Hydrogen, Fuel Cells, and the WilderHill Clean Energy Index (ECO)

Dr. Robert J. Wilder

Commentary 1.1

In comparison to many well-proven technologies in the WilderHill Clean Energy Index, it's clear heightened risk applies to volatile hydrogen (H2) and fuel cell (FC) stocks. Mindful that early-development companies here see great changes in valuation—we offer some thoughts on hydrogen & fuel cells within the Index. As perhaps the most costly and uncertain of all clean energy approaches of the Index (although it's clear the technology works—it's been powering spacecraft for years), the question whether hydrogen and fuel cells can move beyond their past 'hype' merits serious discussion.

Before that review however it's worth emphasizing that while H2 FC stocks may not achieve economic viability, there are now many technologies in the WilderHill Index economically viable in their own right. This point is significant. Diverse clean energy exists already: wind farms are sprouting and making power cheaply, there's growing global use of biofuels, better energy-use techniques to reduce power demand and improve efficiencies. This report was written using new solar power with just seven years to full payback. We expect happily that it's quite early in the game for a good many of the cost-effective alternative energy technologies that can grow within the Index.

Thus breakthroughs in cost should not be needed for much clean energy (CE) — these areas are already near or are making profits. Realistically though, there are promising CE avenues that *might* one day be significant — but are not yet so. Hydrogen and fuel cells are a prime example: they're not presently cost effective, yet are a part of the WilderHill Index (ECO) tracking the CE sector. Their significance is a topic of this commentary.

To some extent the issues here are typical of new technology; a glance at loss-making companies doing research and development (R&D) can prompt questions of why these have lofty stock valuations. Companies emphasizing R&D often lack concrete products or even earnings: indeed their wide-ranging stock valuation reflects the difficulty of valuation. In the case of hydrogen and fuels (like many technologies) part of the answer stems from expectations of future profit, and that's one reason for inclusion in the Index. But there is another key aspect in terms of their inclusion in the WilderHill Index — and that's based on their technical significance and promise they hold for clean energy.

Viewed technologically, H2 FC firms *may* prove crucial to the future of clean energy. This clearly has impact for the WilderHill Index where we do not try to 'pick stocks' on financial criteria, but rather review stocks and assemble sectors based on technical and substantive significance. With this in mind, an overview of H2 FCs may provide insight into the Index especially as the future of this technology is comparatively speculative.

The Case of Hydrogen and Fuel Cells

On the one hand, hydrogen fuel cells have faced an unwanted 'hype' that can overshadow great obstacles faced in lowering costs and creating infrastructure. That said the efforts by companies large to small to bring H2 fuel cells to economic feasibility within the clean energy sector are real—and relevant to the WilderHill Index (ECO). The shared goal is to make FCs commercially viable in comparison to other options. That's helped by prices trending upwards for oil, making foreseeable cost-effectiveness a closer proposition.

Although they're being discussed together here from an engineering standpoint, hydrogen (H2), and fuel cells (FCs) each do very different things. Hydrogen basically requires energy in order to be made and stores it as 'energy carrier'; fuel cells convert hydrogen to desired power wherever needed. Within the WilderHill Index (ECO), the fortunes of hydrogen firms are mainly tracked within the "Cleaner Fuels" or "Energy Storage" Sector of the Index—and fuel cells are typically tracked within the "Energy Conversion" Sector.

Interestingly, hydrogen could be used apart from electrochemical fuel cells. H2 could be utilized (rather than gasoline for instance) in modified Internal Combustion Engines (ICEs) in future cars. There are companies working on using hydrogen in ICEs: that is a potential area of inclusion within the Index (ECO). Nonetheless, long-term benefits of hydrogen and fuel cells converge and thus the two are commonly linked in discussions. Used together, they *could in theory* be an efficient, very low-pollution energy solution.

The story of hydrogen fuel cells in terms of clean energy stock valuations is interesting for several reasons: they've pointedly captured investors' fancy at several different times in recent years; high cost of the technology presently is an impediment, but if overcome one could see rapid penetration by H2 and FCs and greater stock valuations. Also H2 and FCs are often mischaracterized as the energy source itself (when hydrogen is an energy carrier and fuel cells are conversion devices). And H2 FCs are among the options farthest from being cost-effective, yet the most potentially influential if commercialized.

If the costs of hydrogen fuel cells could be brought down to economic feasibility—and again that's a big if since it requires an order of magnitude reductions—then exuberant bouts of optimism might properly be reflected by high valuations in this field. This would reflect a reaching infrastructure for hydrogen and new thinking. Until then (if ever) given our view of prospects for H2 FC technology, we expect innumerable ongoing downturns in H2 FC securities, as well as upturns and feel they're inevitable in the business cycle.

What gives us some cause for optimism, is that the price of clean energy (including hydrogen and fuel cells) depends mainly on costs of technology, and these costs are only dropping. Clean energy thus contrasts sharply with fossil fuels; compare clean energy and H2 made by wind etc with oil's ongoing price fluctuations, finite supply, environmental

impacts and supply vulnerabilities, and we expect clean energy will only grow in significance. For technological reasons, hydrogen fuel cells may be part of this story.

What we suggest to anyone interested in more background on hydrogen and fuel cells, is to spend time learning about the technical aspects of H2 FCs as at University libraries.

Of some financial note, this emerging technical field has few institutional analysts yet following it thoroughly—and it's not uncommon for individual fuel cell firms to see movements of 10% or even 15% and more in a single trading day. Lack of extensive comprehension by large institutions helps allow for much volatility, this arguably can also be seen as a potential advantage. It may create market inefficiencies since only some micro-cap securities here are deeply-analyzed and their earnings forecast. This surely contributes to notable volatility of the WilderHill Index. It also likely helps the Index as a diversification tool since it may move in rather divergent ways from broader markets.

Note we've observed over many years that a recognizable pattern seems to repeat itself with H2 and FC stocks. A press release or story at times proclaims with excitement some advance or milestone—or a media piece appears to make hydrogen 'a sure thing'—and that company's stock or the whole sector reacts with a big spike upwards. That pattern is generally unhelpful in our opinion; however the WilderHill Index is designed to track the CE's sector movements and thus it should move along with these brief gyrations.

Certainly the stocks of fuel cell makers have already gone through some exuberance. A startling period was late 1999/early 2000 when the stocks of a few pioneering makers of fuel cells saw a brief but spectacular rise; however those (remaining) stocks now trade at prices more like pre-boom years. It's useful to state generally that prices of stocks aren't like a thermometer that reflects weather of the moment (or the past), as much as they're more akin to a barometer attempting to forecast weather ahead. With stocks it's always useful to think ahead to what you believe the future might bring. Group psychology too plays a part; there are times when capital flows seem unconnected to fundamentals.

We take a longer-term outlook with the Index, and so seek to avoid getting caught up in news or press release-driven changes when contemplating changes to ECO composition or weightings that are reevaluated quarterly. Sudden new plateaus, or the bottoms seen in individual stocks are often not long-lived. Rather soon afterwards, a security often trends back nearer a broad trading range at previously. 'Regression to the mean' is one of the more powerful forces in markets. Another weighty maxim is 'risk and return go hand in hand.' Mindful of this all, we offer a brief primer on H2 and FCs in context of ECO.

Fuel Cell Makers

To date considerable media attention has been paid the Proton Exchange Membrane (PEM) type of FC that might power cars of the future. But should there come a time

when FCs are cost effective in cars where competition (in the ICE) is at low cost, then a variety of types will already likely penetrate use in powering cell phones, laptops, homes, cities, etc. Significantly there are numerous companies developing FC types of differing chemistries. These include direct methanol FCs (DMFCs), solid oxide FCs (SOFCs), molten carbonate FCs (MCFCs), alkaline FCs (AFCs), and others with differing attributes—besides PEMFC; all pertinent technologies might be included in ECO.

Thus while PEMs have gotten the majority of press so far, they're but one FC type. The higher efficiencies of other FC types and significant ability among some of them to use varied fuels or liquid fuels like methanol while PEMs are easily poisoned, such as by sulfur plus other considerations, make many types of FCs interesting prospects.

When considering the technologies for inclusion in ECO, one area of potential demand is off-grid or on-grid 'distributed generation' (DG) in homes. Here makers of PEMFCs with 1-10 kilowatts (kW) output could be first to market, or it could be a rival like lesser-known Solid Oxide Fuel Cell (SOFC). SOFCs have advantages of higher efficiency and thermal co-generation along with added practicality of supplying high quality heat for water or space heating. Increasing power densities are intriguing. Being high temperature, they might run conveniently off natural gas without 'fuel reforming' (purification) that's needed for lower temperature PEMFCs. On a larger scale of generation, an MCFC boasts its advantageous fuel flexibility and co-generation possibilities using waste heat.

We've noticed the popular press will often regard any FC producing power as a black box. But it's useful to think about firms making internal components of the "stack"—the heart of a FC. Also fuel cell "balance of plant" (BoP) can be considerable too, comprising for instance compressors to increase air pressure for efficiency, or components hydrating the stack. That many types of FCs can't now operate at ambient air pressure or room temperature infringes on their elegance, but we're at early stages of FC development.

For example some companies considered for inclusion in the WilderHill Clean Energy Index may possess intellectual property rights for unique components in the stack or balance of plant. Makers of specialized flow field plates, membrane electrode assemblies (MEAs), and fuel reformers are building critical components. However, these companies are typically very large and FC component design may be but a small part of what they do. That can mitigate against Index inclusion if FCs are a small portion of their work.

A word about wide-ranging, large technology companies with promise for their own hydrogen fuel cell products. Several well-known global conglomerates are doing important work in this sector and it will be little surprise if any are the first to market or leaders in various H2 FC sub-arenas for cars, handheld electronics, home power etc. But they're generally not now included in the WilderHill Index (ECO) as noted, because their stock price does not currently well represent dynamic fortunes of the clean energy sector.

Remember as well when looking at all makers of fuel cells, some fuel cell firms aren't public and those cannot be included in the WilderHill Index. That said, important firms outside the U.S. can be included if they have an appropriate listing on a major U.S. Exchange with adequate trade volume. Looking ahead we may consider companies in specialized power applications (such as maritime—a large market not to be sneezed at).

In some instances, firms working on fuel cells are excluded when their majority interests are in dirtiest fossil fuels: coal or oil. And for mid-sized generalist companies starting smaller fuel cell efforts, if the progress in this area is not yet well reflected in their changing stock valuations then they are typically not included in the Index. Simply put their stock valuations are not useful as an indicator of the clean energy sector.

That situation may change however if/when fuel cell divisions get spun off from large firms and subsequently trade independently. Quietly, several of the world's very largest companies (many based in oil or automotive sectors) have been coming to see H2 and FCs as potentially viable—even a few long holdouts joined the race. If they do further capitalize and someday spin off pure-play FC firms, these could be potential components of ECO that would accelerate timetables and expand investing horizons considerably.

When looking at comparatively tiny firms about which little is known, these are highly speculative stocks to say the least. Yet they can also be interesting. In the case of tiny firms, especially, ECO Index Rules may prohibit inclusion: component stocks should trade above $1.00/share with a minimum market capitalization of $50 million to be in ECO–yet these Rules are written for flexibility and to allow some micro-caps. At any rate tiny firms are given special scrutiny. No firm is included if they made outlandish claims (as happens occasionally) about their technology or the laws of thermodynamics.

Hydrogen Generation and Storage

The WilderHill Index (ECO) can include companies working on hydrogen generation, storage and transport. Because hydrogen itself has to be produced—that is, broken from its bonds—'green hydrogen' requires alternative energy so that it can be generated from renewable sources. Frequently, H2 is vetted as potentially the very best fuel of choice in the long term—when it's is made from renewable energy sources. Beyond that, hydrogen storage is widely considered another linchpin to broad applications of H2 FCs. Thus generation and storage can be important components of the Index. Hydrogen can boast ecological benefits including it avoids in the first place noxious pollutants vexing internal combustion engines, and it does not require use of carbon-laden oil and coal.

Hydrogen is the most abundant element, both on Earth and in the solar system; it's found in common substances like water around us. It can be made renewably as such as using wind or solar power to pass an electric current that 'splits water'. H2 might also be made from 'brown sources' like coal, oil, or even nuclear power; that however reduces much of

the ecological allure. H2 needn't be dug from below ground like inherently dirty fossil fuels; it could free nations from dependence on foreign energy. Looking ahead, H2 might even be created photobiologically or photochemically, or perhaps mimic photosynthesis, making integrative energy more akin to natural renewable systems that sustain all life.

Hydrogen itself does not need be tied to FCs; it might be used in modified ICEs within dual-fuel cars able to burn H2 or gasoline, a strategy being examined by some car manufacturers. That use could capture benefits of hydrogen during a bridge period when both traditional gasoline and H2 are used. When H2 is used in fuel cells by combining it with oxygen from air to make desired power (along with water and some heat)—there's no carbon emissions that contribute to global warming or other pollutants. With advances to reduce fuel cells' cost, the political will to establish a hydrogen infrastructure and the correct economics, there could be a host of reasons for adopting a Hydrogen Economy.

Because hydrogen's realistically a long-term (although potentially good) solution, a number of interim fuels are under review by governments including methanol, ethanol, DME (dimethyl ether) and naphtha, as well as relatively cleaner "new hydrocarbon fuel" with properties similar to just low-sulfur gasoline. None so far enjoy a clear advantage. Of these only ethanol and methanol are yet likely to be considered for inclusion in ECO; methanol (though caustic to skin) could be made renewably, and ethanol is renewable.

Within the oil industry a spectrum of positions are emerging on hydrogen and clean energy. Some well-capitalized oil companies are taking proactive stands; a few have entered even into solar panel photovoltaic manufacturing, or are examining alternative energy like H2 fuel cells etc with the eye of perhaps becoming much broader energy supply (and not just oil) companies. To the extent that certain clean energy technologies like H2 FCs are a loss-making enterprise at present, that large profitable oil companies might invest considerable capital into research that may or may not pan out, is a benefit to the clean energy field. Those companies may not be part of the WilderHill Index (ECO) because of their fossil fuels majority interests, or inconsequence of clean energy for their stock price, but capital to research clean energy should be always welcome.

Seen another way, consider that the present relative absence of hydrogen and clean energy from the U.S. energy portrait might be an opportunity. Overlooked, pure-play companies toiling away in this field with little notice now, may deserve real consideration and smarter valuations once benefits of alternative energy ars better realized and profits realized. Moreover hydrogen and fuel cell companies are now past the price spikes–-and sharp falls—that once lifted the stocks of obvious hydrogen and fuel cell firms to such heady levels in the Spring of 2000; we're now on the other side of that frenzy.

As shown, while there are a variety conceivable ways to generate hydrogen, some paths are more ecologically friendly than others. We take note of H2 generation methods in the

WilderHill Index (ECO). Presently though there is little demand for ‘green’ hydrogen and most is made industrially by (reform) ‘stripping’ H2 from natural gas at high temperature.

Reforming natural gas at central-located and industrialized sites is the present path. In the future though, two objectives will likely be that 1) hydrogen should be created renewably such as using wind power combined with electrolysis, and 2) this should be done nearer to the need. Recall that Distributed Generation (DG) is a smart, new soft energy path that involves small-scale H2 production from many on-site providers creating an energy carrier tailored to demand. This is starkly different from coal power for instance, or the present U.S. power grid akin to centralized planning with massive inefficiencies.

California’s dismal grid failures, utility power price hikes, and the black-outs of 2001 and later, conspire to vividly point out the several faults of centralized power. The eventual DG transformation to clean alternative energy envisioned here is akin to moving from central computing with bulky mainframes—to small, fast personal computers on desks everywhere. It’s smarter, more efficient, better and cheaper to boot.

The theoretical simplicity of making hydrogen is remarkable. Recall that an electric current passed through water makes H2. This is electrolysis, beautiful for its elegance; electricity causes two hydrogen atoms to separate from one oxygen atom that composes water. (Interestingly a fuel cell works the same way but in reverse: it allows hydrogen and oxygen to recombine, releasing electricity + water and heat. Curiously the FC was invented over 150 years ago when it was noticed after electrolysis split water that an electric current also came the other way from a beaker holding H2 + oxygen).

As noted, storage issues are then particularly important. A persuasive case has been that compressing H2 in tanks is a smart approach. Hydrides are a very interesting option, though they are generally heavy and expensive to produce. Look ahead and a fascinating new technology just over the horizon may be carbon nanotubes. Some eyebrow raising figures were published in the scientific literature for H2 storage per weight within nanotubes, but these data are so far unreplicable. It is a nonetheless a compelling story unfolding now in labs. Should robust results be reproduced, and advances made that allow inexpensive mass production, then nanotubes may even raise the possibility of bringing a Hydrogen Economy to fruition with the FC, hand in glove. However we repeat this is “blue-sky” supposition that’s interesting but probably decades away at this point.

Besides makers of equipment for storing hydrogen in compressed form, or hydrides, a much different approach is gas to liquids (GtL)—or liquids that could deliver a user-friendly and H2-rich medium. After all, the public is already accustomed to working with volatile and dangerous liquid fuels like gasoline, in safe ways. Attention has thus been paid to methanol as a feedstock, as it’s a liquid, has high hydrogen content and can be used unreformed in a direct methanol fuel cell. However, methanol is corrosive and toxic to humans—thorny problems indeed, but surmountable and of interest to the Index.

There is still a third notable aspect of hydrogen and fuel cells for the Index, which is to examine companies working in power delivery, management and conditioning. Like input into the fuel cell, this output side is essential because electricity made by a fuel cell must be harnessed to match demand, or creates usable output. From a stock standpoint, these companies have the least nexus in the public's mind to H2 and fuel cells, and so were the least run up by the bubble-like attention paid to this sector in early 2000.

There are still relatively few publicly-held, pure-play companies in this arena; but those that meet minimum quantitative rules might be considered for inclusion in the WilderHill Index (ECO). As hybrid cars gain popularity, it's useful to look at power management there in vehicles since they bear much similarity to systems needed in possible H2 FC cars. Hybrids are an important testing platform now, for potential future all-electric vehicles. Other firms here help forge industry standards such as in 'anti-islanding' for DG on the grid, to prevent solar power being sent from homes to grid during black-outs.

In sum, we feel hydrogen and fuel cells are a notable albeit speculative aspect of the clean energy sector today. Not long ago, one had to strain to find technical information regarding H2 and fuel cells. Now the opposite is coming true, given their potential should costs ever be brought down to manageable levels. In discussing hydrogen and fuel cell components in the WilderHill Clean Energy Index (ECO), we do not mean to promote these experimental technologies—nor imply they'll be profitable soon. But we are confident they have significance now as notable technologies when tracking the clean energy sector. It shall be interesting to watch what the next 10 years might bring, and whether companies here can move from loss-makers to genuine profitability.
