Profiting From a Nuclear-Free Third Millenium

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Nuclear power has suffered the greatest collapse of any enterprise in the industrial history of the world. The twentieth century will end with installed nuclear capacity less than 10%, and an ordering rate less than 1%, of the lowest IAEA forecasts made a quarter-century ago. No vendor has made money selling reactors. U.S. investments exceeding a trillion dollars are delivering only about as much energy as biofuels. A nuclear plant with zero capital cost is cheaper to write off (and give away equivalent electricity-saving equipment) than to operate. Nuclear power's unpleasant capital- and repair-cost escalation and technical surprises are worldwide phenomena, independent of politics. Even France's nuclear program was outpaced twofold by energy efficiency, bankrupted its operator in all but name, and is unlikely to be replaced by more reactors.

Nuclear power's competitor was originally presumed to be giant coal plants. These are now equally obsolete on the margin: many competitors work better and cost less than either. That's why central thermal plants are seldom ordered nowadays except by centrally planned energy systems.

If no existing nuclear plant suffers an accidental or malicious radioactive release serious enough to compel their early shutdown, they will probably operate until they're too costly to maintain. In theory, they must also compete in economic dispatch, but in fact, many U.S. reactors have won "must-run" status entitling them to run whenever available even if uneconomic, which ~20–25% of them already are against market-clearing prices. (In Sweden, Sydkraft unsuccessfully sought compensation for *not* continuing to lose money by running Barsebäck at an operating cost roughly twice the price of imported power.) The U.S. short-run marginal cost of delivered nuclear electricity is typically reckoned at ~$0.015–0.039/kWh. Net capital additions—major repairs that are really hidden operating costs—increase those figures (as would fully internalised waste and decommissioning costs, now typically socialised). What else besides existing coal plants, often running at or below $0.02, costs less?

The most potent competitor, manyfold cheaper than running existing nuclear plants anywhere in the world, is end-use efficiency—a resource that's also manyfold larger. Its average historic U.S. cost, including many poorly designed and chiefly residential programs, is only $0.02 per saved kW-h. In industry and commerce, however, well-designed retrofits can save most of the electricity now used at empirical costs typically ~$0.005/kWh in the business sectors (a 16-month payback at a 5-cent tariff)—even less than zero in new buildings and factories.* (My own 90% saving in household electricity had a 10-month payback in 1984; today's technologies are far better and cheaper.) Moreover, ancillary improvements in service quality, such as a ~6–16% gain in labour productivity in efficient offices, are often an order of magnitude more valuable than these energy-cost reductions themselves. Proven methods (www.rmi.org/store/pid76.asp) can also convert the scores of implementation obstacles into lucrative business opportunities. And in developing countries, efficiency investments can cut marginal capital needs by four orders of magnitude, making the power sector—now a black hole for one-fourth of development capital—a net exporter of capital to fund other development needs.

Typically the next cheapest competitors are new generators. They include, in arbitrary order, combined-cycle gas turbines (often ~$0.027–0.03 per delivered kWh), industrial and commercial co- and trigeneration from large plants or microturbines (~$0.005–0.03/kWh net of thermal credit), and some renewables (well-sited windpower costs ~$0.04–0.05 and will soon drop to $0.03, less a $0.01 subsidy in the U.S.). These costs all exclude any marginal or historic capital investment in the grid; embedded grid costs would add ~$0.024/kWh to average U.S. power delivered from central plants, but nothing to onsite generators.

A winning dark horse, ~60%-efficient proton-exchange-membrane fuel cells, is poised to capture most of the power market in buildings, which use two-thirds of U.S. electricity. Their ~$800/kW initial price in ~2000–01 will drop rapidly, ultimately to less than $50/kW. A recently published strategy for the transition to a climatically benign hydrogen economy, profitably at each step starting now (www.rmi.org), is starting to be rapidly adopted by major firms. One of its consequences—wellhead reforming of natural gas with CO_2 reinjection—would make the world's two centuries' worth of known gas profitably usable without climatic harm.

Meanwhile, the next revolution—distributed utilities—is gaining momentum. My forthcoming book *Small Is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size* shows how 75 "distributed benefits" of decentralized electricity sources can typically increase their economic value by roughly tenfold, making even solar cells cost-effective today in most applications. Even more valuable than familiar electrical engineering attributes—lower grid costs and losses, higher reliability and power quality, dispatchable reactive power, infinite ramp rates, etc.—are the lower financial risks of small, short-lead-time modules. For example, a 10-kW resource installable overnight could cost 2.7 times as much per kW as a 50-MW resource installable in two years, yet yield identical financial performance. In the new arena now emerging, discount rates are project-specific and risk-adjusted, new market actors understand financial economics, and competition increasingly embraces all options. Continuing nuclear ownership consolidation may improve operations more than it concentrates risks, but the firesale prices realized at recent used-reactor sales confirm a market perception of low or even negative asset value.

Nuclear waste accumulates, and neutron fluence raises decommissioning costs, proportionally to nuclear power generation. Moreover, nuclear power's having died of an incurable attack of market forces—plus the end of the Cold War—offers a unique opportunity to make nuclear materials, skills, and equipment no longer ordinary items of commerce (except for minor, special, and readily safeguarded medical and industrial uses). This would make such bomb-kit ingredients harder to get, more conspicuous to try to get, and politically far costlier to be caught trying to get or supply, because for the first time, the reason for wanting them would be unambiguously military. This exposure of illicit transactions—now hidden in and rationalized by a vast flow of supposedly innocent civilian nuclear commerce—would not make nuclear bomb proliferation impossible, but would make it far more difficult, and would focus its resource flows into narrower, more readily monitored channels.

Some advocates hope an oil shock will restore nuclear power's market credibility. Oil shocks may well recur, though the world is far better prepared for them—the Gulf War triggered no oil shortages. Yet the rational response would be not the slowest, costliest option—and the one whose output, electricity, is least fungible for oil—but rather efficiency, distributed thermal and thermoelectric systems, natural gas, and biofuels. Anyhow, oil problems will fade away as superefficient cars (www.hypercarcenter.org) save as much oil as OPEC now sells, helping to make oil uncompetitive even at low prices before it becomes unavailable even at high prices. Moreover, each fuel-cell Hypercar™ will be a 20–40-kWe mobile power plant. When parked, 96% of the time, it can be plugged into the hydrogen appliance in a nearby building and into the grid, electricity sales to which should repay up to half the car's lease cost. Such a fleet will ultimately have ~5–10 times as much generating capacity as all utilities now own—yet another nail in the nuclear coffin.

Nuclear advocates' last hope is that climate concerns will revitalize their option. Alas, they've overlooked opportunity cost—the impossibility of spending the same money on two different things at the same time. If saving a kW-h cost (pessimistically) as much as three cents, and delivering a kW-h of new nuclear electricity cost (optimistically) as little as six cents, then the six cents spent for each new nuclear kW-h could instead have bought *two* kW-h worth of efficiency. The nuclear purchase therefore displaced one *less* kW-h of coal-fired electricity than the same money could have done by buying the cheaper (efficiency) option instead. That's why the order of economic priority must also be the order of environmental priority; why it's irrelevant whether nuclear power can beat coal power as long as any other option costs still less; and why nuclear power makes global warming worse.

Nuclear power is a future technology whose time has passed. Its economic problems are so ineluctable that it would still fail even if it had no political, environmental, safety, or security problems. And as the retirement of the older, higher-quality nuclear pioneers continues the worrisome trend predicted by Nobel physicist Hannes Alfvén—that the enterprise will "pass into ever less competent hands"—each dollar spent to address the unsolved problems will buy ever less solution.

Looking after nuclear power's legacy will be a business with a long future; but the operation of today's nuclear fleet will not. Despite immense investments, devoted efforts, and dedicated careers, those plants will long stand as a monument to what happens when a technology avoids market and political accountability for long enough to make really big mistakes, and when its advocates develop a reputation for mendacity. Its epitaph could be: "Here lies a technology that failed because it did not take its discipline from the marketplace, its values from its customers, and its design from nature." Its seemingly great promise was betrayed by tragic flaws. But the real tragedy would be if we didn't learn from this sad story. Nuclear power has been called "a fit technology for a wise, farseeing, and incorruptible people." A pity we haven't more of them.

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*Hawken, Lovins, & Lovins, *Natural Capitalism*, Little Brown (NY) & Earthscan (London), 9/99.

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