Forum on Physics & Society of The American Physical Society July 2004

Comment on The American Physical Society Hydrogen Report

Amory B. Lovins

Like several other well-publicized recent assessments, the March 2004 APS Panel on Public Affairs report "The Hydrogen Initiative" reaches erroneous conclusions about hydrogen economics and storage, due to three main fallacies:

1. By tacitly assuming today's heavy, inefficient vehicles, the panel concludes that "no material exists to construct a hydrogen fuel tank that meets the consumer benchmarks. A new material must be developed." In fact, those benchmarks (300-mile range, 3-5 minute fill, high safety, negligible leakage) are readily met by presently commercial filament-wound carbon-fiber tanks if used in very efficient and crashworthy fuelcell vehicles made of ultralight advanced polymer composites. An illustrative 2000 virtual design for an uncompromised, cost-competitive midsize SUV [1] offers 330-mile range, 114-mpge EPA-adjusted efficiency, and excellent packaging using safe and cost-effective 350-bar hydrogen tanks now on the market. New manufacturing methods for carbon-fiber-reinforced thermoplastic vehicle structures appear capable of ≥80% of the performance of hand-layup aerospace composites at ≤20% of their cost, beating aluminum in cost per part and steel in cost per car, while offering automakers major reductions in required capital, parts, and assembly.

Such light, efficient vehicles remove any need either for a new hydrogen storage material or for liquid or solid storage, both of which are far costlier than simple compressed-gas storage. Compressed-gas storage does require compression energy, but it's minor and largely recoverable; and as the 2000 design demonstrates, combining good platform physics with fuel-cell efficiency overcomes hydrogen's inherent bulk. The panel's qualitative objections based on these old issues don't withstand quantitative analysis.

2. The panel concludes that the cost of natural-gas-reformed hydrogen must fall by at least 4x to compete with \$1.50/gallon gasoline. In fact, distributed miniature reformers now being commercialized, or hydrogen piped from near-urban refineries used as merchant hydrogen plants, can compete well at the wheels of the car, net of fuel cells' 2-3x tank-to-wheels efficiency advantage over gasoline Otto engines. (Comparing cost per MJ of fuel rather than per unit of delivered traction — a mistake I made throughout the 1970s and 1980s — is of course fallacious when the desired end-use is moving the car.)

The more interesting question is how well fuel-cell cars and reformed-methane hydrogen can compete with gasoline in a gasoline hybrid-electric car like the doubled-efficiency 2004 Toyota *Prius*. (A *Prius* powertrain in the ultralight, low-drag SUV design just mentioned, but with a 0-60 mph time reduced from 8.2 to 7.1 s, would get 66 mpg.) It turns out that 5x-efficiency cars create a robust business case for hydrogen fuel-cell propulsion, while today's inefficient platforms don't. Thus hydrogen needs superefficient cars far more than vice versa — but once we have those cars, hydrogen clearly beats gasoline in cost per mile, using reformer technology now in service (centralized) or being commercialized (distributed). Cars with such good physics (low mass, drag, and rolling resistance) also make the fuel cell three times smaller, so it can be introduced many years earlier even at a threefold-higher price per kW.

The panel is correct that electrolytic hydrogen is too costly — at least unless its electricity costs well below 2ϕ /kWh delivered to the filling station. But this means that electrolytic (or thermolytic) hydrogen can't justify further subsidies to or R&D investment in nuclear power, as the nuclear industry and Administration misrepresent, with the panel's apparent concurrence. Some renewables may ultimately be able to meet this stringent cost target, but nuclear technologies never can.

3. The panel omits the key strategy for an expeditious and profitable transition to hydrogen — integrating fuel-cell deployment in mobile and stationary applications so that each helps the other happen faster [2].

How did these errors occur? The panel forthrightly states in its methodological appendix that "The authors did not carry out a new analysis of the scientific elements of the Hydrogen Initiative," but only "distilled" a rather narrow range of prior sources, nearly all governmental and many unquantitative and outdated. It's embarrassing to see APS issuing a me-too report pervaded by the same methodological flaws that undermined the similar reports lately issued by NAS/NRC, OTP, and others. POPA's distinguished panel and reviewers did not represent the range of knowledge needed to span the state of the art in key hydrogen-related technologies, and appear to have overlooked key evidence well-known to many active practitioners [3]. I fear the result, echoing the conventional wisdom of five or ten years ago, does no credit to APS and will unduly retard sound R&D planning for the hydrogen transition [4], even though POPA correctly emphasizes integrating hydrogen R&D with efficiency and renewables. The Administration's hydrogen and automotive strategies have important flaws [5], but POPA hasn't correctly identified them. This lost opportunity is unfortunate.

Amory B. Lovins, Chief Executive Officer Rocky Mountain Institute 1739 Snowmass Creek Road, Snowmass, Colorado 81654-9115, USA

phone: + 1 970 927-3128 or -3129

fax: + 1 970 927-4178

Internet: ablovins@rmi.org (read by assistants),

amory@rmi.org (private)

Homepage: www.rmi.org

- 1. A.B. Lovins & D.R. Cramer, "Hypercars®, Hydrogen, and the Automotive Transition," *International Journal of Vehicle Design* 35(1/2):50-85 (2004), http://www.rmi.org/sitepages/pid175.php#T0401.
- A.B. Lovins & B.D. Williams, "A Strategy for the Hydrogen Transition," Natl. Hydr. Assn. Ann. Mtg. 1999, http://www.rmi.org/images/other/Trans/T99-07 StrategyHCTrans.pdf.
- 3. A.B. Lovins, "Twenty Hydrogen Myths," June 2003 white paper (>50,000 downloads in first few months), http://www.rmi.org/images/other/Energy/E03-05_20HydrogenMyths.pdf, to be published in Intl. J. Hydr. En. (2004).
- 4. A.B. Lovins, J.G. Koomey, O.-E. Bustnes, & E.K. Datta, *Winning the Oil Endgame: American Innovation for Profits, Jobs, and Security*, in production, Rocky Mountain Institute (http://www.rmi.org), July 2004
- 5. E.g., A.B. Lovins, "FreedomCAR, Hypercar®, and Hydrogen," invited testimony to USHR Science Committee (Energy Subcommittee), June 2002, http://www.rmi.org/images/other/HC-FreedomCAR.pdf.

--