Critical Issues in Domestic Energy Vulnerability

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Alliance to Save Energy Summit
Washington, D.C., 25 October 2001

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*

Déjà vu all over again

- ***"National security is threatened not only by hostile ideology but also by misapplied technology; not only by threats imposed by enemies abroad but also by threats that America heedlessly—and needlessly—has imposed on itself. Despite its awesome military might, the United States has become extremely vulnerable, and is becoming more vulnerable, to the simple, low-technology disruption of such vital infrastructure as energy supply, water, food, data processing, and telecommunications."***
- ***"Terrorism, technical mishap, or natural disaster that damaged the domestic energy system could be nearly as devastating as a sizeable war. Covert para-military or nonmilitary attacks on key infrastructure are so cheap, safe, and deniable that they may prove a fatally attractive instrument of surrogate warfare."***

A.B. & L.H. Lovins, "Reducing Vulnerability: The Energy Jugular," summary article in R.J. Woolsey, ed., Nuclear Arms: Ethics, Strategy, Politics, *Institute For Contemporary Studies, San Francisco, 1984; see also Lovinses, "The Fragility of Domestic Energy,"* Atlantic, *Nov. 1983*

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: LNG, LPG

- *1 LNG marine tanker's CH_4 can form a flammable mixture >200× Great Pyramid's volume*
- *Heavier-than-air plume can drift for many km, then ignite; firestorm's radiant heat can cause 3° burns and start fires 2–4 km away*
- *LNG terminals (Tokyo Harbor, near London) have had near-misses; Boston Harbor has one*
- *U.S. has >50 aboveground LNG stores of ≥130 kT (plane near-miss '81); 1/4-kT tank trucks*
- *One truck falling off SE Expwy could fill whole Boston subway or tunnel or sewer system*
- *One 3/4-kT LPG railcar's fuel-air explosion could cause 2° burns ~2 km away*
- *LPG/LNG trucks could be hijacked, detonated*

Examples: oil downstream (1981)

- *Tightly coupled system: 20 y ago, U.S. had a few months' usable total storage, well-head-to-car; refineries had 3–5 d, pipeline customers 5–10 d; generally far less now*
- *>50% of U.S. refinery capacity was in three states (TX, LA, CA), >69% was in six states*
- *Refinery concentration and specialization have increased markedly since 1981*
- *In 1978, sabotage of 77 refineries would cut cap. by 2/3, "shatter" economy (GAO); takes one RPG, wrench, rifle,… at each site*
- *SPR useless if three pipelines are cut*

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 gas and oil supply to eastern U.S. in 1 night w/o leaving Louisiana***
- *Algerian extremists in 2001 threaten to blow up their main gas pipe to S. Europe*
- *Head of a major U.S. oil production firm: "With a hundred pounds of dynamite, distributed among about eight places, I could cripple the country"*

Examples: pipelines (1981)

- *Bore, prime movers, pumps/compressors, controls, telecoms, operators*
- *Many colocated; vulnerable junctions, river/swamp crossings, controls*
- *Move ~3/4 of U.S. crude oil to refineries, 1/3 of refined products, nearly all gas*
- *Limited flexibility for rerouting*
- *"Big three" nearly 5 Mbbl/d, + TransCan*
- *Six hits could sever pipeline service between main U.S. oilfields and East / Midwest; ten, 63% of 1981 product cap.*
- *Control centers are rather soft targets*

North Slope oil: fattest terrorist target?

- ***ANWR oil would raise TAPS flow to U.S. 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 becoming less reliable; economic life dubious***
  - ***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***
- ***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?***

A concluding 1981 quotation

"These brittle devices are supposed to form the backbone of America's energy supplies well into the 21st century—a period likely to bring increasing uncertainty, surprise, unrest, and violence. The U.S. cannot afford vulnerabilities that so alter the balance between large and small groups in society as to erode not only military security but also the freedom and trust that underpin constitutional government."

Military history lessons

- *Goering/Speer said after WWII: Allies could have shortened war 2 y by bombing Nazis' highly centralized el. system*
- *78% of Japan's WWII el. (like most Vietnamese later) came from dispersed hydro —sustained 0.3% of bombing damage*
- *Significant attacks on centralized energy systems occurred every few days in '80s*
- *Energy-system attacks now part of U.S. & Russian standard tactics—Iraq, Afghan.,...*
- *Energy* **decentralization** *favored by Israel, China, Sweden,… for military security*

The good news: resilience is cheaper

- ***Energy insecurity 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 from many engineering disciplines suggest ~20 principles of a design science of resilience whose systematic application 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 ~3x; 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 (~60–80 business opps.)*
- *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 advantages —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*

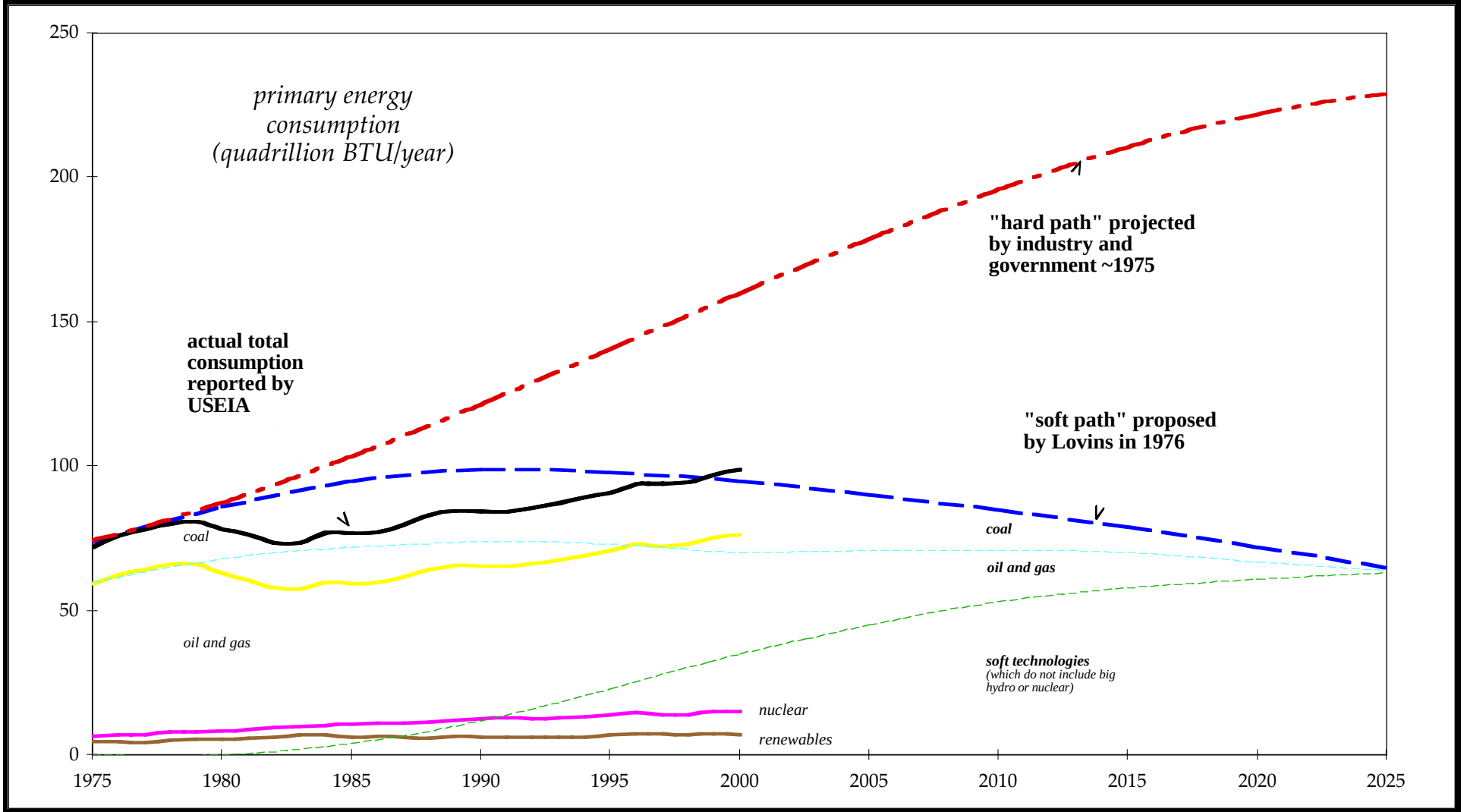
Then add sustainable, resilient supplies

- *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*
- *>120 "distributed benefits" increase typical economic value by about tenfold*

A Guidepost: Four Times Square, NYC
(Condé Nast Building)

- *1.6 million ft²; 47 stories*
- *non-toxic, low-energy materials*
- *50% energy savings/ft² despite doubled ventilation rates (could have saved considerably more)*
- *Gas absorption chillers*
- ***Fuel cells on roof***
- ***Integral PV in spandrels on S & W elevations***
- ***Ultrareliable solar & fuel-cell power helped recruit premium tenants at premium rents, yielding a market win for developer Doug Durst***
- *Fiber-optic signage (signage required at lower floor(s))*
- *Experiment in Performance Based Fees rewarding savings, not costs*
- *Market average construction cost*

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



Reduced U.S. E/GDP 1975–2000 was:

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

The U.S. 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 only in its infancy.)

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***

Price and regulation are not the only policy tools, and may not be the most effective. Add 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***

(See ABL's 12 June 2001 ECEEE plenary, at www.rmi.org)

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*

So energy resilience can improve comprehensively, systematically, quickly, and profitably, making major failures impossible
by design...

…and advanced energy productivity is the key!

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.