Critical Issues in Domestic Energy Vulnerability

Amory B. Lovins
CEO (Research), Rocky Mountain Institute, www.rmi.org

Aspen Clean Energy Roundtable VIII
Montreux Energy, 8 October 2001

Energy security for dangerous times

- *I'll summarize, then update, definitive 1981 Pentagon study* **Brittle Power: Energy Strategy for National Security** *(A.B. & L.H. Lovins, 500 pp., 1200 refs.), soon to be reposted at www.rmi.org*
- *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 rejected by U.S. 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 consistently and excessively focused attention on cutoffs of oil imports***
- ***It's a real issue, not just politically: "One aircraft, or even two people in dinghies, could probably shut down 85% of Saudi oil exports for up to three years (the period... [to remake] key components for the loading terminals). Such an attack could be repeated once the damage was repaired."***
- ***But most of the 78% of U.S. energy use that* isn't *imported oil can be cut off at least as easily, but faster, for longer, in larger pieces***

Out of the frying-pan into the fire

- *Oil crises, far from raising awareness of the "fragility of* all *centralized energy systems, focused attention exclusively on the vulnerability of oil imports. The domestic energy system is now so vulnerable that even eliminating oil imports …would barely begin to reduce America's inventory of critical energy chokepoints."*
- *Some currently popular "energy security" centerpieces like ANWR would make U.S. energy insecurity* much *worse*

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 production (1981)

- *Ghawar field exceeds oil output of all but 1–2 other* countries*; indefensible, as are supertankers (even to pirates in small native boats: 21 robbed in 8 mo. in 1981)*
- *Fortunately, U.S. wells are 10^3× less concentrated than Saudi Arabia's*
- *But Gulf of Mexico has juicy platforms*
  - *Coast Guard ship can reach any of 3,000 in 8 h (good weather); blowing it up takes <8 min*
  - *Fireboats might handle up to three modest fires, if not bottled up in their single canal*
- *3/4 of U.S. oil is lifted in just four states*

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 is in three states (TX, LA, CA), >69% in six states*
- *Refinery concentration and specialization have increased markedly*
- *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 flows 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 product capacity*
- *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*
  - *1290 km, >1/2 aboveground and accessible*
  - *Already incompetently bombed twice; shot at >50×; sabotaged; recent 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*
  - *Last week, 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, ~33+ 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 Arctic warms*
- *Some in industry believe within 5–10 y, maintenance costs will be unaffordable*
- *Quite a key to national energy security!*

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*

Alas, in the past 20 years...

- ***Little has changed, none 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, continuing today, emphasizes the most vulnerable options, and tends to ignore or try to suppress the resilient ones that can make the system efficient, diverse, dispersed, and renewable***
- ***So DOE is undercutting DoD's mission***

A concluding 1984 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

- *Significant attacks on centralized energy systems occurred every few days in ’80s*
- *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*
- *Energy-system attacks now part of U.S. & Russian standard tactics,* e.g., *last night*
- *Energy decentralization favored by Israel, China, Sweden,… for military security*

Fortunately, 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

Designing for resilience (1981–84)...

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

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%*
- *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 buffer stocks could last not for days or weeks but for up to nearly a year, buying precious time to mend or improvise around what's broken*
  - *Electric efficiency stretches distributed resources*

A 5×-efficiency midsize SUV...and nega-OPEC

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), on time and on budget, with attributes never before combined in one vehicle. This show car is in Aspen.

- *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 won't damage passenger compartment*
- *Head-on collision with a car twice its mass, each @ 48 km/h, meets U.S. safety std. for 48 km/h barrier crash*
- *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)*
- *Stiff body, digital all-wheel traction*
- *Ultrareliable; flexible, customizable; wireless diagnostics/upgrades*
- *320 000-km warranty, no dent or rust*
- *Undamaged by 10 km/h collision*
- *Competitive cost expected @ ~50k/y*
- *Decisive manufacturing advantages — 10× lower capital, parts, assembly*
- *Could plug in: 35-kW power station!*

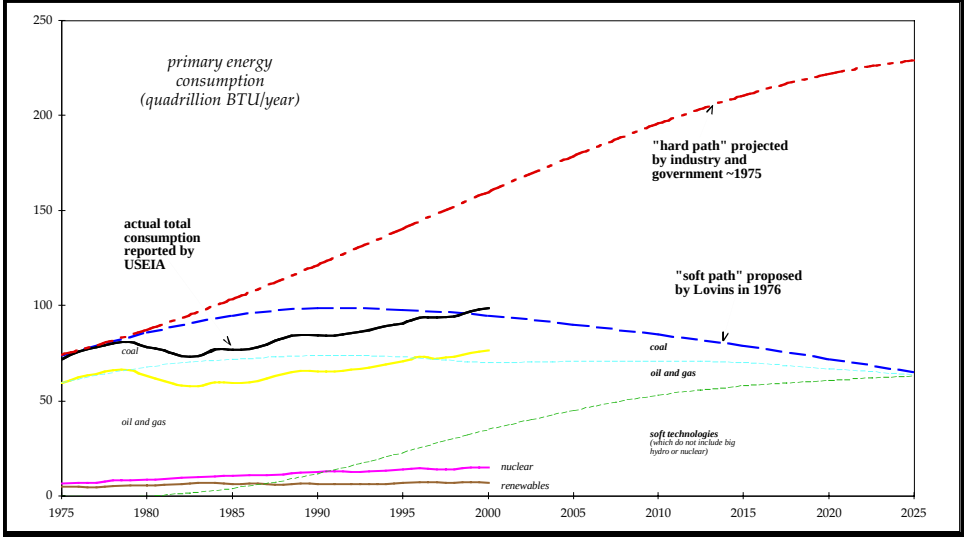
Then add sustainable supplies

- *Wind and PVs are fastest-growing sources; global wind adding 5 GW/y (nuclear added 3 GW/y in 1990s); wind now cheaper than 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 clean portfolio; 10 y later, economic studies show utility & region financially better off*
- *>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"



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.