

Hydrothermal Processing

Overview

Genifuel Hydrothermal Processing

- **Advanced process efficiently converts wet materials to biofuels and clean water**
 - Can produce bio-crude oil, natural gas, or both together
 - More than 99% of organic matter is converted
- **Process perfected by US Department of Energy at PNNL over 40-year period with extensive testing**
- **“Solving Three Problems at Once”TM**
 - Renewable energy, wet waste disposal, clean water
 - Profitably produces renewable energy
- **System is small, fast, automated, and scalable**

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Summary Statement

- **Best technology available for converting wet wastes to renewable fuels, according to:**
 - US Department of Energy Studies
 - Three US National Laboratories
 - Top Universities
 - Major oil company
- **Winner of 2015 R&D 100 Award given to the 100 best new technologies available in the market (must be for sale—no concepts or models allowed)**

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The Problem and the Opportunity

- **Wet waste materials are everywhere, with huge quantities worldwide**
- **Wet waste treatment has often meant large-scale dumping into watersheds or oceans, squandering fresh water, energy and nutrients**
- **Government regulations are increasingly requiring difficult and expensive treatment and will continue to trend in this direction**
- **Demand and value for renewable energy and biofuels are expanding rapidly**

Process Concepts

- **Process is similar to fossil fuel formation, but faster**
 - “Does in 1 hour what nature does in 1 million years”
 - Bio-crude and gas are similar to fossil equivalents
- **Best technology available for converting wet wastes to hydrocarbon fuels**
- **Equipment is compact and highly scalable**
- **Tested on more than 100 feedstocks**
- **Fuels produced are drop-in replacements using existing infrastructure**

Partial List of Tested Feedstocks

Waste	Dairy Manure, Poultry Manure, Pig Manure, Municipal Solid Waste, Pulp and Paper Mill Waste, Plastic Bottles
Aquatic	Water Hyacinths, Kelp (Marine), Red Algae (Marine), Green Algae (Brackish), Green Algae (Marine), Green Algae (Fresh), Diatoms, Cyanobacteria
Ligno-Cellulosic	Wood Slash, Sawdust, Corn Stover, Poplar Fermentation Residuals, Wood Gasification Residuals, Cellulosic Fermentation Residuals
Herbaceous	Napier Grass, Sorghum, Sunflowers, Corn Stover, Marigolds
Food Processing	Potato Waste, Corn Ethanol Bottoms (DWG), Grape Pomace (Wine Making), Cranberry Pomace, Digester Sludge, Kraft Paper Black Liquor, Cheese Whey, Coffee Grounds, Spent Distillers Grain, Vinegar, Olive Wash Water, Chicken Processing Waste, Fish Processing Waste, Gelatin Mfg. Waste, Rum Vinasse, Soda Pulp Wastewater, Soft Drink Factory Waste, Potato Processing Crumbs, Shrimp Waste, Potato Peels, Dairy Waste, Onions, Corn Canning DAF, Apple Pomace, Beer Waste
Chemical Waste	Nylon Wastewater, Acrylonitrile Wastewater, Fatty Acid Waste, Metal Chelate Solution, Sodium Cyanide Waste, Polyol Wastewater, Vitamin Fermentation Broth, Paint Booth Wash, Methyl Ethyl Ketone, Propylene Glycol, Carbon Tetrachloride, many other chemical compounds

Feedstocks Available for Hydrothermal Processing

Feedstock	World Million t/y	USA Million t/y
Non-Dairy Cattle Manure	2,510	396
Food Processing Waste	2,397	422
Pig Manure	2,154	340
Algae	1,260	270
Cellulosic Ethanol Bottoms	1,260	270
Muni Solid Waste (paper and organics only)	819	225
Dairy Cow Manure	747	53
Wastewater Treatment Solids	66	24
Beer Production	27	5
All Other	1,686	301
TOTAL	12,926	2,305

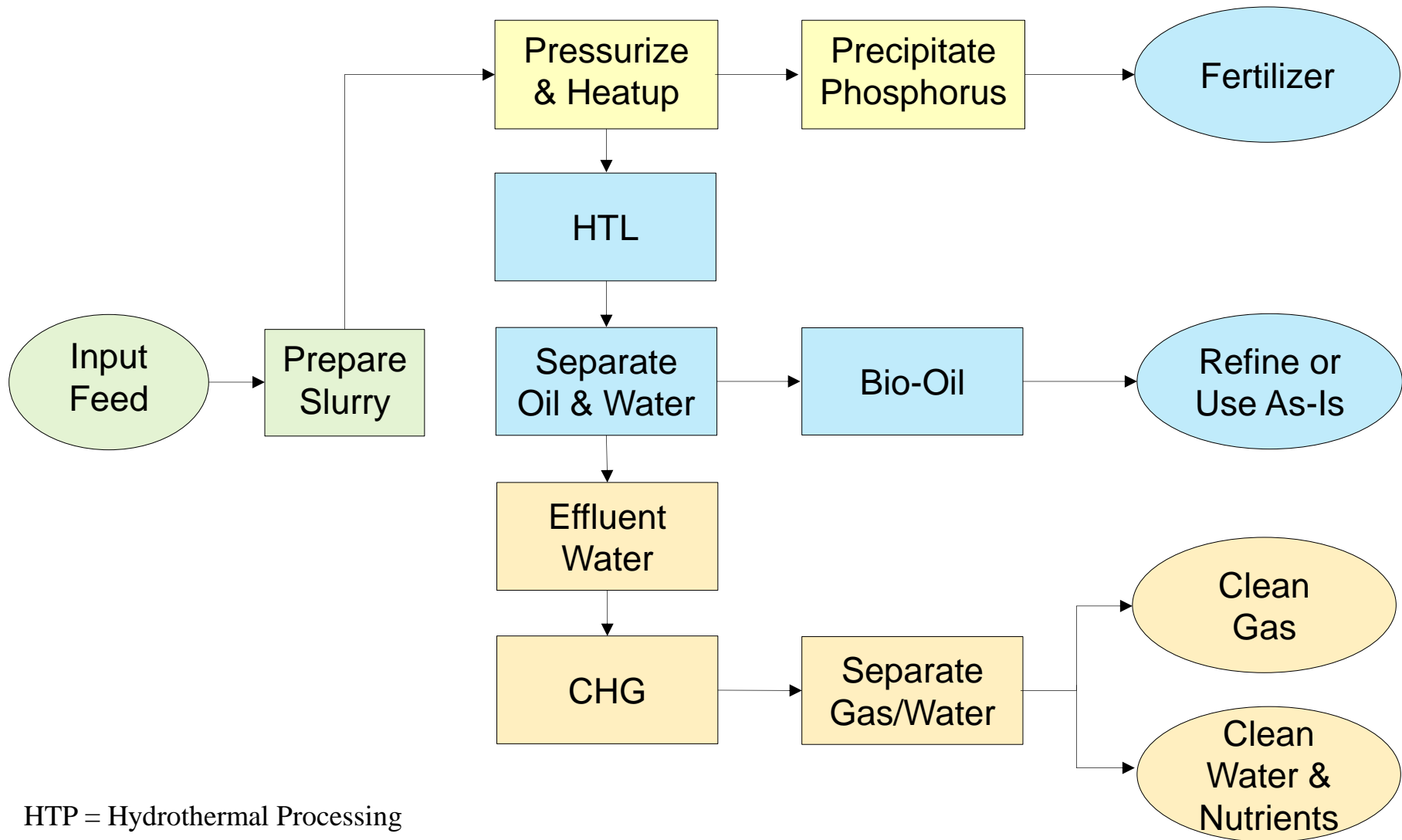
1. All amounts shown as metric tons of wet slurry @ 20% solids.
2. All amounts are actual amounts for 2010 except algae and cellulosic ethanol, which are estimated at 5% of transportation fuel supply.
3. Assumes 54% of available feedstocks are ultimately recovered worldwide.
4. "All Other" includes waste from pulp and paper processing, water and landfill remediation, organic chemical waste, poultry manure, etc.

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How It Works

- **Hydrothermal Processing (HTP) uses only pressurized hot water--no solvents**
- **Wet feedstock is made into water slurry with 15% to 35% dry equivalent solids (not actually dried)**
- **Process is NOT supercritical, which is important to the overall economics and success of HTP**
 - 350°C and 207 bar (662°F and 3,000 psi)
- **Continuous process converts more than 99% of the feedstock organic content in 30-45 minutes**
- **Process is efficient--uses 12% of energy (88% free)**

Combined Oil-Gas Hydrothermal Process Flow



HTP = Hydrothermal Processing
HTL = Hydrothermal Liquefaction
CHG = Catalytic Hydrothermal Gasification

Status: Shipped to Customer in 2015



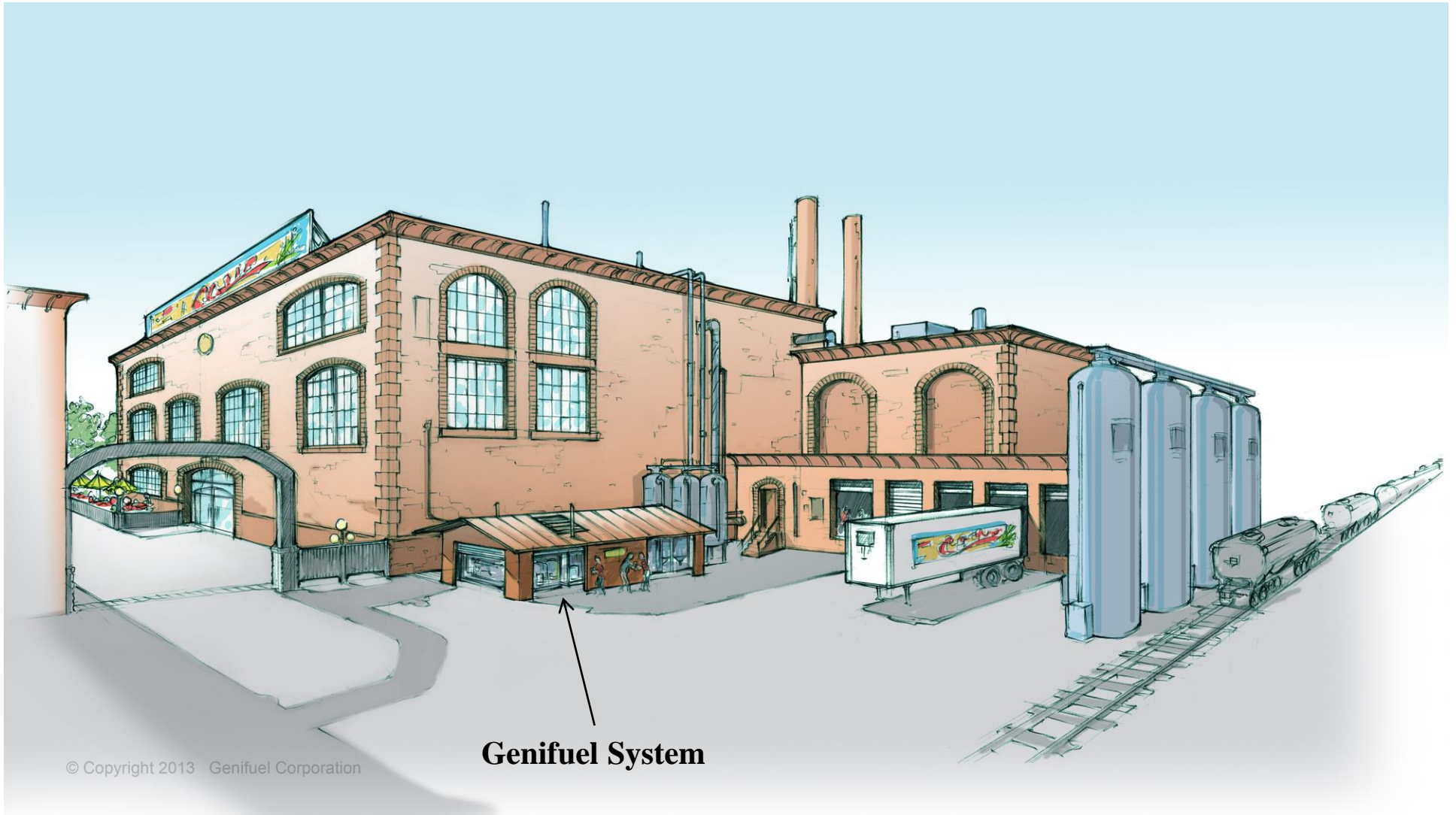
Products

- **Bio-crude can be used as is, or upgraded to refined fuels in a conventional refinery**
 - May need small pre-treater depending on refinery
- **Methane can be used several ways**
 - Use as fuel for generator to make electricity and heat
 - Remove CO₂, then inject into natural gas pipeline or use locally as CNG
 - Gas is clean (no sulfur, phosphorus, siloxanes)
- **Most feedstocks produce fuels and power which are eligible for renewable incentives internationally**

Biocrude Oil from Hydrothermal Liquefaction



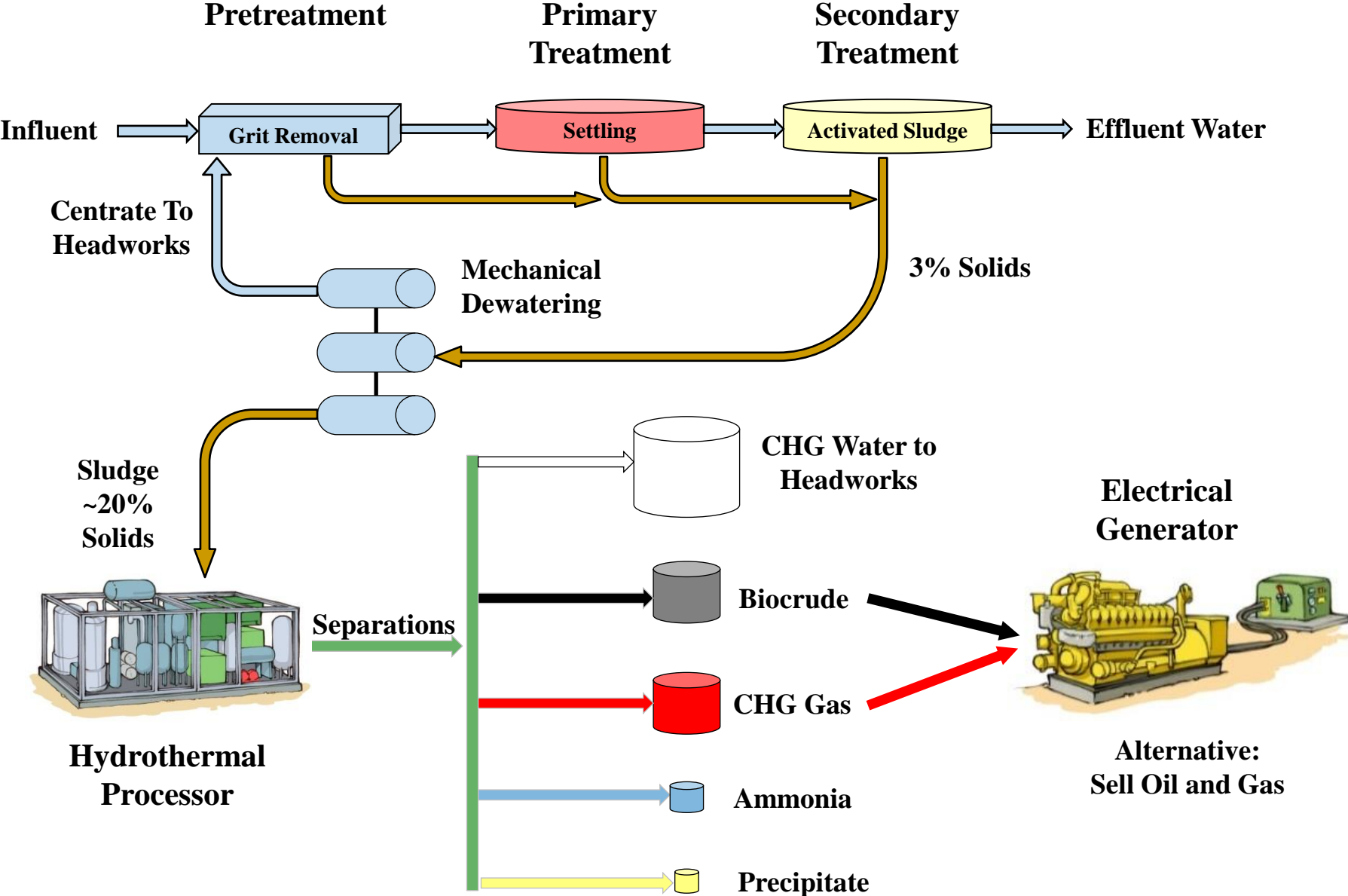
Concept of Hydrothermal System Installed at Brewery



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Genifuel System

Wastewater Treatment with Hydrothermal Processing



Recovery of Plant Nutrients

- **Primary nutrients N, P, and K are recovered**
 - Phosphorus is sent to fertilizer manufacturer and made bio-available with simple acid treatment
 - Nitrogen is in effluent water as ammonium carbonate, a common fertilizer
 - Potassium is in effluent water in bio-available form
- **All micro-nutrients are also recovered in the water**
 - Iron, boron, magnesium, copper, zinc, etc.
- **Water can be spread on land or added to irrigation**
- **CO₂ can also be recovered**

Intellectual Property (IP)

- **Genifuel has 19 patents issued or pending, either directly or jointly with PNNL**
 - Genifuel has exclusive worldwide rights
- **Five patents licensed from PNNL**
 - Half are recent with full (20 year) life remaining
- **Genifuel has five trademarks for its process**
- **Know-how and trade secrets related to process and systems**

Other Biomass to Fuel Technologies

- **Anaerobic Digestion (AD) is most widely known**
 - Biological process, more than 2,000 years old
 - Slow and incomplete conversion--app. 50% in 20 days vs. 99% in 30 minutes for hydrothermal
- **Cellulosic ethanol production**
 - 35% of carbon goes to fuel, vs. 85% for hydrothermal
 - Alcohol lower value than hydrocarbon fuels
- **Another technology—high-temperature pyrolysis—is not practical for wet materials**
 - 25% of the energy is lost drying the material
 - Output oil is lower energy and higher cost to refine

Comparison to Anaerobic Digestion

Item	Genifuel	Digestion/Fermentation
Technology	Hot pressurized water	Biological
Feedstock Sensitivity	Low	Moderate to high
Operation	Stable and consistent	Varies—feed and temperature
Footprint (typical)	Small—800 square feet	Large—22,000 square feet
Volume (typical)	Small—8,000 cubic feet	Very large—550,000 cubic feet
Speed of Reaction	Fast—30 minutes	Slow—weeks
Digestion Completion	99%	40-60%
Byproducts	Sterile water	Bio-sludge
Gas Quality (for AD)	Clean	Contaminated with sulfur
Liquid Fuel Output	Bio-crude in oil mode	Alcohol in fermentation mode
Handling of Sand and Dirt	Fair	Good

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James Oyler, President—Brief CV

- **Built and managed energy practice for Booz, Allen & Hamilton, worldwide consultants (1972-1976)**
- **Sector President for Harris Corporation, a Fortune 500 Company (1976-1993)**
- **President and CEO for E&S, a NASDAQ technology company sold to Rockwell Collins (1994-2006)**
- **BSEE 1967, M.A. Cambridge University (UK) 1969, Officer US Army 1972, Certified Mgmt. Accountant**
- **Holds nine issued patents and eight pending patents**

Why Do This?

- **Well-tested technology with low risk and strong IP**
- **Profitable opportunities widely distributed throughout the world, with huge market potential**
 - Depending on unit size, US more than 100,000 units
- **IP, R&D, and initial scaling already proven**
- **Process model supports rapid feasibility studies**
- **Regulatory environment becoming strongly supportive worldwide**
- **Project economics increasingly good as renewable energy demand and waste disposal costs rise**

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