CRITICAL NATIONAL NEED IDEA

"JUMP-STARTING A HYDROGEN ASSISTED ECONOMY WITH A CHEAP, RENEWABLE HYDROGEN SOURCE"

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INTRODUCTION – THE SOCIETAL AND NATIONAL CHALLENGE

Freeing America (and the world) from its dependency on fossil fuel has become an urgent need. This is acknowledged at virtually every level of governmental, scientific, geo-political, sociological, and cultural research and study. Therefore, this white paper will not dwell on establishing the importance of this issue, rather it will address one scheme for emancipating ourselves from fossil fuel dependence, which, while high-risk, is also high-reward.

Freeing our Nation from fossil fuel dependency may be achievable in a unique way by **combining wind-power harvesting with hydrogen production in a new paradigm**. This envisions a modification of the conventional "Hydrogen Economy", termed the "Hydrogen *Assisted* Economy" (HAE). The HAE retains all the benefits of the conventionally proposed Hydrogen Economy while eliminating its drawbacks; this is accomplished in part by utilizing a totally non-polluting, renewable, natural source of power to fuel our economy. *Vital to this, are the techniques now being envisioned for oceanic wind-power harvesting that eliminates most of the drawbacks of land-based wind power harvesting, while maximizing harvest yield. These techniques offer both high-risk and high-reward. Other than minimal private contributions, this area of research has not been funded to date.*

THE HYDROGEN ECONOMY?

In his 2003 "State of the Union" address, President Bush made a strong public statement for support and cooperation with the Euro-nations concerning development of the so-called *Hydrogen Economy*. Much has been written about the possibility of a hydrogen economy. In short, "an economy that derives most of its energy needs from hydrogen ". Such a definition is of course misleading since hydrogen serves merely as a media for conveying energy from intrinsic sources of its origin to the point of end-use, and is, in and of itself, not an intrinsic energy source (such as is petroleum, solar flux, wind, tide, geothermal, nuclear, etc). Hydrogen must be *created at the expenditure of* actual intrinsic energy sources before it can fulfill its role in the economy. The generic concept of an *energy conveyor* has been even further exemplified by proposals to use other media in this role, for example; the "Lithium Economy" (where Lithium facilitates electrical storage devices as an energy conveyance), or the "Liquid Nitrogen Economy" (whereby the low heat content of liquid Nitrogen is used to run "Stirling engines" to produce useful work), or the "Electron Economy" (in which energy is conveyed to points of need via electrical transmission), etc.

Simplistic claims that elemental hydrogen can meet virtually all forms of energy utilization is likely naïve. For example, while much has been written about the development of hydrogen fuel-cells for powering consumer vehicles, it has become common wisdom that it is both imprudent and impractical to use elemental hydrogen in consumer vehicles. Even automakers have abandoned serious attempts to design and deploy vehicles using hydrogen fuel. It will probably prove both unsafe and impractical to carry hydrogen on-board vehicles due to:

- Hydrogen's highly explosive nature,
- Problems with containment,
- Its *low volumetric energy density* (for example, it will not be used any time soon to fuel aircraft due to fuel tank volumetric implications),
- Its chemical reactivity with metals that can degrade tanks and plumbing, thus requiring regular inspection and expensive initial construction, and,
- When used in liquid form, its extreme low temperature that requires complex tank insulation and necessary boil-off.

Other, major problems have been identified related to the inefficiencies inherent in expending *intrinsic renewable energy sources* to generate hydrogen which is consequently used *merely* as an energy conveyor (Ulf Bossel, "Does a hydrogen Economy Make Sense?" Proceedings of the IEEE. Vol. 94, No. 10, October 2006). For instance, it is estimated that using hydrogen *fuel cells* to power vehicles would be only a 20% efficient usage of a renewable AC power source (if used to produce the hydrogen). This is compared to a 70% efficiency if vehicle batteries were simply *charged directly* via the same renewable power source. This speaks for vehicles being powered by storage batteries rather than fuel cells, and indicates the essentially unavoidable advent of the fully electric auto era if we are to achieve fossil fuel independence. This also plays right into this white paper's scenario for a re-definition of what should constitute a "hydrogen economy".

CAN THE "HYDROGEN ECONOMY" BE SALVAGED?

Likely, the conventional definition of the hydrogen economy will not withstand the test of analytical scientific scrutiny and practical implementation. Major issues facing the conventional hydrogen economy are given below.

Issue 1: The amortization (or neutralization) of the **end-to-end inefficiencies** inherent in the **pervasive usage of hydrogen** as a means of energy conveyance across the wide spectrum of consumer needs.

Issue 2: The **cost and disruption** related to the implied **infrastructure impact** necessary to proliferate hydrogen usage into the many roles conventionally envisioned within the hydrogen economy.

Addressing and answering these issues will point the way to a new definition of the hydrogen economy.

ADDRESSING ISSUE 1

Suppose that a plentiful, cheap, renewable source of hydrogen were available (this is addressed later in this white paper). Such a hydrogen source would defuse these inefficiency arguments used to counter-indicate hydrogen's role in eliminating our Nation's fossil fuel dependency and carbon-footprint. In defense of hydrogen as an energy conveyor, it should be pointed out that hydrogen has the particularly endearing attribute that for industries requiring *process heat*, hydrogen (as opposed to Lithium and Liquid Nitrogen, for example) can be *combusted directly* to meet this need in an efficient and zero-polluting fashion. This is an attribute that is unique only to hydrogen and electrons amongst the many proposed energy conveyors. Note that electrical power of course would suffer *transmission line losses* in being conveyed to the point of such end use for simple conversion to industrial heat.

If non-fossil-fuel generated electrical power could replace even just the present uses of conventional electrical power (ie. industrial and domestic), this would indeed be a significant reduction in both fossil fuel dependence and carbon footprint for our Nation. If one further envisions the conversion of ground transportation to (renewably provided) battery electrical power, then our Nation will have completely eliminated its dependence on petroleum down to those applications that *no other energy-form will currently satisfy* such as aircraft fuel, plastics production, chemical industry; this remaining need can probably be met by our Nation's own domestic petroleum and gas resources.

SUMMARIZING THE RESPONSES TO ISSUE 1

By devising a *plentiful, cheap source of renewable hydrogen* to replace fossil fuel in existing conventional power plants, then simply energizing the existing national electrical grid with this power supplied by a renewable, non-polluting energy source, a major step will have been taken to enhance our Nation's energy security and minimize its carbon footprint!

ADDRESSING ISSUE 2

While issue 2 might be construed to represent a significant impediment to adopting a hydrogen type economy, examining this briefly should neutralize such concerns.

Consider Power Generation, Distribution, and Utilization.

- A network of required electrical power generation facilities already exist in the form of conventional fossil fuel based power plants, and primarily need to have only their *heating systems* modified (note: *down-stream* from the heating process, the resulting steam that powers the turbines would now simply have origin from a different combustion process, and would thus need no retrofitting).

- These power plants are already conveniently integrated into our Nation's electric power grid.

- By restricting the use of hydrogen to only utility plants, elemental hydrogen will then be safely handled only by qualified personnel. The consumer then does not have to deal with the dangers and expense of maintaining hydrogen in their personal infrastructure (such as vehicles, homes, etc).

- After homes and industry are provided with clean, renewable power (which is already seen above to be possible with minimal disruption), essentially all that is left is the vehicular transportation issue. This aspect of evolutionary change can be accomplished, in a minimally disruptive fashion, at the convenience of the national economy.

A GRACEFUL TRANSITION TO A HYDROGEN-ASSISTED-ECONOMY

The answers and solutions to the issues addressed above give rise to a new paradigm for using hydrogen; This paradigm will be termed the **Hydrogen-Assisted-Economy (HAE)**. How would we make a transition in a practical and expeditious fashion to the HAE, thus leading the way to the alleviation of our Nation's fossil fuel dependency?

One of the major advantages of a conversion to the HAE is that the entire process can be accomplished in a completely controlled, step-wise, evolutionary fashion. Below are the steps that would be taken:

1. Develop the renewable hydrogen source. No infrastructure modification would even be attempted <u>until</u> the hydrogen generation systems were proven operational. **Addressing this issue is the primary thrust of this white paper**.

2. Execute a staged-controlled-sequential conversion of <u>existing</u> fossil-fuel electric generation plants into using hydrogen in place of fossil fuel as their heat source. Note: upon completion of this step, we will have effectively converted all <u>existing</u> conventional electrical power usage (both domestic and industrial) to the renewable hydrogen base, but

will have accomplished this gradually, with no societal impact, and with a minimum, controlled, infrastructure impact.

3. Introduce and proliferate electric vehicles for use in *local city travel*, with battery re-charge accomplished via existing domestic electrical access.

4. As electric vehicle technology continues to improve, introduce and phase-in all-purpose electric vehicles with inter-city range. This step would be complemented by the addition of high-capacity *re-charge facilities* at existing conventional *gas stations*.

This leaves one question now unanswered, which is addressed immediately below.

WHERE DOES THE HYDROGEN COME FROM

Current commercial hydrogen production techniques have significant carbon foot prints (at many levels, ranging from their "raw-ingredient dependency upon fossil compounds", to the "energy sources required for the chemical transformations". Hydrogen thus produced is of absolutely no value whatsoever in achieving the HAE. Creation of the required hydrogen with minimal resulting *carbon foot-print* implies water electrolysis via renewable electric power. Since electrolysis requires electrical power, it would make no sense to use *domestically produced forms of renewable electrical power* to make hydrogen, which would in turn, then be combusted in power plants to make electrical power again! This would be clearly an insane modus operandi. In fact, the only intelligent thing to do with all existing forms of renewable electrical power in existence today would be feed them directly back into the grid, so as to further enhance the overall national energy security level.

What is of great significance in our quest for cheap hydrogen is that ***there has been identified a unique source of hydrogen that is NOT obtainable on domestic soil!***

ACHIEVING THE RENEWABLE HYDROGEN SOURCE

One of the foremost potential areas of renewable power production being examined today is wind power. *Conventional* wind power harvesting technology has become a highly sophisticated discipline, and is probably nearing its zenith of achievement and efficiency.

Harnessing of wind power via wind turbines is the mainstay of the *conventional* wind power paradigm, but, this approach suffers from two fundamental limitations, namely,

• ***Wind Boundary Layer Attenuation:*** All conventional wind-power systems suffer from an inability to operate at altitudes where stronger and steadier winds are experienced! This is because wind in the earth's boundary layer progresses from the *free-stream wind velocity existing higher-aloft* to essentially *zero* at the actual ground surface. For medium to high wind conditions, full wind velocity (corresponding to near-winds-aloft) may not be realized until up to a 1000 meters of altitude; but, even at 200 meters altitude, the wind usually doubles over what it is at 50 meters. Since intrinsic energy content of the wind varies as the “wind speed cubed”, the available energy can be 8 times greater at 200 meters than it is at 50 meters. For conventional wind turbines, the practical height of construction results in operation only in the lower regions of the earth-wind boundary layer (the tallest turbines rarely exceed 50 meters)

• ***Size:*** To reach higher altitudes (which consequently also allows larger turbine blades) implies a higher infrastructure cost just in the form of towers to loft the turbine blades. While high towers exist in civil technology, the difference is that towers supporting wind turbines are also supporting a device (the turbine blades) whose primary purpose tends toward creating (rather than avoiding) aerodynamic drag in order to extract the wind’s kinetic energy; this works as a huge burden on the structure and the economics of wind power. Certainly, tall structures, such as *sky-scrapers*, exist abundantly, but their economic model is quite different from that of the wind turbine.

As an alternative to conventional wind turbine harvesting, Kite-based wind-power systems are also being proposed and developed. While kite systems have the ability to avoid the boundary layer limitation, a number of problems are inherent in *conventional* kite-based systems. These are,

• ***Wind Magnitude Variability:*** When the wind dies, every form of wind power generation becomes non-productive. For kite-based system, this can be quite problematic from a structural/operational standpoint. Solutions to this problem takes various forms, depending upon whether the system design requires wind to actually maintain topology (such as kite-only based systems), or systems that are held aloft by the wind itself (such as auto-gyro based systems).

• ***Wind Direction Variability:*** For extraction units with fixed bases (or other inherent directional biases) wind azimuth variation is particularly difficult to adapt to, even to the point of likely being at least one of the pivotal reasons that ground-based kite power generation has failed to attain practical fruition yet. For extraction units with rotating bases, cost of construction increases; even conventional wind turbines have a cost penalty to allow operation under variable wind azimuth.

A wind power scheme that is either immune to, or responds gracefully to, wind direction and magnitude variability and can harvest at higher altitudes, has potential for significant impact on the proposed conversion to the HAE.

The one remaining consideration for such schemes is operational location. Delivering the resulting electrical power production to the national grid implies a national continental location. But, suppose that the ideal scheme to harvest wind power were not located within our Nation’s continental boundary? In such a case, the transmission of the harvested power to the nearest grid entry point becomes problematic.

A typical situation that could result in such a conundrum would be *wind power generation at sea,* which enjoys many attractive attributes. Various ideas have now been put forth to harvest wind power in the oceanic environment. These vary in their designs, but most enjoy one or more of the benefits of oceanic harvesting, namely:

1. Since such a system may be free to roam the oceans in search of wind, these generators can "freely follow the synoptic wind patterns", whereas the land-based schemes depend upon synoptic weather patterns that happen to impact their geographical location at any particular point in time. This free roaming ability thus minimizes (or eliminates) the “no-wind” down-time problem of fixed based systems.

2. Some ocean-based schemes can be made insensitive to Wind azimuth variability, in fact they might simply follow the wind azimuth as a natural aspect of their “wind-chasing attribute” (described in item 1 above).

3. The real estate needed as a base-of-generation-operation is free and plentiful.

4. Since ocean-based systems would likely employ kite-based technology, they can more easily neutralize the *boundary layer limitation*; furthermore the boundary layer has minimum depth over smooth surfaces such as the ocean, thus making it even easier to minimize its deleterious effects.

5. There would be minimal to no interference with air travel for those schemes that project significantly in altitude.

So, ocean based systems may present great benefits for wind-power extraction. However, they would suffer from the problem of delivering their power to the grid. **One solution to this would be to use hydrogen as the conveyor of the harvested energy; conveniently, hydrogen is also the prime ingredient for the HAE**. For example, hydrogen could be created at sea by *high-pressure electrolysis* of water into hydrogen and oxygen and then simply transported back to land to fuel HAE power plants!

SO, WHAT DOES THIS MEAN TO NIST?

To support the above outlined practical and effective conversion to a Hydrogen Assisted Economy (HAE) to create essentially a fossil-fuel free National environment, the generation of abundant, cheap, and renewable hydrogen must be achieved. This could be potentially accomplished using wind power systems roaming the oceans. These would use hydrogen as the media of energy conveyance to the conventional electrical power plants that had been converted to the hydrogen-fueled HAE scheme.

<u>The one remaining issue to address</u> would be the envisioning of such a wind-power harvesting system, followed by a thorough systems and operation analysis to determine end-to-end efficiency in creating hydrogen from wind using such a scheme. *Since the raw*

input energy (wind power) is free, then the only costs involved in producing the hydrogen is the capital to build the wind-harvesting device, operate and maintain it, and finally transport the hydrogen to land. The end-to-end efficiency implied in these steps does not have to attain any particular pre-conceived level, as per, quotes such as "using hydrogen at 20% efficiency is prohibitive for a successful hydrogen economy"; all that is required is that such systems operate at a reasonable profit margin that makes them attractive as a capital investment. While such margins would of course depend upon the cost of alternative forms of energy, other compelling reasons for adopting such an approach could hinge upon how critical it is to minimize carbon foot-print, and to attain energy security for our Nation.

WHAT NEEDS TO BE DONE NEXT

Neither Land-based **nor** Ocean-based Kite power generation has received **any governmental funding**. This is likely because it is relatively new amongst renewable power generation schemes and (while possessing possible high-reward), also represents high risk.

The NIST/TIP program could significantly advance our understanding of a proposed Hydrogen Assisted Economy and its related power source by recognizing the need to investigate such an ocean-based scheme, and (1) instigating research and design-analysis to the point of reliably identifying the end-to-end efficiency of operation, (2) ascertaining its hydrogen production potential, and finally (3) identifying costs to a level that a reliable profit margin for such an endeavor could be calculated for comparison to other alternatives proposed to render our Nation independent of other-nation sources of petroleum.

This would be done by the issuance of a request for grant proposals to accomplish a thorough understanding of such systems and their promise as a means to facilitate a Hydrogen Assisted Economy.

WHO IS INTERESTED IN RESPONDING TO SUCH A NIST RFP

The international Drachen (kite) Foundation for the last 8 years has played an active role as a point of contact in the field of kite power generation within our Nation. In this roll they have identified a body of talented researchers and technicians covering the spectrum from individuals to companies that are vitally interested in furthering kite-wind power to assist in the attainment of National energy security. The authors of this white paper have identified at least 6 companies (that would qualify as interested small businesses), 3 universities, and 70 unrelated individual specialists (engineers, scientists, experimenters, kite designers, etc), all of whom have contacted the Drachen Foundation of their own volition seeking information on all aspects of kite-power generation development.