HYDROGEN IN A SUSTAINABLE ENERGY'S FUTURE:

DESIGN IMPERATIVES FOR DELIBERATE SUSTAINABILITY

Stephanie Cairns[1]

What roles will hydrogen play in a sustainable energy future? I challenge anyone to answer this with confidence, for the simple reason that there is no one hydrogen future. Hydrogen, like electricity, is an energy carrier, and like electricity, there is a bewildering array of scenarios for its primary energy source, production, distribution and end-use technologies. The least attractive among these scenarios would head us towards worse climate change, worse environmental problems, greater vulnerability of energy systems, and higher energy costs. The best among the scenarios could indeed hold the promise of a more sustainable energy future.

Instead of asking "what roles will hydrogen play in a sustainable energy future?", I believe we should be asking "what roles do we want hydrogen to play in creating a sustainable energy future?". What lessons can we draw from a century of development of the petroleum industry and of electric utilities, to inform us on how to guide emerging hydrogen systems along more sustainable paths?

Let me propose five design imperatives for hydrogen in building a more sustainable energy future. Although this workshop emphasizes paths to a low-carbon society, I deliberately cast the net to the broader environmental, economic, and social components of sustainability.

- Catalyzing a carbon-neutral energy system;
- Achieving a quantum-step improvement in energy-system efficiency;
- Improving the resilience of energy supply;
- Reducing poverty through affordable energy: and
- Fostering consumer commitment to prudence.

CATALYZING A CARBON-NEUTRAL ENERGY SYSTEM:

Hydrogen fuels should be the catalyst for a shift to a carbon-neutral energy system. This can be accomplished through the hydrogen industry's choices of primary energy sources, individual suppliers, and its commitment to offset carbon emissions where they do occur. As an emerging industry, the hydrogen sector has enormous potential to set a new standard of carbon-neutral performance that could influence the entire energy sector.

[1] Wrangellia Consulting,Victoria, BC. (stephanie@wrangellia.ca)

The concept of a hydrogen economy is all too often used interchangeably with that of a low-carbon economy. But in fact whether the production of hydrogen yields carbon benefits will depend entirely on its pathways—the choices of primary energy, intermediate energy carriers, distribution systems and final use. These need to emit lower levels of carbon on a life cycle basis than do the incumbent energy pathways. Many hydrogen pathways will not do this. I quote a 2003 study of several dozen transportation hydrogen pathways, conducted for Fuel Cells Canada, which concluded that "*….GHG emissions for the hydrogen pathways range from 1.3% to 395% of the gasoline baseline vehicle…..it is clear that an unmanaged 'Hydrogen Economy' is not a panacea for solving the GHG emissions problem….There are hydrogen pathways that can produce very significant GHG emission reductions and energy savings but there are also pathways that would result in increased GHG emissions and increased energy use*."[2] Similar conclusions have been reached in studies by the National Round Table on the Environment and the Economy[3] and the Pembina Institute,[4] among others.

Carbon capture and geological storage are being advanced by many as "companion technologies" that would enable fossil-fuel based hydrogen to be produced with a net carbon reduction benefit. These technologies face many of the same challenges and 10 to 30 year timelines as hydrogen technologies—they are still largely in development, significant reductions in costs are needed, and they will require a large new infrastructure. They appear to be better suited to large, centralized production facilities, and therefore to a mature stage of hydrogen production.

Some prefer zero-carbon renewables as the primary energy source for hydrogen. There are indeed many compatibilities between these technologies: hydrogen offers a solution to the intermittency and storage challenges of many renewables, it could offer the economies of scale required to drive renewable energy production costs down, and renewables can be deployed at an incremental rate and on a distributed basis that could be a good match to the emerging nature of hydrogen demand, particularly during a transition period. But we need to test whether hydrogen production is the most carbon-effective use of zero-emission renewable energy—for example in some regions, a better use of this resource, from a carbon perspective, would be backing out coal-fired electricity generation until clean-coal technologies are adopted.

---

[2] (S&T)[2] Consultants Inc., *Hydrogen Pathways, Greenhouse Gas Emissions and Energy Use*, prepared for Fuel Cells Canada, December 2003, p. ii.

[3] National Round Table on the Environment and the Economy, *Economic Instruments for Long-term Reductions in Energy-based Carbon Emissions*, Appendix C. NRTEE 2005.

[4] Pembina Institute, *Life Cycle Value assessment of Fuel Supply Options for Fuel Cell Vehicles in Canada*, Pembina Institute, June 2002.

The objective of carbon-neutrality could be considered a bold objective. Or it could be considered a reasonable expectation for any new industry launched in 21st century—the social licence to operate in the greenhouse world.

ACHIEVING A QUANTUM-STEP IMPROVEMENT IN ENERGY-SYSTEM EFFICIENCY;

At the global level, only one third of primary energy inputs presently reach the point of use.[5] Contemporary vehicles are on average only 14 percent efficient well-to-wheels.[6]

If hydrogen can provide end-use services (such as mobility, heating and cooling, lighting) more efficiently across the full fuel chain than do incumbent energy forms, this will reduce the energy sector's net environmental impacts and thus contribute to a more sustainable energy system. The shift to a hydrogen economy presents the decided luxury of developing many entirely new technologies in the energy chain, including end-use technologies; a quantum step in energy-chain efficiency should be one of the objectives for hydrogen's contribution to a more sustainable energy future.

This would have obvious productivity benefits. A more efficient energy system would also reduce the energy sector's many other environmental impacts, by offering the same end-use service per pound of toxic waste, or per acre of habitat disturbed.

Climate change concerns increasingly dominate today's energy and environment policy debates, and with good reason. But a hydrogen-based energy system could be carbon-neutral, and still carry a heavy life-cycle ecological footprint from the fuels used to generate the hydrogen. For hydrogen to contribute to a sustainable energy future, it also needs to reduce the energy sector's other environmental impacts, including:

- **Emissions of criteria air pollutants.** While fuel cell technologies will eliminate air pollutants at the tailpipe, the same is not necessarily true across full hydrogen fuel cycles. Hydrogen using fossil-fuels or biomass as a primary energy source will have upstream emissions of criteria air pollutants.
- **Production of toxic and radioactive wastes.** Similarly, many hydrogen feedstocks will produce toxic or radioactive wastes.
- **Incursion into and fragmentation of critical wilderness habitat.** Oil and gas exploration and development now outstrips the forest industry in fragmenting and scarring Canada's globally significant boreal landscape, with virtually no requirements for reforestation and habitat restoration. The proposed natural gas pipeline development in the Mackenzie Valley

[5] World Energy Assessment, *Overview: 2004 Update*, United Nations Development Programme, New York, 2004, p. 47.

[6] Amory Lovins, *Amory B. Lovins's Hydrogen Primer*, Rocky Mountain Institute. www.rmi.org/sitepages/pid985.php. Accessed October 11, 2005.

will trigger massive industrialization in one of North America's last, globally unique wild ecosystems.

IMPROVING THE RESILIENCE OF ENERGY SUPPLY:

Hurricane Katrina gave us one foretaste of the vulnerability of society when centralized energy production systems are disrupted. We can all imagine similar scenarios in the future. If we believe we are entering an era of increasing extreme weather events, or we believe that higher geopolitical tensions and terrorist security concerns are part of our future, we may also look to hydrogen to improve the resilience of energy supply systems in three ways:

i) by using regional sources of primary energy, so that supply lines are minimized;
ii) through more distributed production of energy, so that fewer people are affected when a production centre is disrupted; and
iii) by drawing on more diverse primary sources of energy, which can hedge the economy against price inflation or price volatility in one commodity.

REDUCING POVERTY THROUGH AFFORDABLE ENERGY:

The news this last month has been filled with stories of increased costs in heating oil and natural gas, elevated gasoline prices, and concerns about the impact of rising fuel and electricity costs on many industrial sectors. If this is challenging in a wealthy, oil producing country like Canada, consider the impact in those countries which spend significant portions of their convertible currency earnings on energy imports—countries such as Uganda, Nicaragua, or India whose energy imports equal over one third of the value of all their exports.

A sustainable energy future needs to include affordable energy for the poor of the world. Yet if world oil production does peak in the next 10-15 years, as many predict, current price shocks will be but a modest preview of the future. Can hydrogen's contribution to a sustainable energy future include reducing poverty by making energy more affordable for all? One way it could achieve this would be if it could enable regional sources of primary energy to substitute for imported fuels.

FOSTERING CONSUMER COMMITMENT TO PRUDENCE.

Too often, technology solves problems with more of the same processes and patterns that caused the problems in the first place. Couple this with the problem of reverse adaptation—the adjustment of ends to match the character of available means—and it is all too clear that technology is not the panacea for a sustainable energy future. For similar reasons, purely economic solutions will at best be partial. We are all familiar with the rebound effect, whereby efficiency gains are eradicated by increased consumption. If our goal is to develop deliberate sustainability, then great technology must merge not only with effective economic instruments, but also with bold social commitments. Changing how people value energy—from a culture of casual, often gluttonous, consumption to a culture of respectful use-- must also be one part of a successful shift to a genuinely sustainable hydrogen-based society.

CONCLUSION

Objectives such as these—or obviously others, once a vigorous debate has taken place—can form the design imperatives for a deliberate agenda to make the emerging hydrogen energy system the vanguard for a shift to a sustainable energy system. No doubt there is no one ideal hydrogen pathway, and no doubt there will be a need for trade-offs among objectives.

But the sobering reality is that at present, there are no signals in place to drive this nascent energy system in a sustainable direction; in fact the incumbent market and policy signals, which have been designed to support the development of an unsustainable hydrocarbon economy, will likely reinforce the unsustainable status quo. We need to abandon this agnostic position on hydrogen pathways, and declare societal expectations for what a knowledge-based industry in the 21st Century needs to help us achieve—and that includes a substantial advance in energy sustainability. The phenomenal promise hydrogen holds as a vector for a more sustainable energy future risks being squandered. There is an essential but as yet unclaimed civil society and governance role in averting such a tragedy.