Introduction to HyBrTec

Recovering Hydrogen from Wastes

Most non-renewable hydrogen is produced by steam methane reforming (SMR) and renewable hydrogen from water electrolysis. Without considering efficiency, capital or operating costs, hydrogen from SMR has a minimum value of 1.45 times the cost of methane. In addition, for every ton of hydrogen produced by SMR, 10 tons of greenhouse gas (GHG) carbon dioxide is co-produced and released from the feedstock and processing. The electrolysis of water requires a pure feedstock and considerably more energy than what the hydrogen will produce when reacted with air. Chemergy's patented HyBrTec process efficiently recovers hydrogen from wastewater, biowaste and sulfurous wastes. These hydrogen-rich liquid, solid and gaseous waste feedstocks all have negative-value, are highly-regulated environmental pollutants and are an escalating economic burden to industry, commerce and the public.

Biowaste is any organic cellulosic material including sewage, manure, municipal solid waste, agricultural residuals, paper, kitchen & yard waste, and plastics. Sulfurous-wastes include gaseous hydrogen sulfide and sulfur dioxide found at oil refineries, oil & gas wells, power & sewage treatment plants and landfills. Wastewater is any water contaminated with organic and/or inorganic material including biowaste, fertilizers, pesticides, carcinogens, microbes, pathogens and emerging waterborne contaminates containing pharmaceuticals, personal care products and endocrine disrupting compounds.

Unique to HyBrTec is that 175-200ºC heat is released in processing and 4-6 gallons of potable water are co-produced per kilo of hydrogen recovered. If the hydrogen is used as a fuel and any residual energy content of the negative-valued feedstock is omitted, the process offers a waste-to-hydrogen-to-energy efficiency greater than 100%. Byproducts are elemental sulfur, sulfuric acid or carbon dioxide depending on the feedstock. Sulfur or sulfuric acid from sulfurous waste are valuable commodities. The carbon dioxide from processing biowaste is organic in origin and not considered a GHG, which can be vented or used with recovered hydrogen to synthesize fertilizers and conventional fuels, i.e. ethanol, methanol, 'green' diesel and natural gas. In addition, HyBrTec co-provides an efficient energy storage capability, which increases the value and use of intermittent solar & wind energy resources, promotes well-distributed micro- & smart-grids that exploit local energy resources, reduces capacity demands and mitigates disruptions.

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, which requires $40-$200 per ton to process before use or disposal with costs increasing annually. In 2014 3-4% of total U.S. electricity consumption was used by WWTP; producing 7.9 million tons of biowaste and releasing 45 million tons of GHG annually. The latent energy in this biowaste could meet 12% of the nation's electricity demand. Fuel and electricity are required in all stages of the treatment process, representing a substantial cost to WWTP. In contrast to being a public economic, energy and environmental burden, HyBrTec allows WWTP to be energy independent and profitable. Due to water shortages, higher energy & capital costs and climate issues, water-energy concerns are of growing importance to WWTP.

One of the lesser known dangers of oil and gas production is hydrogen sulfide. This deadly gas is a common by-product of oil and gas operations globally. Exposure to the gas can stop a person's breathing at levels of 500 parts per million. At 700 parts per million, it can make people unconscious. It is also a corrosive, making it more likely that oil storage tanks where hydrogen sulfide is present will leak. Moreover, the gas deadens the sense of smell, so people exposed to hydrogen sulfide are less likely to recognize the danger they face. Hydrogen sulfide contaminates oil and gas wells, corrodes pipelines and equipment, and is a highly poisonous industrial byproduct waste that is often flared to dispose and reduce its environmental impact. Sulfur dioxide is a regulated emission from coal- and high-sulfur oil-fired power plants. HyBrTec sweetens sour-gas and cleans flue-effluent by recovering hydrogen and sulfur without consuming reagents in a regenerative process.

Petrochemical processing requires hydrogen to remove sulfur as hydrogen sulfide from gasoline, diesel, jet fuel and oils through hydrodesulphurization. The amount of hydrogen consumed 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 hydrogen sulfide that must be further process into sulfur and water or sulfuric acid. Annually over 500,000 tons of hydrogen valued at over $1 billion 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. Investing in hydrogen for desulphurizing is a "stay-in-business" investment. 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. The sulfur content of crude oil is increasing, a trend likely to continue in the foreseeable future.

As a hydrogen production technology, HyBrTec promotes an economically sound C^4 paradigm shift away from:

1) Costly non-renewable resources to environmentally hazardous and negative-valued wastes,
2) Capital intensive large central plants to small well-distributed and mass-produced systems,
3) Collecting and transporting waste feedstock to using it onsite where produced.
4) Climate changing fuels to climate neutral hydrogen.

HyBrTec Development Programs

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 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).

Of the HyBrTec technologies for the recovery of hydrogen from waste feedstock, the processing of hydrogen sulfide is the simplest and least expensive to take to the next TRL. Flaring, illustrated at right, is the practice of burning gases that are contaminated with hydrogen sulfide and are uneconomical to collect and sell or present a safety problem. When sour-gas is co-produced, operators will often flare the gas to convert the highly toxic hydrogen sulfide contaminate into less toxic compounds. Flaring pollutes the air, contributes to climate change, deprives revenue and wastes the methane resource. Stakeholders burdened with sour-gas flare when allowed. https://viirs.skytruth.org/apps/heatmap/flaringmap.html#lat=29.43243&lon=15.26825&zoom=3&offset=15 The World Bank reports that 150 to 170 billion m^3 of sour-gases are flared annually, valued at about $30.6 billion.

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

Chemergy's goal is to demonstrate a TRL-6 prototype system for processing hydrogen sulfide and sweetening sour-gas. Chemergy is seeking a $350K investment to fund a laboratory bench-top prototype system as a demonstrator for industry stakeholders. It is anticipated, that subsequent to successful pre-commercial demonstrations, as an alternative to flaring, or well-capping stakeholders would provide revenue through contracting or licensing agreements based on the value of re-opened wells, recovered hydrogen and the methane not flared.

Program	Goals	Cost	Time
Sour-gas processing: hydrogen sulfide removal, sweetening and hydrogen enriching sour-gas			
Prototype	System demonstration for stakeholders burdened with hydrogen sulfide	$350K	Months 1-6
Field Demonstration	Containerized portable system for on-site demonstrations at oil refineries, well-heads, etc.	$2M	Months 6-18
Commercialization	Manufacturing, assembly and delivery of modular standardized and specialized systems	$5M	Months 12-24

In addition, Chemergy is seeking $500K in investment to design, assemble, test and evaluate an EDM prior to a pilot plant demonstration processing biowaste. The anticipated programs for commercializing are illustrated below.

Program	Goals	Cost	Time
Processing any wet organic biowaste including: sewage, manure, MSW, agri-residuals, plastics, etc.			
Engineering Development Model	Heavily instrumented in-house system for systematic characterizing operating conditions with various feedstock	$500K	Months 1-6
Pilot Plant	Heavily instrumented containerized system with extra-robust equipment for extensive field testing & evaluation	$2M	Months 6-30
Demonstration Plant	Fully continuous scaled up system based on pilot design using larger commercial equipment.	$5M	Months 24-48
Commercial Plant	Modular commercial products in two sizes: Alpha (10 wet tons/day) then Beta (40 tons/day)	$12M	Months 36-48
Residential Appliance	Develop prototype (year 1-2); UL certified product (year 2-4); manufacturing 20K units/yr (year 5)	$20M	Months 6-60