Complete Resource Recovery: C, N, P, K, & metals

Topic Solution Summary

The Ocean Foresters propose to replace aerobic and anaerobic digestion and landfills with complete resource recovery, for blends of biomass which can be pumped. The replacement, Hydrothermal process (HTP) combined with ammonia recovery, concentrate and move energy, nutrients, and metals from places of excess to places of need. For example, recover energy, nutrients, and metals from municipal wastewater, municipal solid waste, dairy farms, mining slag, and ocean dead zones. Sell the energy and metals. Move the nutrients to land and ocean farms.

The Genifuel HTP separates energy (carbon-hydrogen) from nutrients (phosphates, ammonia, sulfur, potassium, metals). The energy can be either all biogas (60% CH_4: 40% CO_2) or a bio-oil and biogas. Phosphates and sulfur precipitate early in HTP. The nitrogen becomes 2% aqua ammonia in clear water output from the HTP. The PRD Tech ammonia recovery unit concentrates the ammonia to dry powder ammonium sulfate or other ammonia products.

Most "wastes" and many biofuel plants are wet, less than 40% solids or more than 60% water. Dewatered municipal sludge is 15 to 30% solids. Seaweeds are 10 to 14% solids with loose water shook off. With HTP, maximum energy efficiency is with about 30% solids, but materials as wet as 10% solids may be processed economically. The feedstock can be any carbon source, including: municipal wastewater sludge, cattle or swine manure, hazardous or non-hazardous wastes, municipal solid waste, cafeteria or packaged supermarket food waste, used lubricating oil, grass, drugs, old paint, leaves, woodchips, plastics (including Styrofoam), paper, cardboard, food processing waste such as animal parts, etc.

HTP converts nearly all the nitrogen in the feedstock to ammonia. The ammonia and any metals from the feedstock are dissolved in the clear pasteurized effluent water. PRD Tech is developing a process to recover/concentrate the ammonia into a commercial grade 19% aqua ammonia, or ammonium chloride, or dry powder ammonium sulfate, or ammonium bicarbonate. The production of ammonium bicarbonate would scrub the CO_2 from the biogas. Processes also exist to recover metals from the clear water.

Submission and Supporting Evidence

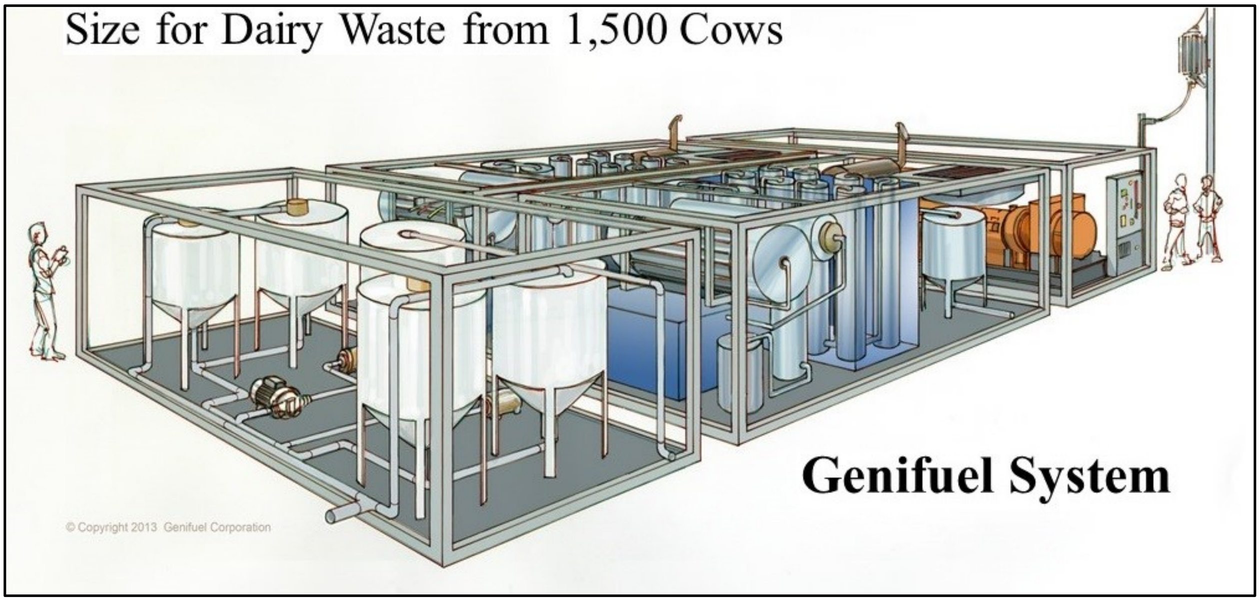

Figure 1 – 1,500 dairy cows would produce about 100 wet tons/day of fresh manure

Technical feasibility – Genifuel has built and sold two HTP units capable of continuous automatic processing 1 ton/day of wet material. The customers are operating the units. Pacific Northwest National Laboratory (PNNL), Water Research Environment Foundation (WERF), and Genifuel have tested assorted feedstocks. WERF and about 10 municipal and industrial wastewater facility partners funded a bench scale evaluation of HTP as applied to wastewater sludge. WERF has completed the experimental work on a pilot-scale HTP demonstration. Internal reviews should be complete and the report ready for publication before the site visit meeting. The site visit is scheduled for February 17 and 18, 2016 at the Pacific Northwest National Laboratory in Richland, Washington.

Genifuel has a design for a 20-wet ton/day unit. If every home at a refugee camp or early arrivals at a slum had a feces-separate-from-urine collecting toilet (poop in a bag), the 20 ton/day unit would be appropriate for 20,000 people. The fresh feces would average near the ideal 25% solids. Several companies are producing appropriate toilets, such as Sanivation.com.

PRD Tech has sold one commercial Ammonia$^+$ Recovery (A^+ R) unit concentrating 7,500 mg/L of ammonia-N at the rate of 1 gpm (equivalent to 6 tons/day of water). The product is to 7% (70,000 mg/L) ammonium chloride-N. The customer requested that the effluent water be 400 mg/L ammonia-N, although it could be as low as 5 mg/L –N with very little additional cost. PRD Tech is building a similar size pilot for a trial at Southern California wastewater treatment plant starting in April 2016

The Ocean Foresters are looking for a customer interested the combined HTP and A^+ R paid over time as explained in the Sustainability Committee's entry "Incentive-for-Performance: Leaping the "Valley of Death"" Team members have found funding for, designed, and built innovative wastewater treatment plants both smaller and larger than the proposed HTP unit. One such treatment plant earned "Deal of the Year" from the local business community.

Risk factors – The primary technical risks are cost related: feedstock preparation; and feedstock blending to increase pumpable % solids. The customers and potential manufacturers on the team are well versed in handling the potential feed stocks. For example, the team will access recent improvements in wastewater grinding developed specifically to convert non-disintegrating wipes (and everything else in wastewater) into small particles (less than 6-mm long/wide). Another wastewater technology is mixing polymers or corn stalks with sludge, similar to mixing waste oils or plastic chips into sludge.

Safety risks are similar to boilers and furnaces. While HTP's temperature and pressure are high, the product transformations are not strongly exo-or endothermic. This makes it less expensive to safely increase scale, unlike supercritical water processes which have similar pressure and temperature, but a strongly exothermic reaction. HTP is also quick and simple, compared to the drying equipment for pyrolysis or the fermentation processes of ethanol and bacterial biogas production. (Supercritical water, pyrolysis, and fermentation can be other resource recovery processes.)

Current Stakeholders in HTP:

Water Environment Research Foundation (WERF)
Contact: Jeff Moeller, Director of Water Technologies (jmoeller@werf.org)

- WERF is hosting an open house to conclude their HTP demonstration at PNNL in Richland, Washington, February 16-18
- Pacific Northwest National Laboratory (PNNL)
  Contact: John Holladay, Manager, Biomass Sector (john.holladay@pnnl.gov)
- Genifuel, Salt Lake City, Utah, James Oyler, President (jim@genifuel.com)
- PRD Tech, Cincinnati, Ohio, Dr. Rakesh Govind (rgovind837@aol.com)
- Center for Sustainable Energy
  Contact: Gene Kogan, Senior Project Manager, Combined Heat and Power (Gene.Kogan@energycenter.org)
- U.S. Departments of Defense and Energy, having funded much of the PNNL research.
- Ocean Forests, Ventura, California, Mark E. Capron, President (markcapron@oceanforests.com). The Ocean Foresters are transitioning their seaweed-to-energy, food, and water concepts from anaerobic digestion to HTP.

Future Stakeholders in HTP:

Refugee camps and rapidly growing slums – New refugees and recent slum arrivals lack water distribution infrastructure for in-home/tent toilets. Also, many islands and deserts lack the water needed for flush toilets. HTP accommodates poop-in-bag private and sanitary waste handling while providing energy and jobs for the camp/slum. Eventually, people can upgrade their accommodations with relatively small diameter (perhaps overhead) water distribution and equally small greywater conveyance/irrigation/percolation systems. Or even upgrade to flush toilets with solids holding tanks. Bagged feces might be picked up weekly. Holding tanks would be pumped every few months.

Health care workers – Health care, particularly during contagious epidemics, creates biohazard wastes. HTP could recover resources from all wastes with complete pathogen destruction and supply the energy for respectful cremation of Ebola infected bodies.

Municipalities – Municipalities are considering recovering resources from foodwaste, used paint, used lubricants, and other wet wastes. These wastes are often mixed with plastics. The plastics make the products of anaerobic digestion or composting less valuable.

Miners and Remeditators – Monsanto needs to remove mercury from San Francisco Bay. Mallinckrodt needs to remove mercury from Maine's Penobscot River. The Everglades Foundation is starting a $10m challenge to recover phosphorus from waters of the U.S. Most of the excess phosphorous is from agriculture. Some plants will hyperaccumulate metals or contaminants (mercury, organic nitrogen, phosphorous). The pollutant-loaded plant can be harvested and run through the HTP, moving the metal or pollutant to HTP's clear water product. For example, when manure at 20% solids is the feedstock, the clear water will include 2% ammonia. It is relatively easy to further concentrate ammonia and metals from clear water to commercial products. The plant-to-HTP operation can be mining mercury from river sediments, nickel from mine tailings, returning organic nitrogen from an ocean dead zone to terrestrial agriculture, and the like.

U.S. EPA Innocentive announcement of Nov. 16, 2015 – The U.S. Environmental Protection Agency is partnering with the nation's top pork and dairy producers, U.S. Department of Agriculture, World Wildlife Fund, and environmental and scientific experts to host the ***Nutrient Recycling Challenge***—a competition to find affordable technologies to recycle nutrients from livestock waste and create valuable products.

When employed at a nutrient removal municipal wastewater treatment plant (WWTP) the combination of HTP and A^+ R replaces other capital and operating expenses as follows:

- HTP transforms 100% of the solids into products: eliminating landfill or farm tipping fees; eliminating drying or composting odors and associated electrical energy; eliminating concerns for plastics, pathogens, metals, pharmaceuticals, etc. in the biosolids.
- HTP's best cost-benefit is without aerobic or anaerobic digesters, replacing their capital expense, operating expense, foaming incidents, odors, etc.
- HTP's best cost-benefit is with maximum primary clarification capture, which implies much less energy for aeration during secondary water treatment.
- A^+ R saves energy by consuming $^{1}/_{5}{}^{th}$ to $^{1}/_{6}{}^{th}$ the electricity of biologically converting the ammonia from post-anaerobic digestion dewatering to nitrate.
- A^+ R leaves less than 10 mg/L ammonia-N and 5 mg/L phosphorous returning to the headworks, reducing purchase of methanol (sugar for the nitrate to nitrogen gas step) and delaying capital expenses which might otherwise be needed to increase biologic ammonia removal capacity.

Cost Analysis

The costs and net incomes of Table 1 do not reflect expense reductions possible by optimizing the waste collection system for HTP. For example, dewatering the feedstock from 16% to 32% solids would nearly halve the capital cost per cow, while the same amount of nutrients are recovered processing both filtrate and HTP clear water with A^+R. Unlike anaerobic digestion, the feed material flexibility of HTP offers options for robust (no human or animal contact) waste collection: prevent the spread of Johne's disease or coccidiosis in cattle or cholera in people, enjoy feces-in-bag privacy and security in every refugee tent, or developing world slum home. Plastics and other "contaminants" improve economics by increasing energy production.

Table 1 – Projected Incomes and Expenses for a 1,500 cow dairy

Total Wet Feedstock	100	wet t/day	combined feces and urine	
% Solids	16%			
	Products		Rounded Incomes	
Bio-oil output, $100/bbl	45	bbl/d	$1,640,000	$/yr
Bio-methane output (additional to bio-oil), $0.3/m^3	2560	m^3/d	$280,000	$/yr
Bio-CO2, $10/metric ton (highly speculative, enhanced oil recovery barely pays transportation costs near $10/metric ton)	1246	metric ton /yr	$12,000	$/yr
Phosphate, $600/dry ton-P2O5	50	dry ton/yr	$30,000	$/yr
Ammonia, $500/dry ton-N	150	dry ton/yr	$75,000	$/yr
Sulfur	4	dry ton/yr	$0	$/yr
Pasteurized clear water, less than 10 mg/L N, $1/hcf	22,700	Gallon/day	$11,000	$/yr
Pathogen destruction	"Treatment" values can save $millions relative to other treatment options.		$0	$/yr
Pharmaceutical destruction			$0	$/yr
Waste oxidation			$0	$/yr
Reduced methane/odor emissions			$0	$/yr
Reduced ammonia/odor emissions			$0	$/yr
Additional income needed to break even. This is easily exceeded by the "treatment" value of down-sizing ponds, while eliminating pathogens, pollutants, and odors. Such savings need specific case studies.			$52,000	$/yr
Total Incomes			**$2,100,000**	**$/yr**
Amortized capital expense, 20 year loan			$1,500,000	$/yr
Operating expense			$600,000	$/yr
Total Expense			**$2,100,000**	**$/yr**

This Complete Resource Recovery innovation is an example of the kind of equipment essential for the Sustainability Committee entry "Big Picture Resilience via Ocean Forests" and can be a component in the examples within Sustainability Committee entries "Public-Private Coastal Resilience Innovating" and "Designing Water Law for Future Innovation".