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EPIC Idea Exchange

As described in the attached, Chemergy is developing two processes for the recovery of hydrogen from waste feedstocks. Chemergy proposes a â‰ˆ$3 million, 24-month a pilot demonstration of a system capable of processing 1-3 wet-tons of wet-biowaste daily. The demonstration program would be at the Naval Air Warfare Center Weapons Division (NAWCWD) at China Lake. CA. Chemergy and its subcontractors will provide the detailed engineering plans and specs developed under an earlier program with the Navy providing a site, biowaste feedstock, utilities, PEM fuel cell stacks and participate in system integration, operation, evaluation and analysis. NAWCWD has committed $1.8 million in cash, goods, manpower and services toward the program. The proposed pilot program will produce hydrogen from biowaste, which is then converted to electricity to meet two buildings electrical demand. The pilot system will meet 100% of the buildings' daily electrical load and 100% of its annual electrical use, enabling zero net energy buildings. The Chemergy team is seeking â‰ˆ$1.2 million in additional funding from EPIC.

Additional submitted attachment is included below.

Introduction to HyBrTec:
Producing Hydrogen from Waste

Chemergy, Inc.

Chemergy was incorporated to develop and commercialize technologies that produce low-cost, distributed hydrogen from waste feedstocks. These technologies, collectively called HyBrTec, produce hydrogen from bio- and sulfurous-waste. Both feedstocks have negative-value, are highly-controlled, burdensome and regulated environmental pollutants. Biowaste feedstocks include: sewage, manure, agriculture-residuals, paper & wood wastes; any wet-cellulosic organic material. Sulfurous-wastes include hydrogen sulfide and sulfur dioxide as found at oil refineries, oil & gas wells, landfills, power-plants and wastewater treatment plants.

Conventional Hydrogen Production

Most fossil-based hydrogen is produced by steam methane reforming (SMR) and renewable hydrogen from the electrolysis of water. Without considering plant efficiency, capital or operating costs, hydrogen from SMR has a minimum value of 1.45 times the price of methane; an essential and valuable commodity. In addition, for every ton of hydrogen produced by SMR, 10 tons of greenhouse-gas carbon dioxide is co-produced and released from the feedstock and processing. The electrolysis of water requires a clean, pure feedstock and requires more energy that what the hydrogen will produce when reacted with oxygen (air).

Competitive Advantage

HyBrTec offers distinct advantages over conventional hydrogen production processes:

- Its feedstocks are abundant, ubiquitous, have a negative-value and are an environmental and economic burden to process and dispose.
- HyBrTec exploits two advantages that reduce capital and energy:
  - At moderate temperature & pressure processing is fast and yields are high, which minimizes the size, footprint and cost of equipment.
  - The chemical bonds to release hydrogen are weak, requiring less than half the energy (40%) then what hydrogen will produce when burned with oxygen (air).
- HyBrTec is a highly scalable technology able to process lb/day or tons/minute with commercially available components on-site where feedstocks are available.
- With electricity from renewable energy resources, HyBrTec is GHG neutral.
- HyBrTec offers a profitable economic triad: 1) eliminates waste where it's produced 2) produces $2/kg hydrogen and 3) co-provides efficient energy storage, which promotes developing distributed micro-grids.
- $2/kg hydrogen fueling a 50% efficient fuel cell is equivalent to gasoline at $1/gallon without the harmful 'well-to-wheels' environmental and health effects.
- Accrues State and Federal renewable-energy tax incentives, loan guarantees, GHG cap & trade programs and electrical energy storage subsidies.

Water electrolysis and SMR have markets according to availability of feedstock, energy prices, and subsidies or as public-works projects. However, neither have the long-term potential of HyBrTec by providing a healthy return-on-investment, eliminating disposal issues, recovering hydrogen and having an energy storage capability; at a scale suitable for a household appliance, to the needs of an industry or that of a major city.

Opportunity Processing Biowaste

In the U.S., waste-water treatment plants (WWTP), municipal solid waste, confined area feeding operations, and agriculture produce over 1 billion tons of biowaste annually that requires costly treatment before beneficial use or disposal. Significant amounts of this material cost from $40-$200 per wet-ton to dispose. There is a growing amount of economically and environmentally burdensome biowaste produced each year.

Furthermore, an estimated 3-4% of total U.S. electricity consumption is used for the transfer and treatment of water and wastewater, corresponding to more than 45 million tons of GHGs annually. The U.S. produced 7.9 million tons of biowaste in 2014. The latent energy in this biowaste could meet 12% of the nation's electricity demand. A 10 million gallon/day WWTP producing 7 tons/day of biowaste will require 11 to 17 MWhe of electricity daily. HyBrTec allows WWTPs to be energy independent and producers of thermal energy and renewable fuel.

Fuel and electricity represent a substantial cost to wastewater utilities; one is required for nearly all stages in the treatment process, from the collection of raw sewage to the discharge of treated effluent. Since water-energy issues are of growing importance in the context of water shortages, higher energy and material costs and a changing climate, a solution to the biowaste management problem is needed and timely.

HyBrTec processes wet organic biowaste into hydrogen, non-anthropogenic carbon dioxide, thermal energy and inorganic residuals suitable as a micro-nutrient fertilizer. Feedstocks include: sewage, manure, wood & agricultural residuals and municipal solid waste; any wet organic carbonaceous material that contains unused solar energy. Unique to HyBrTec is that 175-200^{o} C heat is released in processing, which can be used to reduce the feedstock water content to a desirable 50%. Also, 2-3 gallons of potable water is co-produced with each pound of hydrogen. Furthermore, if the residual energy content of the biowaste is omitted, the process offers a biowaste-to-hydrogen-to-energy efficiency greater than 100%. Byproduct carbon dioxide, which is organic in origin and not considered a greenhouse gas, is vented, or used to synthesize other commodities including conventional liquid fuels, i.e. ethanol, methanol, 'green' diesel, etc. using well-established processing.

Opportunity Processing Sulfurous-waste

Hydrogen sulfide contaminates oil and gas wells, corrodes pipelines and equipment, is a poisonous byproduct waste from oil refineries and is often flared to reduce its environmental impact. Sulfur dioxide is a regulated emission from coal- and high-sulfur oil-fired power plants. Chemergy's HyBrTec technology removes hydrogen sulfide and sulfur dioxide from gas-streams, including sour- and flue-gas effluent as recovered hydrogen, sulfur or sulfuric acid without consuming reagents in a regenerative process.

Petrochemical processing requires hydrogen to remove sulfur as hydrogen sulfide from gasoline, diesel, jet fuel and fuel oils through hydrodesulphurization. The U.S. has 150 refineries capable of processing over 18 million barrels of crude oil daily, which must be sulfur-free. The amount of hydrogen consumed in desulphurization depends of the sulfur content of the crude oil. Desulphurization requires 1 lb. of hydrogen for every 16 lbs. of sulfur removed, producing 17 lbs. of deadly hydrogen sulfide that refineries must further process into elemental sulfur, water or sulfuric acid. The sulfur content of crude oil has been increasing, a trend likely to continue for the foreseeable future.

The table below indicates the approximate hydrogen consumption in Standard Cubic Feet (Scf) per barrel (Bbl) of petroleum throughput.

Refinery Process	Type of Process	Purpose	Hydrogen Consumption (Scf/Bbl)
Hydrocracking	Conversion	Yield Improvement	1200-2500
Hydrotreating	Treating	Yield Improvement	800-2000
Naphtha Hydrotreating	Treating	Sulfur Control	25-200
Distillate Hydrotreating	Treating	Sulfur Control	250-1000

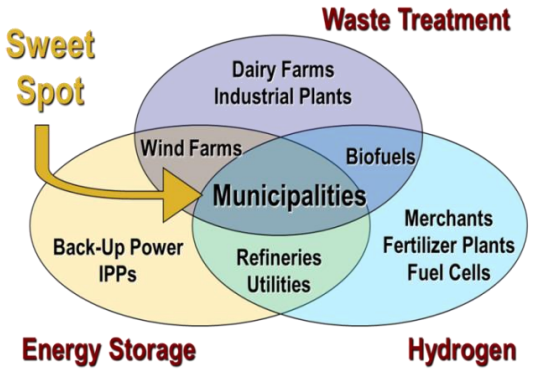
In 2014 approximately 467,000 tons of hydrogen valued at over $500 million was consumed by U.S. refineries desulphurizing their petro-products. Globally, the industry consumed over 4 million tons of hydrogen removing over 64 million tons of sulfur from hydrocarbons. Investments in SMR for producing hydrogen for use in desulphurizing are “stay-in-business” investments. The investment does not yield a ROI, it simply enables the refinery to meet standards on the sulfur content of fuels and thereby remain in business. In contrast, an investment in HyBrTec allows a refinery to recycle and reuse hydrogen lost in desulphurization.

Flaring, illustrated at right, is the practice of burning gases that are deemed uneconomical to collect and sell or present a safety problem. When sour-gas is co-produced as a byproduct of oil extraction operators will often flare the gas to convert the highly toxic hydrogen sulfide gas into less toxic compounds. Depending on the composition of the gas being burned and the efficiency and temperature of the flare, flaring pollutes the air, contributes to climate change, deprives operators of revenue and wastes the unrecovered methane resource.

If flaring isn’t possible wells are capped. Removing hydrogen sulfide from sour-gas would allow reopening these wells and the monies associated thereof along with the addition value of the now sweetened gas, hydrogen and sulfur. Hydrogen sulfide is also a burdensome byproduct of sewage treatment and dilute (non-lethal) but significant quantities are produced in landfills and agricultural anaerobic digesters. Eliminating hydrogen sulfide *and* producing hydrogen from these sources will allow exploiting untapped sour- and bio-gas resources. Recovered hydrogen can be added to the now-sweetened methane, increasing its Btu content and reducing NOx emissions when burned.

In Summary

HyBrTec affords an application triad co-addressing three emerging high-value global opportunities: waste treatment and disposal, hydrogen production, and energy storage. This provides three revenue streams, which maximizes asset utilization. Applications include power generation, agriculture, oil & gas industries, transportation, and the ‘market entry sweet spot’ of municipal WWTPs.



Next Steps

Chemergy has taken the HyBrTec processes through the primary Technical Readiness Levels (TRL) beginning with a TRL-1 (Basic principle observed experimentally), and through TRL-5 (Bench-top system experimental validation) with private, federal and state funding. Remaining TRLs for both bio- and sulfurous-waste processing include: TRL-6 (Prototype system verification), TRL-7 (Integrated pilot system demonstration), TRL-8 (Systems incorporated in a commercial plant) and TRL-9 (Systems proven and ready for full commercial deployment).

Chemergy's near-term goals include demonstrating a prototype system for processing hydrogen sulfide & sweetening sour-gas and operating pilot plant processing 1-3 tons of biowaste daily with energy storage as part of a micro-grid. The long-term goal is to develop, manufacture and market an UL certified residential appliance for processing kitchen, toilet, postal and yard waste into hydrogen & heat. Chemergy anticipates that as goals are met, investment from stakeholders and licensing fees will fund the programs leading to the commercial deployment of systems as projected in the table below.

Program	Goals	Cost	Time
Sour-gas processing: H2S removal, sweetening and hydrogen enriching sour-gas			
Prototype	Process and system demonstration for industry stakeholders burdened with hydrogen sulfide	$400K	12 Months
Field Demonstration	Containerized portable system for on-site demonstrations at facilities, well-heads, etc.	$2M	18 Months
Commercialization	Manufacturing, assembly and delivery of standardized and specialized systems	$5M	12 Months
Wet bio-solid processing: produce hydrogen, carbon dioxide and heat at a WWTP			
Pilot Plant	Heavily instrumented system with extra-robust equipment for extensive testing & evaluation	$3M	24 Months
Demonstration Plant	Fully continuous scaled up system based on pilot design using larger commercial equipment	$5M	24 Months
Commercial Product	Modular commercial products in two sizes: Alpha (10 wet tons/day) then Beta (40 tons/day)	$12M	30 Months
Residential Appliance	Develop prototype (year 1-2); UL certified product (year 2-4); manufacturing 20K units/yr (year 5)	$20M	60 Months

Let's Stop Wasting Waste

HyBrTec eliminates the cost of bio- and sulfurous-waste processing and disposal by producing $2/kg hydrogen, which will promote an energy paradigm shift from: 1) costly resources to negative-valued resources, 2) large, expensive, centralized plants to small, low-cost, distributed systems, 3) collection, transporting, processing and disposal to on-site waste-resource utilization. In 1911 GE introduced a home refrigerator, which at the time cost twice as much as a car and did not provide a ROI; however, its convenience doomed the well-established centralized ice houses and their distributed delivery infrastructure.