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Hydrogen Economy: Not So Difficult—Without Nuclear Power

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A recent survey article[1] rebuts Paul Grant's widely publicized conclusion[2] that a U.S. hydrogen economy would be impractical, at least without a 4× expansion of nuclear power. Such nuclear advocates' hope of salvation via H_2 is mistaken: fuel cells, far from reviving nuclear power by needing it to make H_2, will speed its market-driven extinction by delivering cheaper energy services. And far from requiring "staggeringly abundant" fossil fuels, "enormous" capital outlay, and "a significant area of set-aside land," an orderly H_2 transition would need[1] significantly *less* capital[3], probably no more natural gas[4], less oil and coal, and probably less total land[5] than oil-based business-as-usual.

Grant says powering U.S. highway vehicles with fuel cells would need the "enormous quantity" of 230 kT of hydrogen per day and require government mandates. But this 84 MTH_2/y looks less "herculean" in light of the world hydrogen industry's 2003 production of ~50 MTH_2/y (growing by ~6–7%/y), half for fertilizer and nearly half for oil refineries—a use H_2 vehicles would displace.

Grant correctly suggests future H_2 vehicles could become 2–3× more efficient, though "folks would probably drive that much more" (observed rebound effects are ~5–10× smaller). Profitable, practical efficiency gains in uncompromised light vehicles[6] can actually be 5×, or ~2× for heavy vehicles. The U.S. highway vehicle fleet would then need 50 MTH_2/y, producible by 2.2 PWh/y from cost-effective wind turbines occupying a few percent of the windiest land available in North and South Dakota[7] and leaving the rest of that land for farming and ranching.

Only 4% of global hydrogen is now made by electrolysis, because reforming fossil fuels or biomass is far cheaper: CH_4 at an exorbitant ~$15/GJ makes cheaper H_2 than $0.04/kWh electricity. This should remain generally true with future carbon sequestration, without which reforming natural gas into H_2 and CO_2 could meanwhile cut fuel-cell cars' fuel-cycle CO_2 emissions by ~2–5×. But even if electrolysis could compete, much-improved new U.S. nuclear plants' sent-out electricity[8] would cost ~$0.067/kWh or, with dramatic improvements envisaged by enthusiasts, ~$0.042/kWh —still hopelessly uncompetitive electricity. New windpower sells today for $0.025/kWh (after a $0.017/kWh subsidy, less than fossil-fueled and nuclear plants get), and will ultimately shed another cent—even more if built for electrolysis, eliminating the gearbox and power electronics.

Global windpower could more than power the world. Its installed capacity rose in 2002 from 24 to 31 GW—twice what global nuclear power's global average annual increment in the 1990s. Investors shun nuclear power in favour of wind and two even cheaper alternatives—~90%-efficient gas-fired combined-heat-and-power at industrial or building scale, and end-use efficiency—to be joined in time by fuel cells and even solar cells. Micropower's extra order-of-magnitude economic value from "distributed benefits" makes its edge over any new central station unassailable[9].

No wonder Grant offers no economic comparisons. But market economics may be the best brake on proliferation of nuclear weapons—the key problem he acknowledges—because it's insoluble with but potentially tractable without nuclear power[10].

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[1] A.B. Lovins, "Twenty Hydrogen Myths," Rocky Mountain Institute, 20 June (updated 12 July) 2003, www.rmi.org/sitepages/pid171.php#20H2Myths.

[2] P. Grant, *Nature* **424**, 127–128 (10 July 2003).

[3] By ~$1 trillion worldwide over 40 y, because upstream investments are about one-third lower for gas than for oil, and the difference exceeds the cost of reforming and H_2 storage and delivery: C.E. Thomas, "Hydrogen and Fuel Cells: Pathway to a Sustainable Energy Future," 2 February 2002, www.h2gen.com/main.php?page=why.html.

[4] Or possibly less, because CH_4 reformed to H_2 is roughly offset by CH_4 saved in power plants (especially inefficient peaking gas turbines) displaced by fuel-cell electricity, in furnaces and boilers displaced by heat recovered from fuel cells and reformers, and in refineries' H_2 production to make motor fuels displaced by direct H_2.

[5] Counting land-use by the entire fuel cycle. Light-water reactors' long-term land-use is two orders of magnitude greater than Grant's 0.56 m^2/kW_e, since he counted only the reactor site area, not the uranium fuel cycle: W. Häfele *et al.*, *Energy in a Finite World*, IIASA (Laxenburg), Ballinger (Cambridge, MA) (1981), adjusting for modern LWRs' assumed 0.9 capacity factor and doubled fuel burnup.

[6] A.B. Lovins & D.R. Cramer, *Intl. J. Veh. Design*, in press (2003); see also www.hypercar.com/pages/casestudies.php and www.rmi.org/siteimages/pid175.php.

[7] The potential in class 3+ wind areas, net of environmental and land-use exclusions, is ~1,210 TWh/y for North Dakota and ~1,030 TWh/y for South Dakota (Pacific Northwest Laboratory, *An Assessment of the Available Windy Land Area and Wind Energy Potential in the Contiguous United States*, 1991), plus any enhanced high-level wind potential per C.L. Archer & M.Z. Jacobson, *J. Geophys. Res.* **108**(D9):4289–4309 (2003).

[8] J. Deutch & E.J. Moniz, co-chairs, *The Future of Nuclear Power: An MIT Interdisciplinary Study*, 29 July 2003, www.mit.edu/nuclearpower/—well below historic costs. Delivery costs of several ¢/kWh from the central power plant to distributed electrolyzers, or typically more for hydrogen from central electrolyzers, must be added for centralized but not for distributed power sources or savings, both of which (like windpower) the MIT study ignored.

[9] A.B. Lovins *et al.*, *Small Is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size*, RMI, 2002, www.smallisprofitable.org.

[10] A.B. & L.H. Lovins & L. Ross, *Foreign Affairs* **58**:1137–1177 (1980).