supplies '73–4*
- *Convergence with urban renaissance work*
  - *Mothers of East L.A. (toilet retrofits, water/el.)*
  - *Valerie Pope Ludlum (San Bernadino)*
- *Innovative retrofit technologies*
  - *St. Louis row-house rehab (Sackett/Bakewell)*
  - *WhiteCap / Cool Roof (David Energy Group)*

# *Local implementation: muni utility*

- ***Oceansize, CA's Municipal Solar and Conservation Utility, ca. 1980***
  - ***Leases solar systems on a small deposit***
  - ***City-approved dealers install and maintain***
  - ***55% of utility bill qualified for solar tax credit***
  - ***Can aggregate purchasing, take forward bids***
  - ***First three syndicates initially approved under the program capitalized it with $20M, marketing investment pkgs in CA & elsewhere***
  - ***Net revenue to City after first 1,000 installed***
- ***Nowadays could use www.ipmvp.org—cheap off-balance-sheet retrofit financing***

# *Local implementation: mass retrofits*

- *Decades ago, Los Angeles, Toronto, & Montréal changed their grid frequency*
- *Canadians used fleets of special vans left from cleanup after Normandy invasion*
  - *A van to swap clocks, another to rewind motors and rebuild controls, etc.*
  - *Each neighborhood retrofitted within hours*
- *Dutch switch from oil to Groningen gas, UK to North Sea gas and decimal coinage (~1 y) and smokeless fuel*
- *Swedish switch to right-hand driving (’67)*
- *Scandinavian switch to district heating*

# *Thank you! To dig deeper...*

- **Energy security:** *www.rmi.org/sitepages/pid533.php*
- ***The Alaskan threat to energy security:*** *www.rmi.org/images/other/E-FoolsGoldAnnotated.pdf*
- ***Advanced energy efficiency, green buildings, etc.:*** *www.natcap.org, www.rmi.org, and www.esource.com*
- ***Hypercars:*** *www.hypercar.com and www.rmi.org/sitepages/pid386.php*
- ***Hydrogen transition:*** *www.rmi.org/images/other/HC-StrategyHCTrans.pdf*
- ***Barrier-busting to speed up efficiency:*** *www.rmi.org/images/other/C-ClimateMSMM.pdf*

**About the author:** A consultant experimental physicist educated at Harvard and Oxford, Mr. Lovins has received an Oxford MA (by virtue of being a don), seven honorary doctorates, a MacArthur Fellowship, the Heinz, Lindbergh, World Technology, and Heroes for the Planet Awards, the Happold Medal of the UK Construction Industries Council, and the Nissan, Mitchell, "Alternative Nobel," Shingo, and Onassis Prizes; held visiting academic chairs; briefed 15 heads of state; published 27 books and several hundred papers; and consulted for scores of industries and governments worldwide, including the oil industry since 1973, DOE, and DoD. *The Wall Street Journal*'s Centennial Issue named him among 39 people in the world most likely to change the course of business in the 1990s, and *Car* magazine, the 22nd most powerful person in the global automotive industry. His work focuses on whole-system engineering; on transforming the car, energy, chemical, semiconductor, real-estate, and other sectors toward advanced resource productivity, and on integrating resource efficiency into the emerging "natural capitalism."

**About Rocky Mountain Institute (www.rmi.org):** This independent, nonpartisan, market-oriented, technophilic, entrepreneurial, nonprofit organization was cofounded in 1982 by its co-CEOs, Hunter and Amory Lovins. RMI fosters the efficient and restorative use of natural and human capital to create a secure, prosperous, and life-sustaining world. The Institute's ~50 staff develop and apply innovative solutions in business practice, energy, transportation, climate, water, agriculture, community economic development, security, and environmentally responsive real-estate development. RMI's ~$6-million annual budget comes roughly half each from programmatic enterprise earnings (mainly private-sector consultancy) and from foundation grants and donations. Its work is most recently summarized in *Natural Capitalism* (w/Paul Hawken; 9/99, www.natcap.org).

**About Hypercar, Inc.**: Rocky Mountain Institute transferred most of its internally incubated technical activities on Hypercar vehicles to this partly-owned second-stage for-profit firm, its fourth spinoff, in August 1999. Funded by private investors, Hypercar, Inc. (www.hypercar.com) pursues business opportunities related to the Hypercar concept developed at RMI since 1991. To declare an interest, Mr. Lovins is a minor holder of equity options in the firm.