Small Is Profitable:
The Hidden Economic Benefits of Distributed Generation (and Other Distributed Resources)

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Main findings

Approximately 130 distinct distributed benefits can collectively increase the economic value of distributed resources by typically an order of magnitude ($\sim 10^1\times$)

- ***Details are very site- and technology-specific***
- ***But increased value too small to tilt traditional commodity-cost-based investment decisions toward distributed/green resources seems rare***
- ***Some benefits aren't reported or linked before***
- **Capturing *many benefits depends on policy***
- ***Described here for generation resources, but also applies to storage and efficiency***

Objectives

- Comprehensively synthesize and rigour-ously analyze distributed benefits, quantifying each wherever possible
- Write the standard practitioners' primer
- Create a pedagogy across disciplinary boundaries, especially between electric-al engineering and financial economics
- Embed in historical context
- Offer policy recommendations
- Make widely available for faster learning
- Preview highlights today; solicit your suggestions for improvement

Seismic shift

- ***19/20th Centuries model: power plants have higher cost and outage rate than the grid, so both supply and demand must be aggregated through the grid***
- ***21st Century model: power plants have lower cost and reliability than the grid, so affordable and reliable supply must originate at or near the customer***

Meanwhile, unnoticed...

Central power plants, at least in the United States, stopped getting…

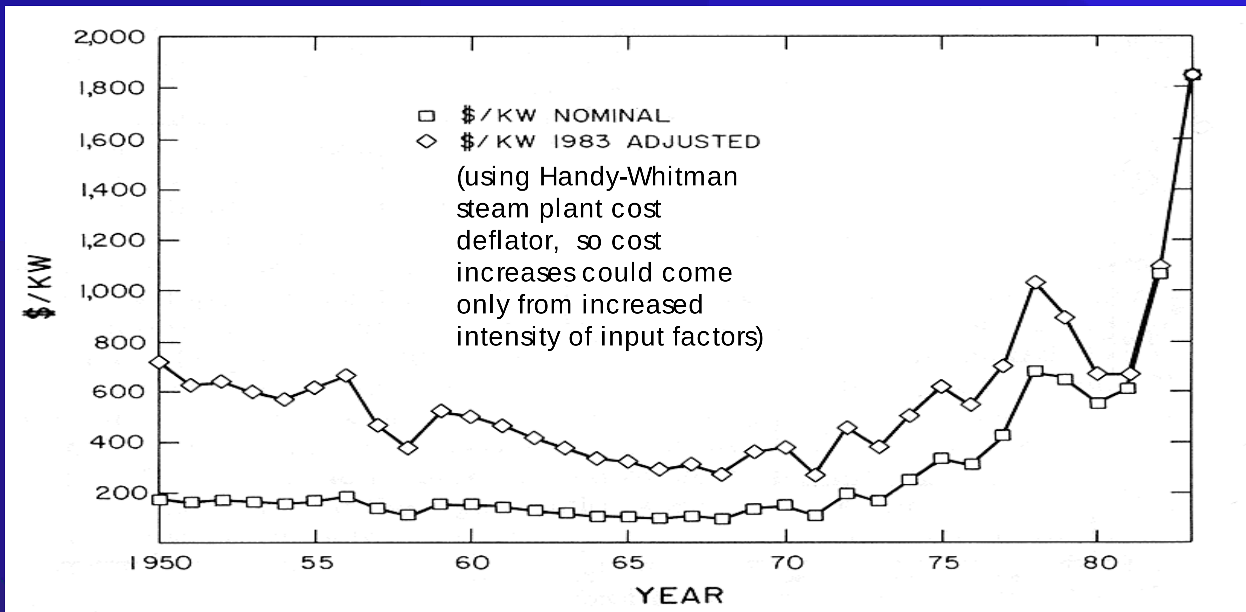
- ***More efficient in the 1960s***
- ***Cheaper in the 1970s***
- ***Bigger in the 1980s***
- ***Bought in the 1990s***

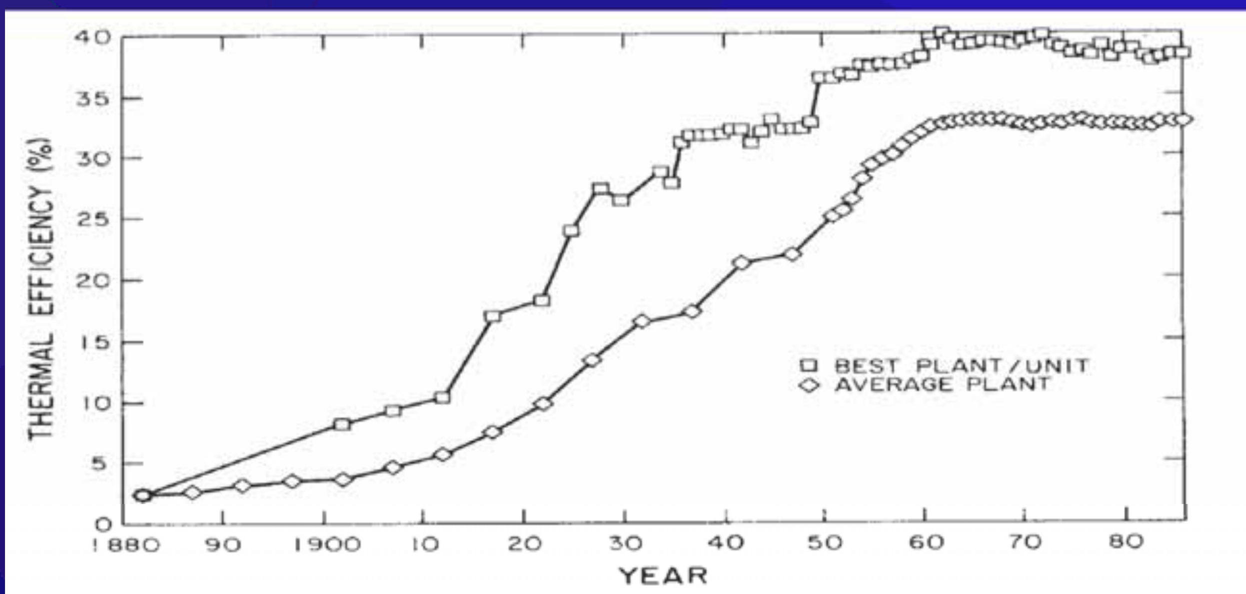
Similar trends are now emerging in most of the world.

Scale surprises: on the margin, distributed resources are taking over the market

- ***The disappointing cost, heat rate, risk, and reliability of large thermal stations were leading their orders to collapse…***
- ***…even before the "potential difference" between nuclear and combined-cycle costs stimulated restructuring that began to delaminate utilities…***
- ***…creating new market entrants, unbundled prices, and increasing opportunities for competition at all scales…***
- ***and launching the scale revolution***

Big units' costs disappointed





Capital-cost economies of unit scale disappeared, then reversed; they were probably illusory anyhow above at most a few hundred MW

Even the thermal efficiency of U.S. steam plants saturated around 1960—supercritical units hit the wall

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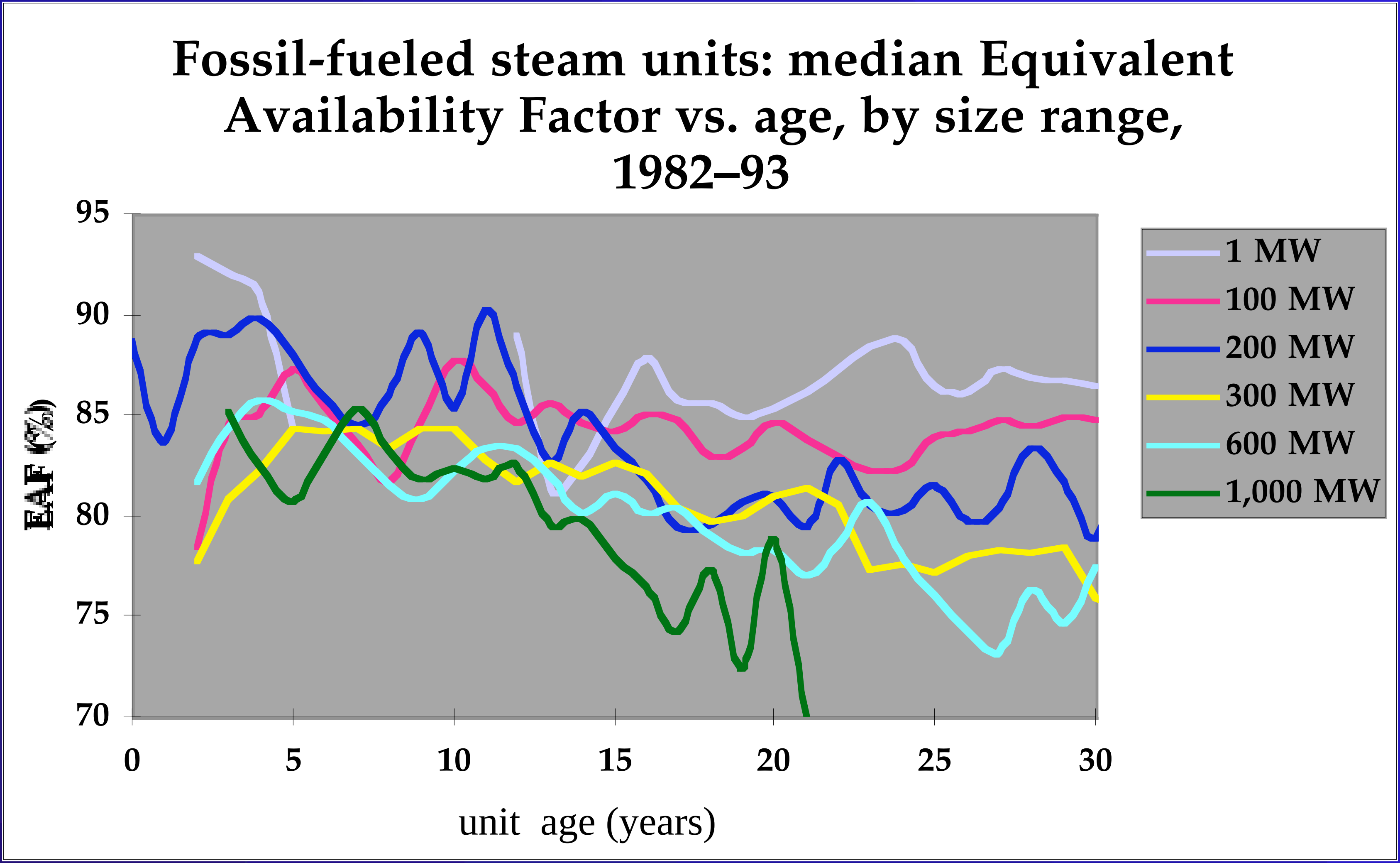
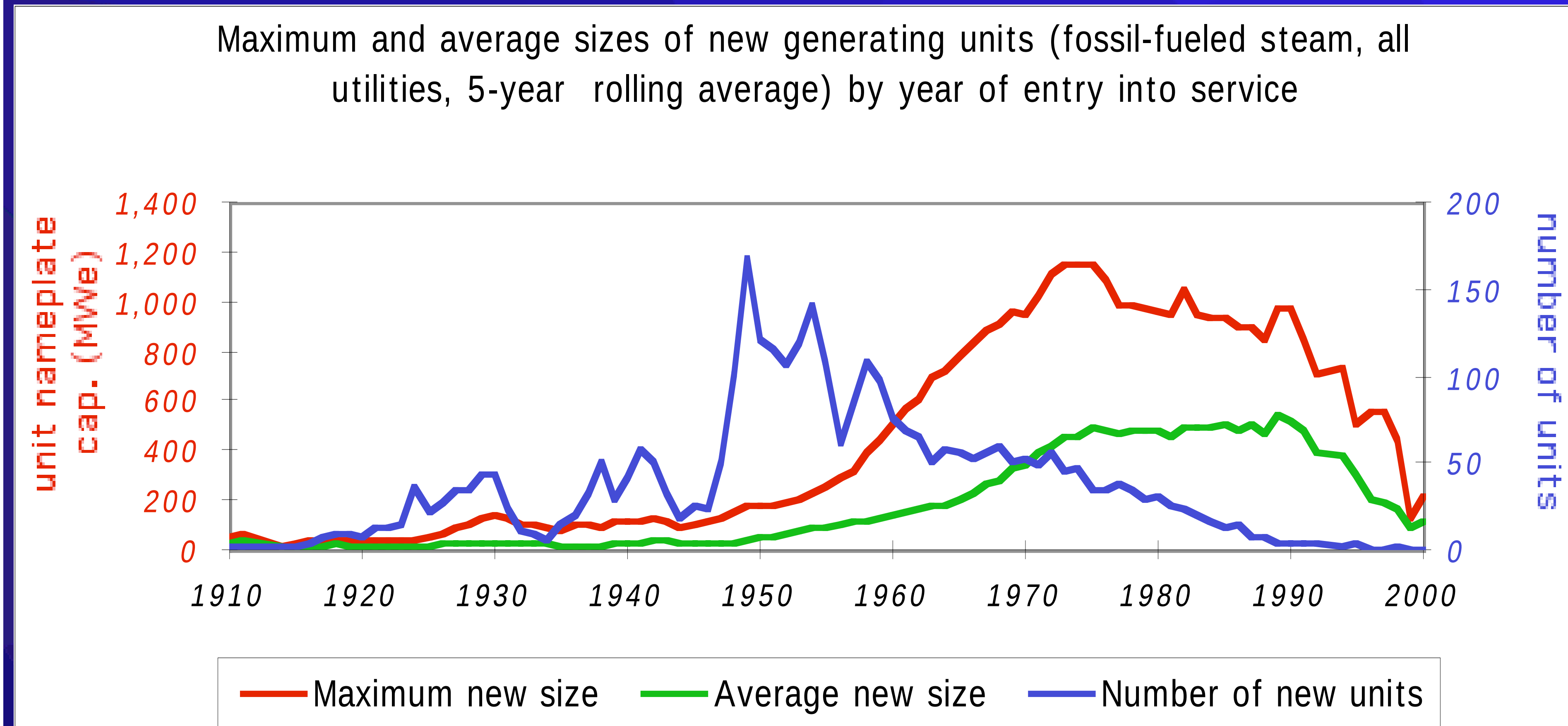
Big steam units aged ungracefully

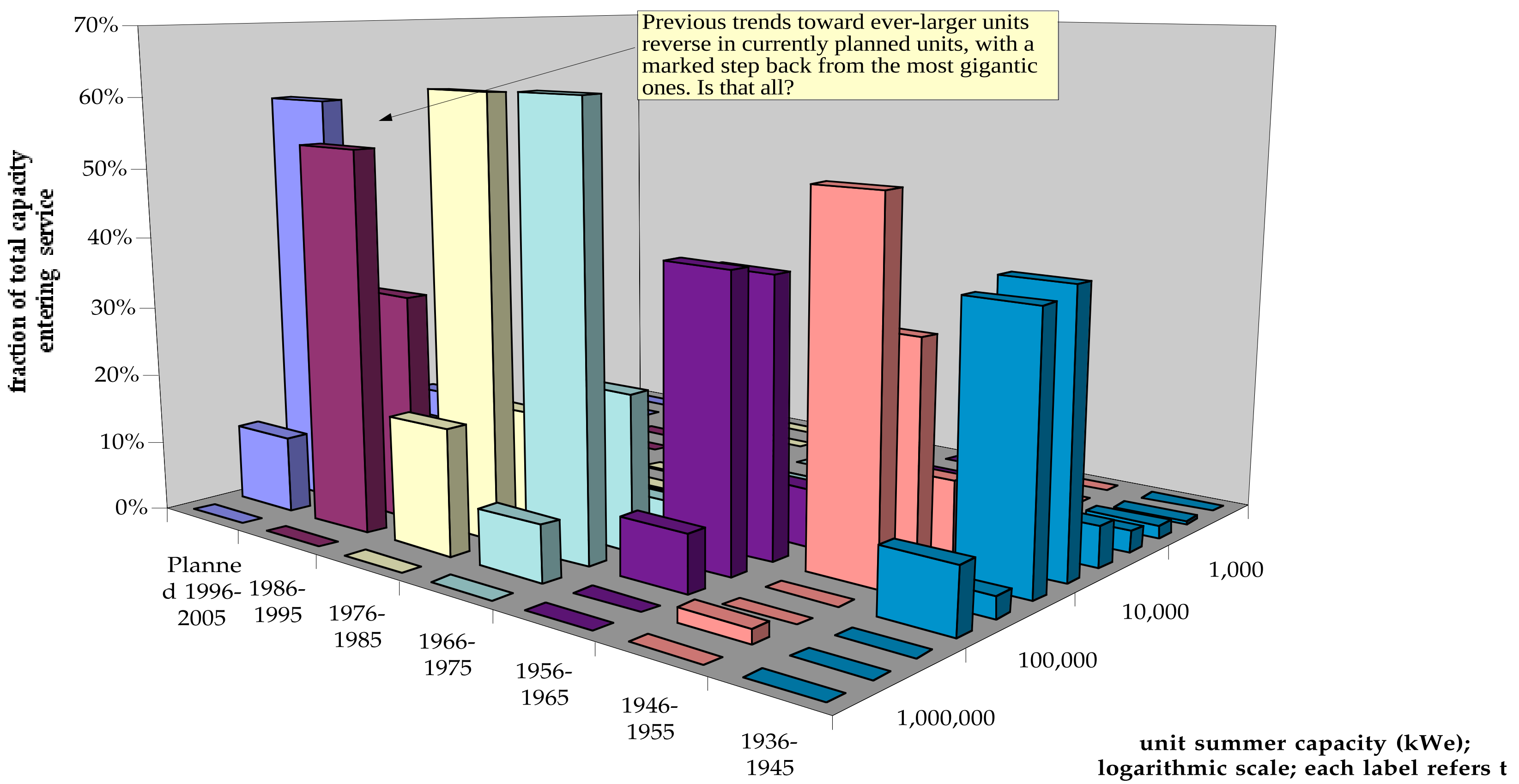


RMI analysis by André Lehmann, using Markovian smoothing of 29 July 1994 NERC raw data on all 1,347– 1,527 U.S. steam units in the years shown; raw data kindly provided by Resource Insight, Inc.

A 5-year rolling average reveals that U.S. fossil-fueled steam unit orders have been fading since the 1970s; their ordering rate, all ≤1/5 the former size, is now back to Victorian levels

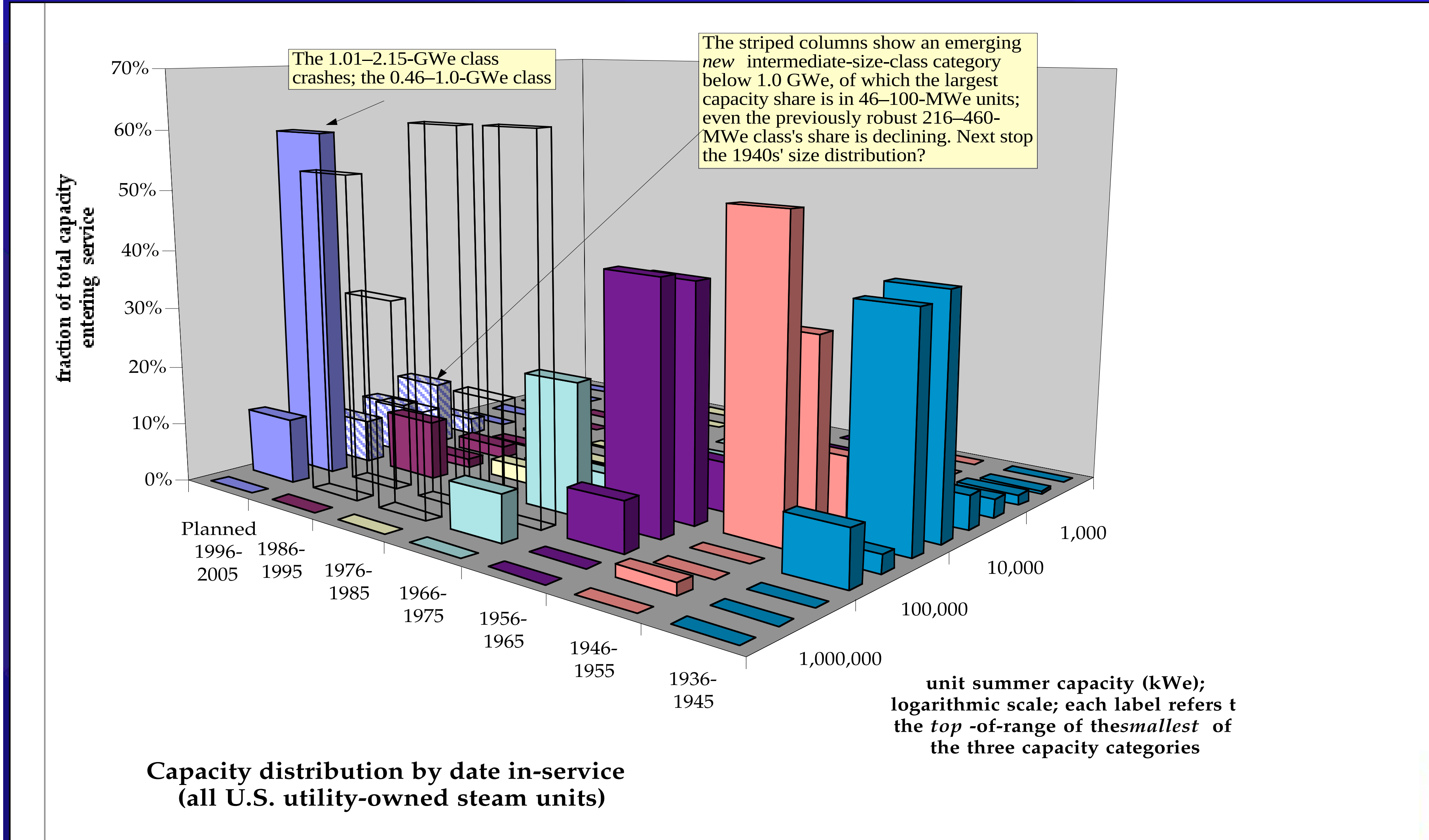


At first glance, it appears that the most recently ordered steam units have only retreated from the largest size range...

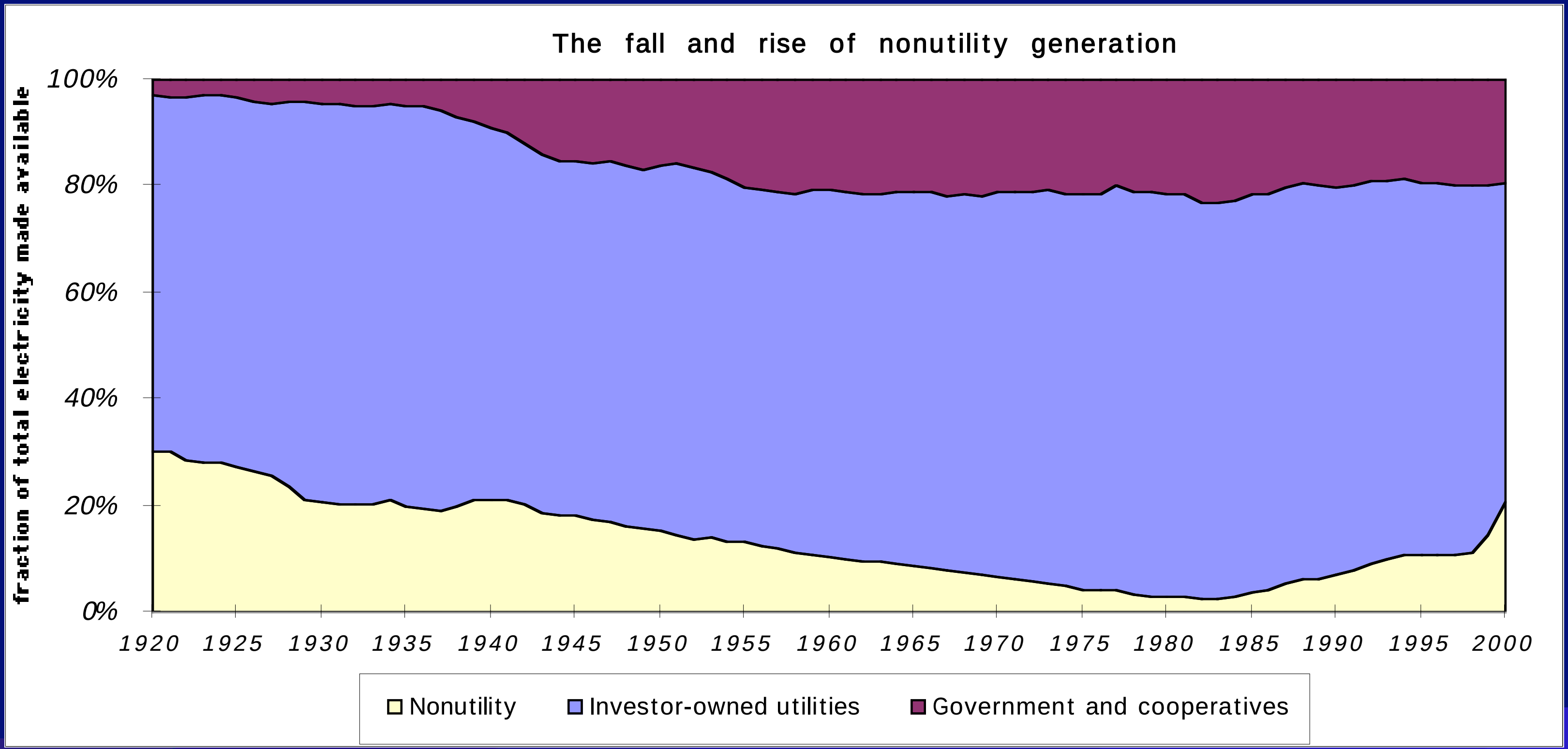


Capacity distribution by date in-service (all U.S. utility-owned steam units)

But make a few front bars transparent, and look what's coming up in the garden ...new steam-unit size is shrinking ≥10×

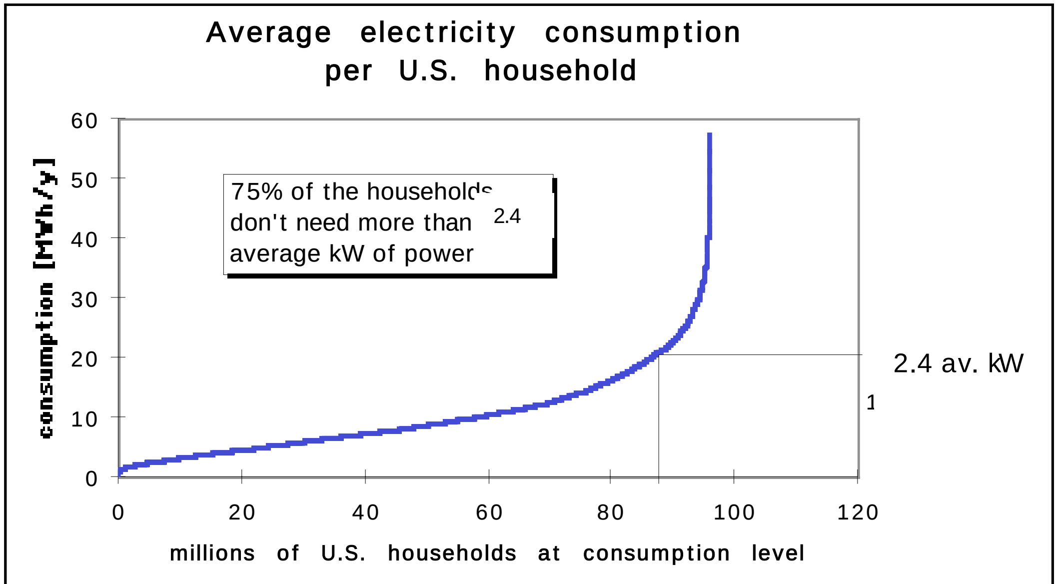


Since 1983, nonutility generation has come back, now making 27% of U.S. electricity

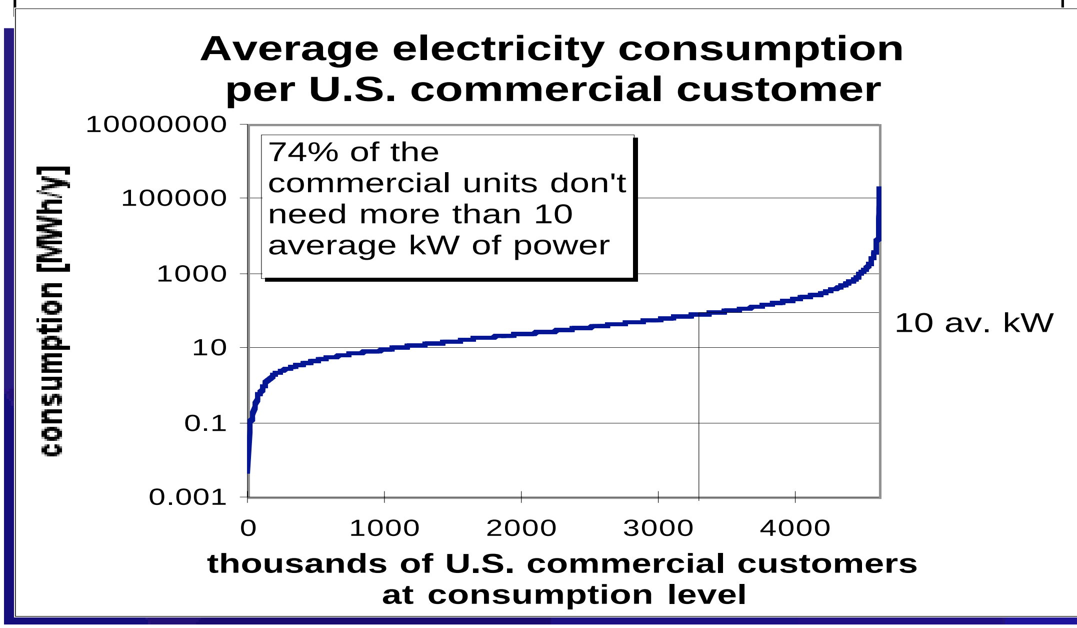


To many, though, it's invisible: many California authorities stated in summer 2000 that the state had added no capacity in the 1990s, but the actual additions, ≥4.5 GW, exceeded total nuclear capacity—it was just distributed and nonutility!

What's the right size for the job? Most customers want kW, not GW



Three-fourths of U.S. households have average loads not exceeding 2.4 kW (EIA statistical sample, 7/93)



Three-fourths of U.S. commercial custom-ers have average loads not exceeding 10 kW (EIA statistical sample, 1992, loga-rithmic vertical axis)

Codifying distributed benefits

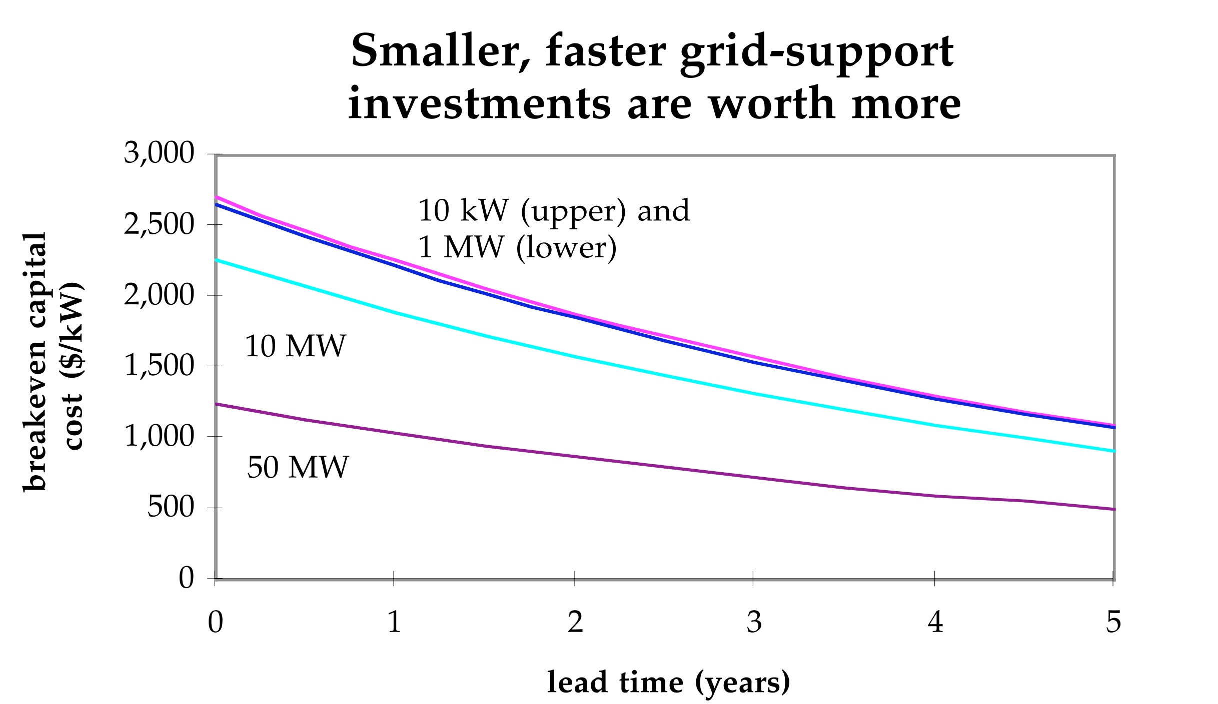
- *Four kinds: financial economics, electrical engineering, miscellaneous, externalities*
- *Many pioneered by utilities, mainly in '90s*
- *As commercial value was discovered and demonstrated while competition loomed, most public-benefit research was halted; most interesting data became proprietary*
- *While respecting confidences, RMI has sought to compile enough data to form the understanding required for public benefit*

Where does the order-of-magnitude typical value increase come from?

- ***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***

≤10^1×: Minimizing regret (financial ecs.)

- *Short lead times & small modules cut risk*
  - *Financial, forecasting, & obsolescence risks*
  - *Overshoot /"lumpiness" in generation & grid*



Tom Hoff's analytic solution shows it's worth paying ~2.7× more per kW for a 10-kW instant resource than for a 50-MW 2-y distributed resource

(with +0 or +5 MW demand/y, 25 MW spare grid capacity, 10%/y discount rate, $500/kW 5-y-lead-time grid expansion; based on decision or option theory approach)

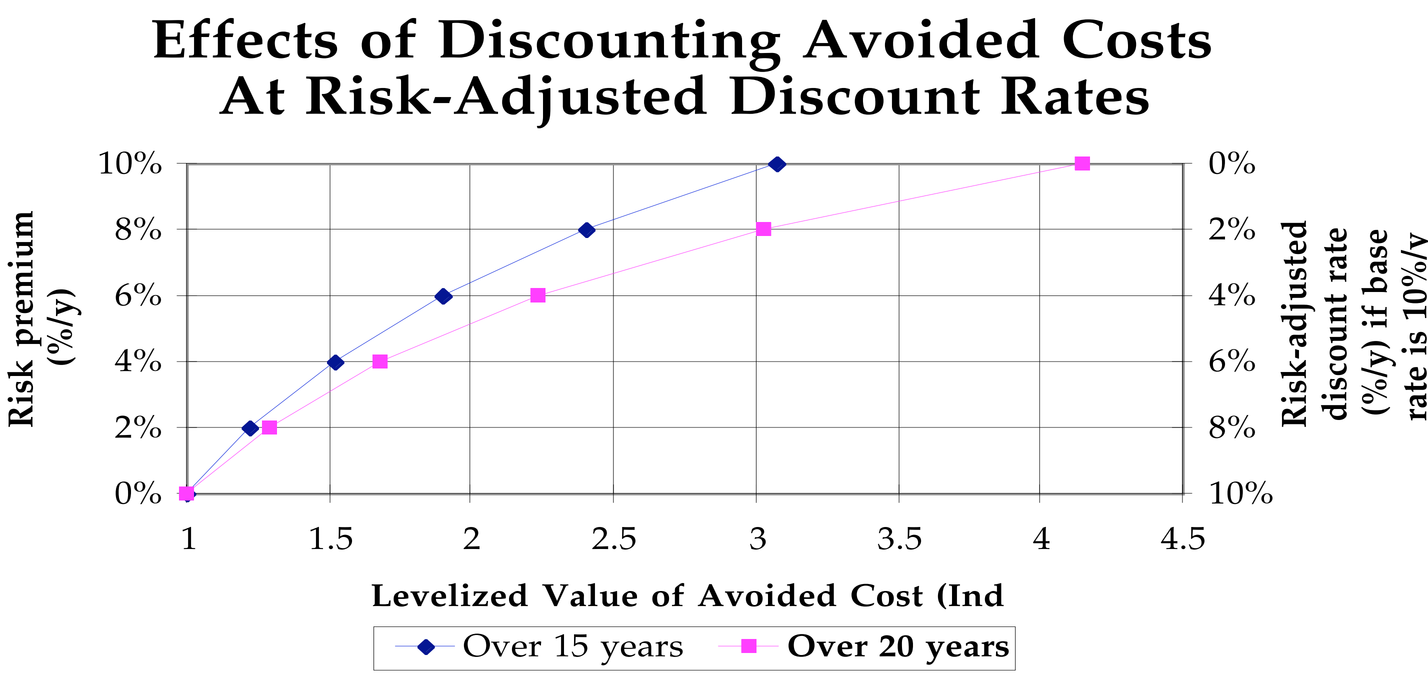
Financial-Economics Benefits (cont'd)

– *Benefit of modularity × benefit of short lead time...especially strong when they're correlated*
– *Portable resources are redeployable*
  • *Benefits' expected value rises* and *risk falls*
– *Rapid learning, mass-production economies*
  • *Modularity captures falling costs,* e.g. *of PVs*
– *"Load-growth insurance" of cogen/efficiency*
– *≥10× lower working capital can cut interest rate*
– *Genuinely diversified supply portfolios*
  • *U.S. coal and gas prices are ~84% correlated*
  • *Include higher-cost, constant-price resources in portfolio for the same reason that Treasuries are included in an optimized financial portfolio*

Financial-economics benefits (cont'd)

– Constant-price resources vs. volatile prices

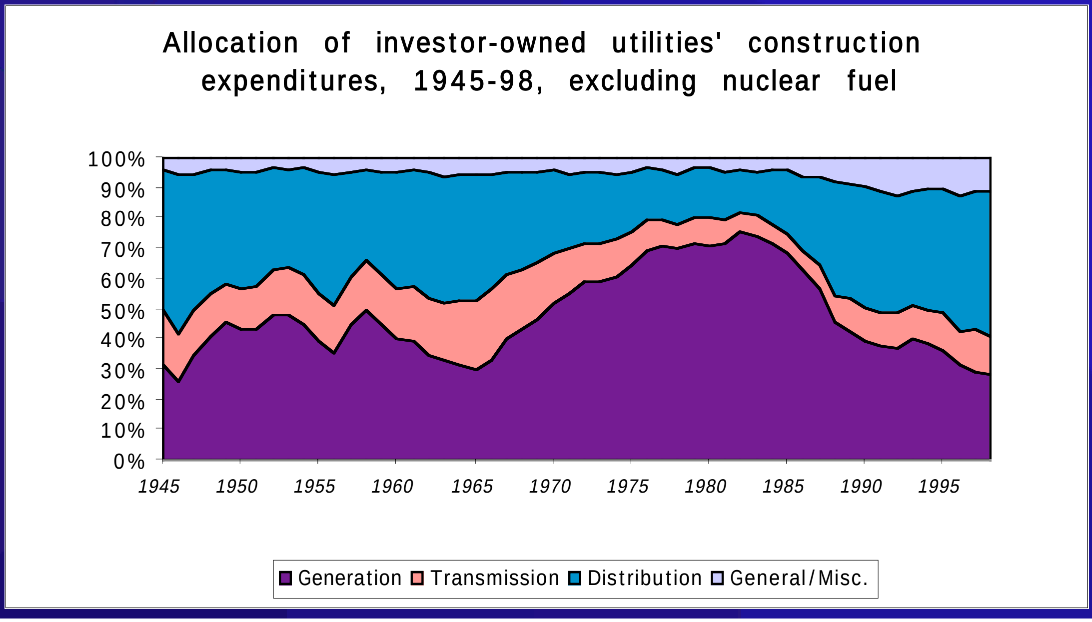
- Risk-adjusted discount rates, using the gas-price risk premium discovered in the market or predicted from historic betas using CAPM, imply that the present value of a gas cost stream should be nearly doubled for fair comparison with, say, wind



Risk-adjusting cost streams can change their present value by about 50–500% vs. assuming that they all have equal risks

Distributed Benefits (continued)

- ~2–3× (sometimes 10×): Utility investments & operations (el. engineering)
  - – Onsite generation or DSM reduces loads
    - Reduced or deferred grid investments
      - – Some distribution bottlenecks cost >US$2,000/kW
      - – Just avoiding routine T&D investments can relieve utilities' greatest capital burden



Except for the 1970s nuclear binge, grid investments have dominated private utilities' expenditures for half a century—even more today when most new generation is outsourced

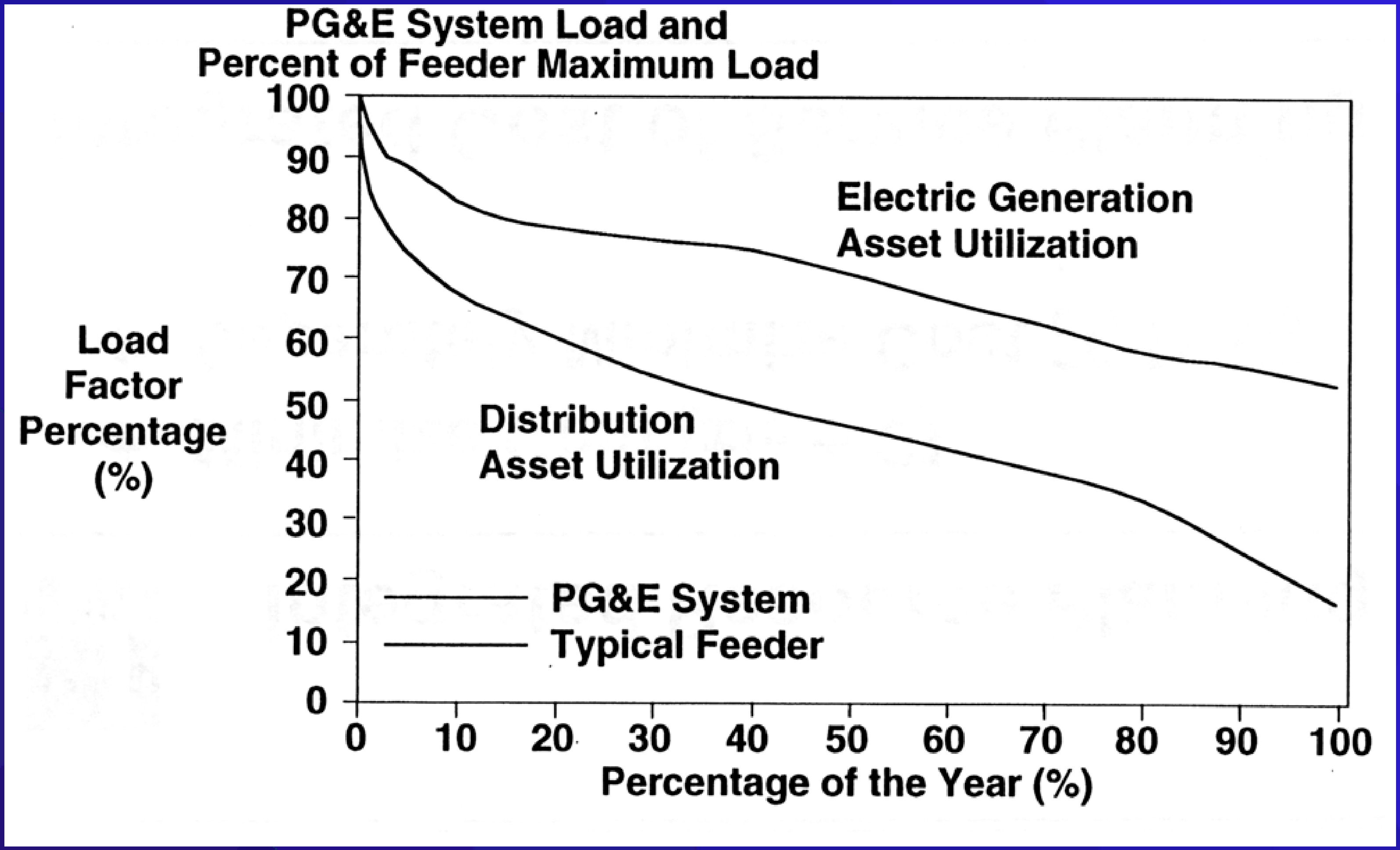
Delivering electricity is expensive

- **Delivering *a kWh to an* average *U.S. major-IOU customer in 1995 cost ~2.34 US¢/kWh—more than short-run marginal gen'g cost, and nearly total cost of new combined-cycle plant***
- ***Delivery to smaller customers costs more: ~3–4+¢/kWh embedded, often ~7–9¢ marginal***
- ***Distributed generation saves distribution costs (often including marginal distribution)* and *the ~2–5¢/ kWh energy cost***
- ***A pure disco has undiluted delivery costs***

Reduced/deferred grid investments (cont'd)

- ***Ontario Hydro's first three experiments in Local Integrated Resource Planning—aiming distributed resources like a rifle, not a shotgun—cut capital costs up to 90%; by 1995, saved C$1.7 billion of grid investments***
- ***New-hookup breakeven distance can be not km but m:*** **e.g.,** ***SMUD's PV alley lights cost ~2/5ths less to install than just*** **connecting** ***to the existing wires, including trenching and conduit cost and the meter (but not energy or meter-reading costs); same on PG&E pylons***
- ***Ing. Caes Daey Ouwens's experiences***

Distribution assets stand famously idle much of the time, much more than generators, despite their often higher capital cost



Joe Ianucci, 1992

A typical early-1990s PG&E feeder was used at <50% capacity >60% of the time, and reached 70% utilization <10% of the time

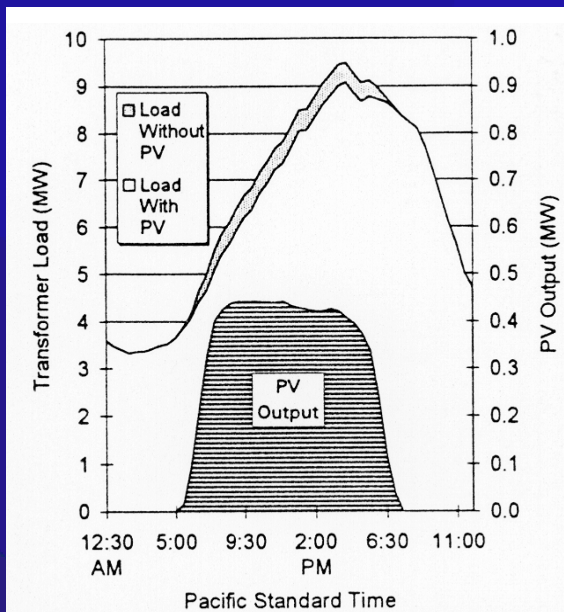
Basking in the hot spots

- *The finer-grained the scale and hence the demand patterns, the less load diversity, so the lower the distribution asset utilization*
- *Aggregating up to feeders, substations, and whole utilities shares gen. capacity*
- *But distribution capacity must reach* every customer, *so it inherently suffers from worsening load factors all the way out to the end of the system*
- *That's where distributed resources win*
- *Same when fine-grained in time domain*

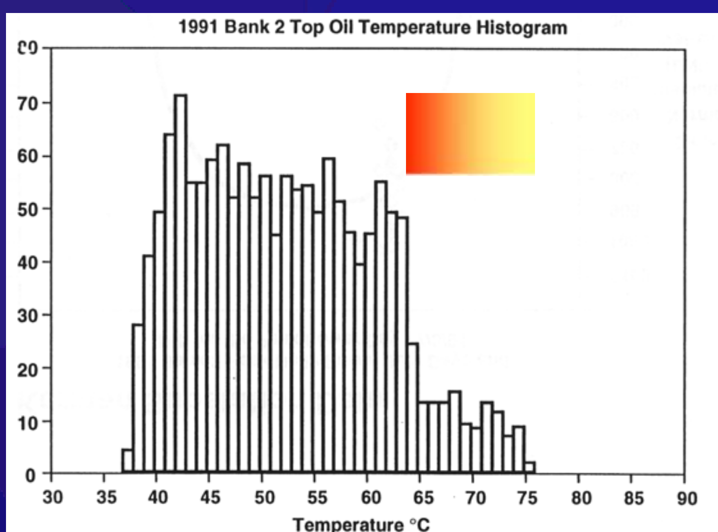
Grid losses increase downstream, so distributed resources cut losses more

- *At system peak, EPRI estimates national-average T&D grid losses double from ~7% to ~14%; but where are those losses?*
- *Murray Davis (Detroit Edison) estimates as typical peak losses 2–3% for T, 6–8% for T+subT, 13–16% for T+subT+D*
- *Therefore resources sited at/near the down-stream end,* i.e. *distributed resources, can avoid the biggest grid losses*
- *They also avoid the biggest grid investments —~US$400–500/kW, not just $100–150/kW*
- *Save V- and VAR-control equipment too*

Precooling is valuable too

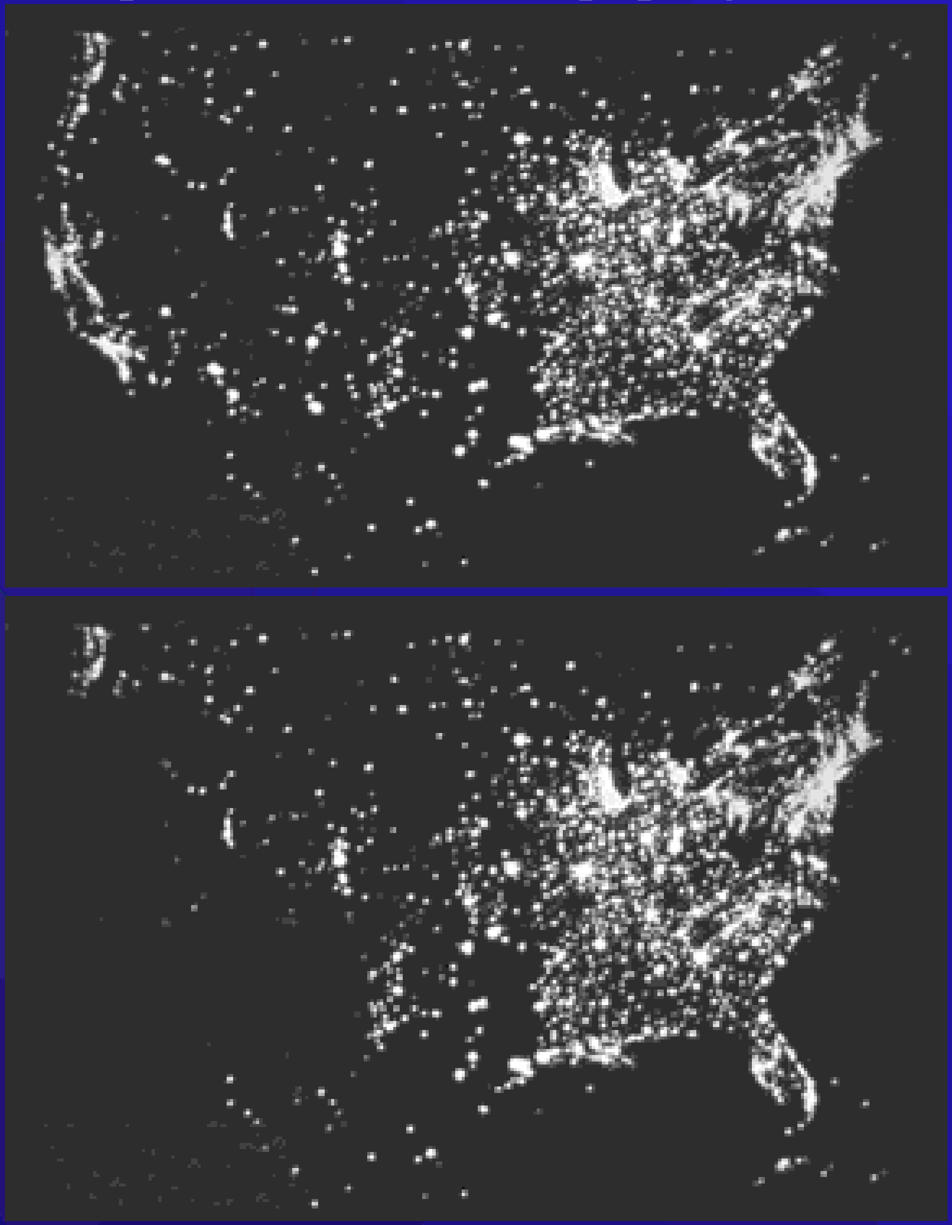


Substation PVs that peak* before *the substation's peak load can still valuably precool the transformer, which has considerable thermal mass; by the time the PV output decreases and the trans-former heats up, the peak has passed. Tracking or SW- or W-oriented PVs can also provide output that peaks much later in the afternoon, increasing their capacity credit and economic value



Because deterioration is twice as fast for each 10 C° of heating,* the last few bins *in the histogram of transformer tempera-ture* represent most of its life-shortening*, so shaving the peak load that causes them will capture* most of the life-exten-sion benefit*: e.g., cooling the Kerman transformer by only ~4–7 C° on hot days stretched its life ~5 y, worth an impres-sive ~US$89/kW-y in original evaluation

Improved supply reliability/resilience



EPRI-website synthetic satellite image, 10 August 1996…utilities routinely keeping the lights on. But ~98–99% of U.S. outages are caused by the grid. For example...

35 seconds later, after an Oregon powerline sags into a tree limb, operational goofs plus poor communications black out four million people in nine Western states and parts of Canada. Local supply prevents that—and up to 95+% of grid failures are in the distribution system

Service reliability and power quality

- Resources nearer loads facilitate isolation and bypassing of distribution faults
  - Fewer customers cut off, for less time
- Isolated generators can give critical uses premium power quality and reliability
  - Central-station system designed for 99.99% availability, but T&D system cuts to ≤99.97% —~10–30× worse than generation alone
  - Many businesses need 99.9999% availability (NB: not a quantity problem!—Mark Mills wrong* by 8×)
  - Normal microgrids can be designed for 99.99%
  - Distributed solutions can provide as many 9s as necessary at modest marginal cost
  - FAA ground avionics: PVs beat grid power

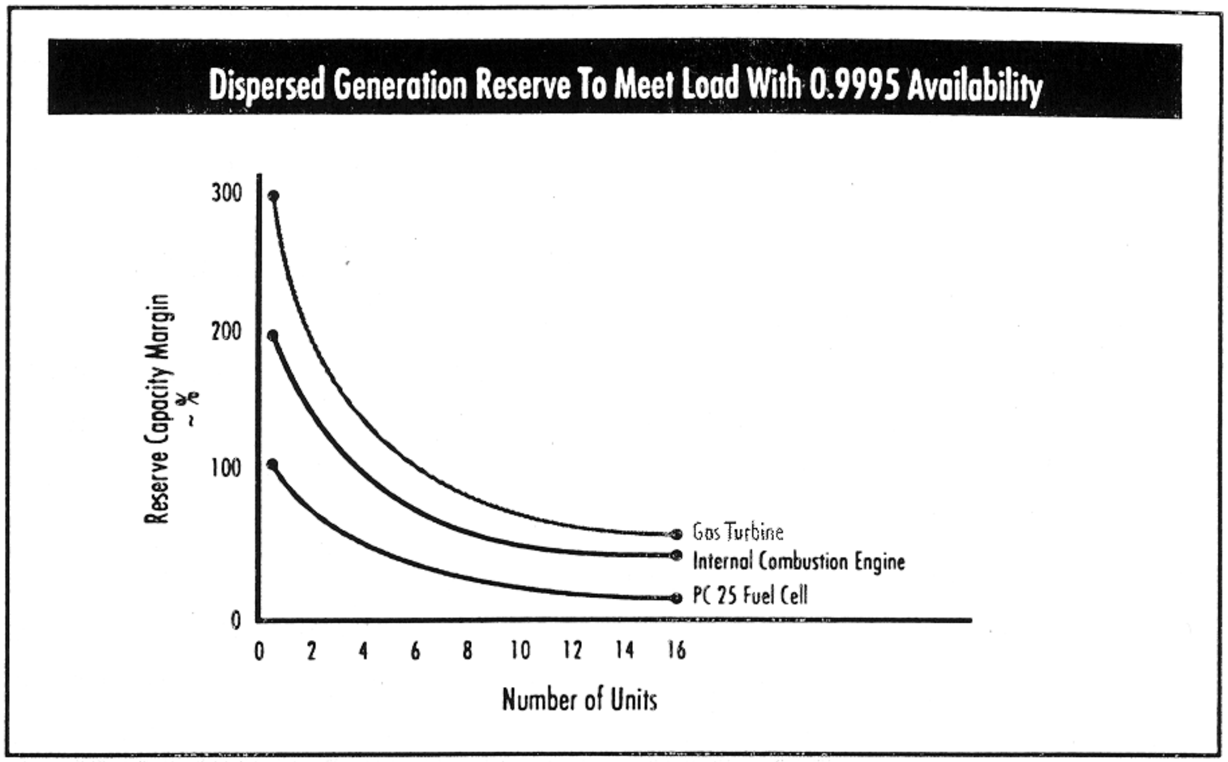
*http://enduse.lbl.gov/Projects/InfoTech.html

Grid & operational benefits (cont’d)

- Centralized resources are thus too costly and unreliable for many smaller customers
- Inverter-driven resources’ flexibility
  - Free reactive power support in real time
  - Near-infinite ramp rates offer transient stability options unavailable from rotating machinery
- Fuel cells can go 0→100% power in a few ms
- Wind turbines’ soft mechanical coupling can improve transient stability and fault clearing
- Smaller units cut reserve margin
  - Also spinning reserve and keep-warm fuel
- Lower av. system cost may reduce buy-back tariffs to independent generators

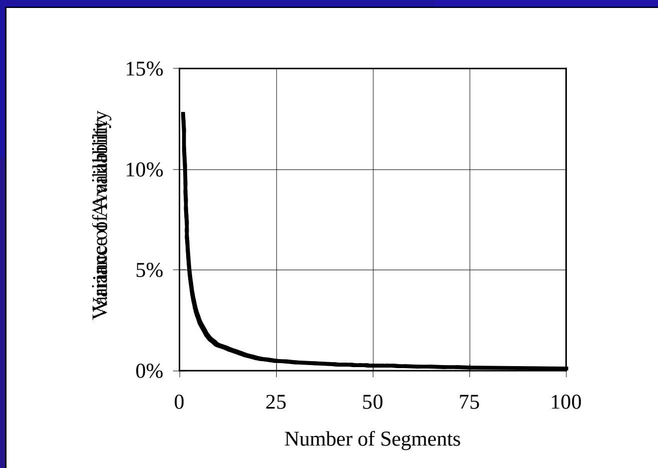
Many distributed resources have extremely high availability

- Fuel cells, PVs, and good wind turbines are extremely available —more so than any fueled heat-engine technologies
- So are intermittent renewables if well diversified and dispersed



Even modestly less reliable units enormously raise required reserve margins to maintain the same reliability in isolated systems; but distributed generators are often ultrareliable

Isolated generators, or those shared in a small "power island," can be justified



Combining a modest number of fairly reliable modular generators can soon achieve extremely high collective availability, because for a plant with n independent identical modules, vari-ance of availability equals p (1–p)/n

But it also takes very few customers to offer enough aggregate load diversity to share generating capacity efficiently, reducing total investment dramatically

Murray Davis (Detroit Edison) calculates that microturbine self-generation isolated competes with central station and grid, with no thermal credit for cogeneration or trigeneration potential; even adding local reserve margin costs less than utility standby power

"Integrating Distributed Resources into Electric Power Systems of the Future,"* Procs. Distributed Generation Conf., *1–2 March 2000, Denver

Emerging logic of the microgrid

Tom Hoff and others state it thus:

1. ***Load diversity makes the total peak load increase more slowly than the number of customers, then flatten out***
2. ***Adding more generating units, especially if they're small, reliable, and diversified, rapidly increases their collective reliability***
3. ***Even if smaller installed units cost more/kW, their optimal unit size can still be quite small***
4. ***Attractive system scale in between full grid connection and stand-alone customers…***
5. ***And no stranded costs to pay!***

Typical U.S. el. competition (levelized utility year-2000 US¢ private internal cost / delivered av. kWh)

- Remote, incl. ~2.5¢/kWh av. delivery cost
  - Nuclear: ~8–15+ (SAfr ~5–10??) (~4–7+ op'g.)
  - Coal: ~6–8 (~4–6 op'g.)
  - Combined-cycle with constant-price gas: ~5–6 (late '90s), 2001 ~6–7 (temporary spot shortage)
  - Remote wind: ~6–7 in 1999, ~5 in 2002 (@ 5.6–6 m/s, 10 m; excludes 1.5¢ Federal subsidy; zero fuel-price risk can nearly double value vs. gas)
- Onsite, avoiding delivery cost (*w/ heat cr.)
  - Photovoltaics: ~18–30, bldg-integrated ≤8–20 (but power quality valuable, & 1990s price –43%)
  - Microturbine trigen* w/const.-price gas: <1–5
  - Industrial cogen* w/const.-price gas: <1–2
  - End-use efficiency: <0–1 (some homes 2–4+)

Distributed benefits (continued)

- ~2× (more for co-/trigen): Other values
  - Thermal integration (heat, cool, dehumidify, chemical process heat,…), FC pure hot water
  - Potential use of local fuels/wastes
  - Photovoltaic roof integration and shading
  - Lower prices for rural land without utilities
  - Scores of other small terms
- Externalities (“NEEDS”)
  - Environmental, social, institutional, etc.
  - Some are (L.A. NO_x) or may be (CO_2) internalized
  - Hard to quantify but may be politically decisive

Twelve drivers of distributed utilities

- ***"Distributed benefits"* sharply raise value**
- ***Supply-side advances***
  - ***Superefficient end-use → less/cheaper supply***
  - ***Onsite cogen/trigen: microturbines, PAFC,…***
  - ***Building-integrated/"vernacular" PVs, cheap windpower, other competitive renewables***
  - ***96+%-efficient electric storage, reversible FCs***
  - ***PEMFCs in buildings, plug-in Hypercars℠,…***
  - ***"Hydro-Gen," renewable H_2, and wellhead-reformed natural gas*; sustainable biofuels***

** Lovins & Williams, "A Strategy for the Hydrogen Transition," NHA 4/99, at www.rmi.org*

Fivefold-More-Efficient Midsize SUV

- 5 big adults, up to 1.96 m^3 of cargo
- Hauls 460 kg up a 44% grade
- 857 kg (47% mass of Lexus RX300)
- Head-on wall crash @ 56 km/h doesn't damage passenger cell
- Head-on collision with a car twice its mass, each @ 48 km/h, meets U.S. occupant protection stds. for fixed-barrier crash @ 48 km/h
- 0–100 km/h in 8.3 seconds
- 2.38 L/100 km equivalent (5× RX300)
- 532 km on 3.4 kg of 345-bar H_2
- 89 km/h on just normal a/c energy
- Zero-emission (hot water)
- Sporty, all-wheel digital traction
- Ultrareliable; flexible, wireless diagnostics/upgrades/tuneups
- 320-Mm warranty—no dent or rust
- No damage in 10-km/h collision
- Competitive cost expected
- Decisive mfg. advantages

An illustrative, uncompromised, manufacturable, and costed concept car (Nov. 2000) developed for a few million dollars in 8 months by Hypercar, Inc. (www.hypercar.com), on time and on budget, with attributes never before combined in one vehicle

Hypercar℠ vehicles will ultimately...

- *save as much oil as OPEC now sells*
- *displace 1/8 of the steel market early, ~7/8 eventually, getting out of the Iron Age*
- *decouple road transport from climate*
- *offer ~3–6 TW of U.S. distributed generating capacity with attractive economics—~5–10× total present U.S. generating capacity*

WHEN? Within your planning horizons!

- *Hypercars will be widely available in ~5 y, dominant in ~10 (see open-source chrono-logy at www.rmi.org/sitepages/tid414.asp)*
- *Old way of making cars will be toast in ~20 y*
- *What about the electricity industry?*

Hypercars can greatly accelerate the hydrogen transition

- ***Make cars ready for direct hydrogen***
  - ***Packageable ~345-bar compressed-H_2 tanks***
  - ***No liquid-fuel reformer needed***
  - ***3× lower tractive load needs 3× fewer kW***
  - ***Tolerates 3× higher $/kW, reached far earlier***
- ***Integrate stationary and mobile uses to leverage both (both markets very big)***
- ***Make the H_2 transition* profitable at each step, starting now, *by a sequence RMI has published*, already being adopted by major energy/car companies***

****"A Strategy for the Hydrogen Transition," Natl. Hydrog. Assoc., 4/99, www.rmi.org***

Four Steps to a Hydrogen Economy

- ***Fuel-cell cogeneration in buildings, making H_2 from nat. gas or offpeak el., soon makes fuel cells affordable for Hypercars***
- ***Fuel them from nearby buildings' extra H_2, sell back power from parked cars, earn $$***
- ***Put cheap H_2 appliances in "gas stations"***
- ***Build up H_2 market justifying bulk prod'n.***
  - ***From wellhead-reformed natural gas (w/CO_2 reinjection) or renewable electricity (greatly improving its economics); maybe HCs/coal?***
  - ***≥2 sources, many scales, robust competition***
  - ***Climate-safe, practical, profitable, mkt-driven***

Twelve drivers (continued)

- ***Grid and control advances***
  - ***Advanced switches/telecom let automation of the distribution grid shift topology from unidirectional tree to omnidirectional web***
  - ***Pervasive real-time energy and stability pricing, customer communication; "out-of-control" distributed intelligence?***
    - ***Control can disperse at least to substation level***
    - ***Perhaps even to customer or device level***
    - ***Outcome uncertain but direction clear***

Twelve drivers (continued)

- Market/institutional advances
  - Competition values many previously unmonetized distributed benefits
  - So does unbundling power quality & relia-bility, grid stability, cost control,…
  - New market entrants better understand needed disciplines (financial ecs.,…)
  - Local Integrated Resource Planning (being done by >100 North American electric utilities) prospects for distributed benefits

The distributed utility revolution

- All twelve drivers reinforce each other, regardless of restructuring outcomes
- The shift to distributed generation is rapidly accelerating
  – US new units mainly at 1940s scale ($10^{6–7}$ W)
  – Will soon be at 1920s scale ($10^{3–4}$ W)
- Important rules remain unresolved
- But market demand will probably force simpler interconnects, net metering (now in ≥34 states),…
- Integration w/efficient end-use is starting

Policy needs

- ***Most restructuring rewards the wrong thing (selling more kWh at low prices, rather than reducing customers' bills and society's total costs), and tends to reinforce incumbents' monopolies***
- ***Most restructuring seeks commodity competition in bulk generation, which is rapidly becoming obsolete***
- ***Barriers to distributed generation are being tackled locally and rather slowly***
- ***Green power needs to be marketed as*** **a constant-price resource**

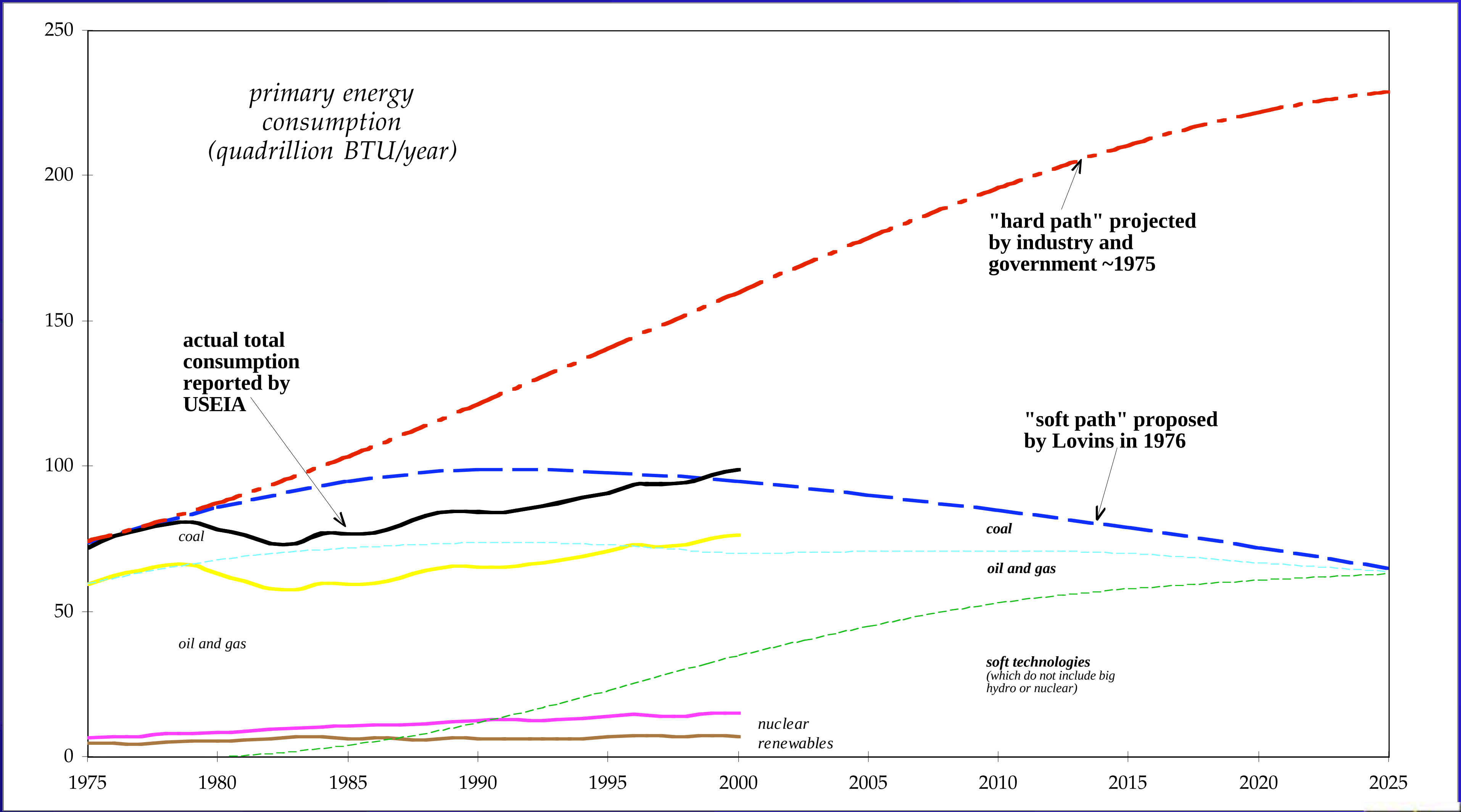
Policy needs (cont'd)

- *Who gets which distributed benefits often depends on policy changes*
- *RMI's book will discuss many policy issues, with examples, in the context of evolving electricity business stra-tegy and public-policy objectives*
- *The wider context of* Natural Capital-ism *(www.natcap.org) is also impor-tant for understanding distributed resources' benefits and prospects*
- *So is the renascent "negawatt revolution" now gaining momentum*

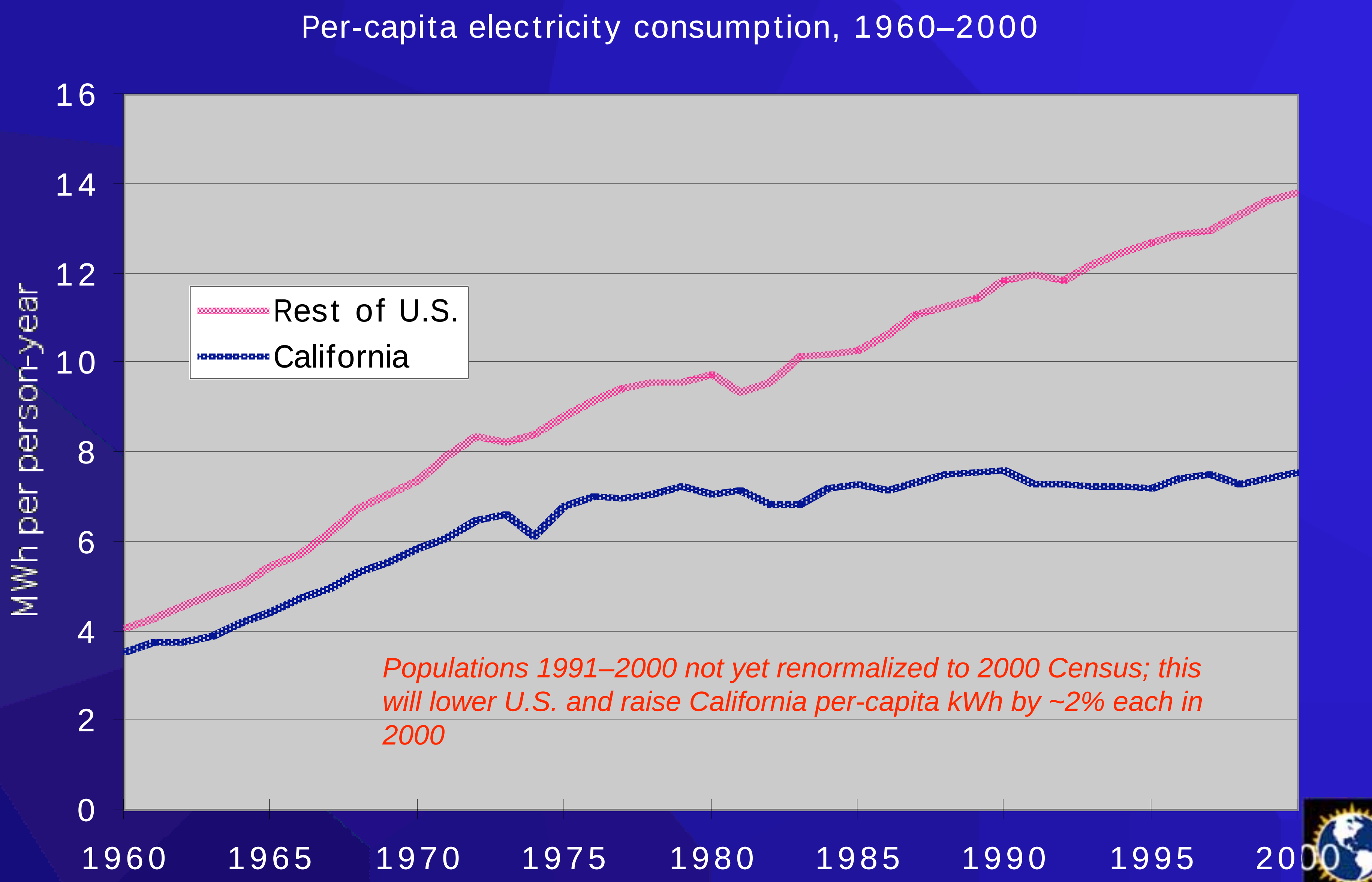
Negawatts: another conversation...

- ***Customers are starting to figure out that negawatts cost less than megawatts (and often yield vastly more valuable side-benefits, e.g. labor productivity)***
- ***Electricity's price will probably become less important***
- ***Customers will want to buy more efficiency and less electricity; the only question is from whom they'll buy***
- ***It's a sound business strategy to sell customers what they want…before someone else does***
- ***Vastly better tools, delivery methods, financing today***
- ***Negawatts needn't be deregulated because, being invisible to most policymakers, they were never regulated: anyone can still sell them anywhere!***
- ***Whole-system design, optimizing for multiple benefits, can often make very big savings cost less than small or no savings ("tunneling through the cost barrier")***
- ***Efficiency often potentiates distributed generation***

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



California: policy really does work



A simple question

- *How could a California electricity system that met a 53-GW peak load in summer 1999 fail to meet a 29-GW peak load in January 2001?*
  - *Yes, there was a hydro drought (–5 GW), some plants were down, etc...*
  - *But half the capacity didn't disappear!*
- *Something beyond a simple capacity inadequacy must have occurred. Hmmm…enough capacity, not enough electricity, so…?*

So what's happening in California?

- Noncauses claimed: soaring demand, Internet, no power stations built, oil shortage
- Complex actual causes: botched restructuring + concentrated mkt power raised profits for selling less electricity (~10–15 GW withheld); disincentivized efficiency and gas storage; canceled clean plants; anticompetitive prac-tices; efficiency can't bid against supply nor get a price signal; freeloaders on pool; etc.
- Nonsolution: same firms add more capacity?
- Solutions: demand-side management (kW_p/GDP –14% 6/00–6/01), distributed generation, reward both, remove incentives to withhold capacity
- A cool July has already put CA in overshoot

California's shortage-to-glut saga

- ***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 gen-eration, 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***

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

- *Thus, had this boom been allowed to continue through 1985, those dispersed generators, averaging only 12 MW each 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 about two years—yet for years afterwards, ≥24 other states were all still seeking to sell CA their surpluses at once*
- *White House wants to repeat experiment (though fortunately it's unfinanceable)*

Risk of national rerun of 1985–86

- *2001 conditions eerily reminiscent of 1980*
- *1979–86: second oil shock + continuation of Carter Administration's oil- and energy-saving policies (which cut Persian Gulf oil imports by 87% in 1976–85)* **cut total** *US energy use 5% and oil use 13% whilst real GDP grew 20%: E/GDP fell by 3.4%/y*
- *In 1996–2000, E/GDP fell 3.1%/y, nearly matching that record—despite* **record-low and falling** *energy prices through 1999*
- *Higher 2000–01 prices won't slow savings*
- *Now add supply push (+200 GW to 2007)*
- *Only a few % of eff. reserve crashes mkt.*
- *Likely yet again to ruin suppliers — will have expansion's cost without revenues*

Analogies beyond electricity

- H_2, local biogas raise similar gas opps.
- Even more important water analogies
  - Distributed supply: roof capture/cisterns
    - Leave cisterns normally 50% empty for stormwater
    - Justified by avoided central potable water supply or storm-water removal capacity (Byron study)
  - "Distributed reservoirs" if remotely controlled
    - Los Angeles/Tree People '98 experiment: retrofit old bungalow with 13 m^3 cisterns, retention grading, driveway drywell, mulched swales; 71-cm "storm" (30 kL/20 minutes); not a drop left the site
    - Flood control, water imports –50–60%, less toxic runoff, better air/water, –30% yard wastes to landfill, beauty, jobs (~50k "urban watershed mgrs")

The right size for wastewater systems

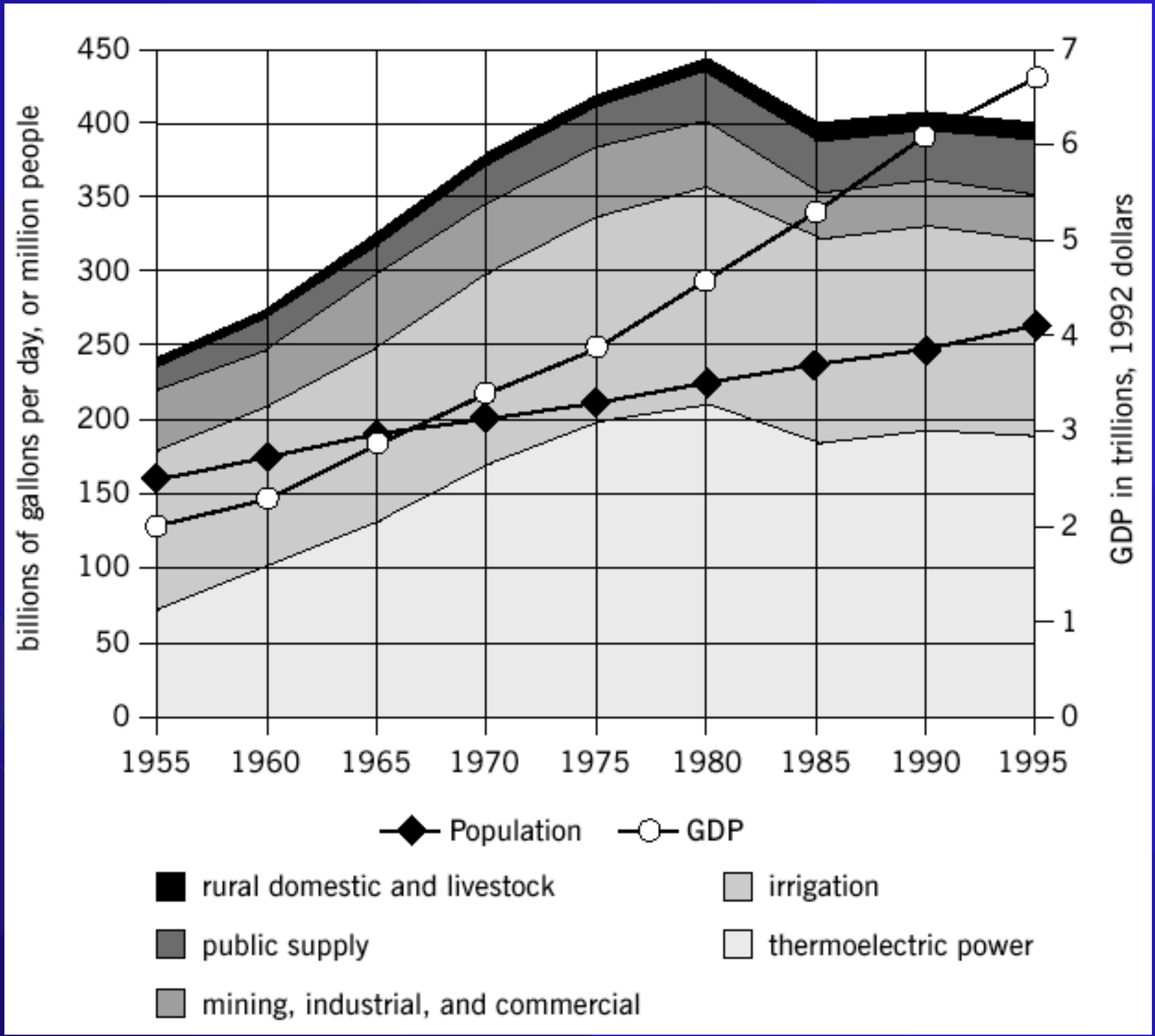
- *2001 RMI/EPA seminar identified scores of distributed benefits; report 6/02*
- *Adelaide whole-system capex analysis (Clark, Tomlinson, Perkins, Wood '95–7)*
  - *Wastewater treatment capex ∝ scale$^{2/3}$, but ~90% of* system *capex is for* collection, *which has severe diseconomies of scale*
  - *~10^{1-3}× smaller systems therefore cost* less, *"can be more readily developed and appear able to compete", can build more flexibly*
- *Village/neighbourhood scale is also ideal for cheaper biological treatment*

Sewage is a valuable resource

Dr John Todd

Better still: don't make wastewater in the first place! (urine-separating toilets, greywater irrigation,…)

US has been quietly saving water twice as fast as energy



Thank you! And please visit...

- ***www.rmi.org (general information)***
  - ***Its Transportation section gives public information about Hypercars; also big sections on energy and Calif. electricity***
  - ***Linked to www.hypercar.com (the new technology development company)***
  - ***Linked to www.naturalcapitalism.org or www.natcap.org for short (the wider context—making business far more profitable by behaving as if nature and people were properly valued)***

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 honourary doctorates, a MacArthur Fellowship, the Heinz, Lindbergh, World Technology, and Heroes for the Planet Awards, the Happold Medal, 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, many of them electric utilities. *The Wall Street Journal* named him among 39 people in the world most likely to change the course of business in the 1990s, and *Car* magazine, the 22^{nd} most powerful person in the global automotive industry. His work focuses on whole-system engineering; transforming the car, energy, water, chemical, semiconductor, real-estate, and many other sectors toward advanced resource productivity, and integrating resource efficiency into the emerging "natural capitalism."

About Rocky Mountain Institute: This independent, nonpartisan, market-oriented, technophilic, entrepreneurial, public charity 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 help 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 property development. RMI's ~US$5-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* (with Paul Hawken; Little Brown/Earthscan, 1999).

About Hypercar, Inc.: Rocky Mountain Institute transferred most of its Hypercar-related technical activities to this partly-owned for-profit firm, its fourth spinoff, in August 1999. Funded by private investors and currently entering its second stage,, Hypercar, Inc. pursues business opportunities related to the Hypercar concept developed at RMI since 1991.