Biosolids & Renewable Energy Innovation Technology Seminar

Hydrothermal Processing in Wastewater Treatment

James Oyler
President Genifuel Corporation
November 2017
jim@genifuel.com

Why Hydrothermal Processing?

- **Solids Management is a critical issue in wastewater treatment and a source of significant cost**
- **Hydrothermal Processing addresses this issue by converting solids to renewable fuels**
- **Eliminates solids disposal cost and generates significant revenue**
- **Renewable fuels offset fossil fuels and associated new GHG**

Why HTP

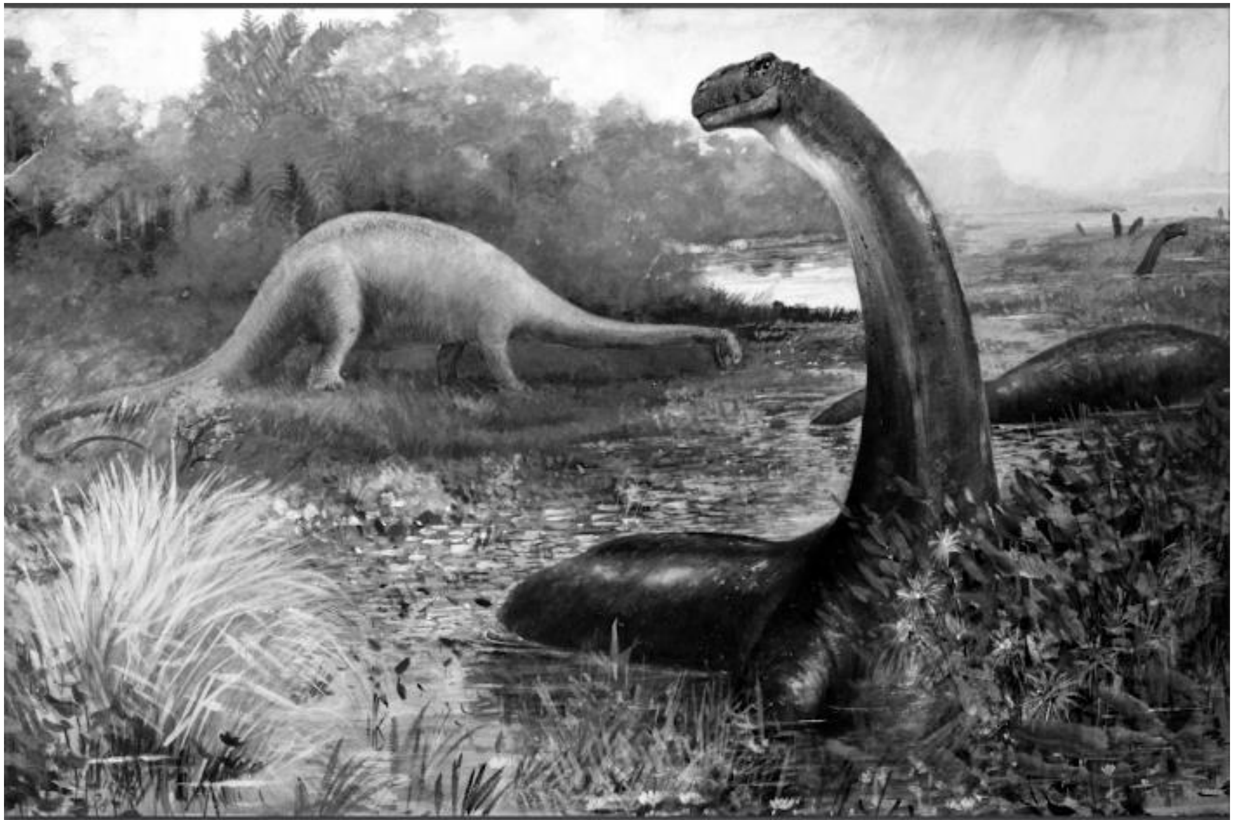
Background

- **Process developed over 30 years by the US Dept. of Energy at Pacific Northwest National Lab**
- **Licensed exclusively to Genifuel**
  - Both PNNL and Genifuel have contributed patents
- **Over 100 feedstocks tested**
  - Focus is now on wastewater solids

Genifuel

Technical Concept

- **HTP is similar to the formation of fossil fuels, but in minutes rather than millions of years**
- **Oil is similar to fossil crude but generally lower viscosity**



Brontosaurus by Charles R. Knight, 1897

Hydrothermal Processing Overview

- **Hydrothermal Processing (HTP) uses temperature and pressure to efficiently convert wet organic matter to biocrude oil and methane gas in less than an hour**
  - Captures >85% of feedstock energy; uses <14% of fuel energy produced to run the system
  - T = 350°C; P = 200 bar (20 MPa)
- **Eliminates biosolids and reduces operational costs**
  - Significantly reduces GHG emissions vs. alternatives
- **Accepts any type of wastewater solids—primary, secondary, both together, or post-digester biosolids**
  - Can also co-process food waste and other wastes

Genifuel

Hydrothermal Overview (cont.)

- **Unique process step precipitates phosphorus in the form of a dense clay-like solid; 98-99% removal**
  - Converts to fertilizer in same way as phosphorus ore
- **Effluent water clear and biologically sterile**
  - COD <60 mg/L, mostly small acids, e.g. formic, acetic
  - Large molecules destroyed, e.g. pharmaceuticals, estrogens, pesticides, fire retardants, etc.
  - Contains N as ammonia; ongoing R&D to recover
- **Systems or products often eligible for incentives**

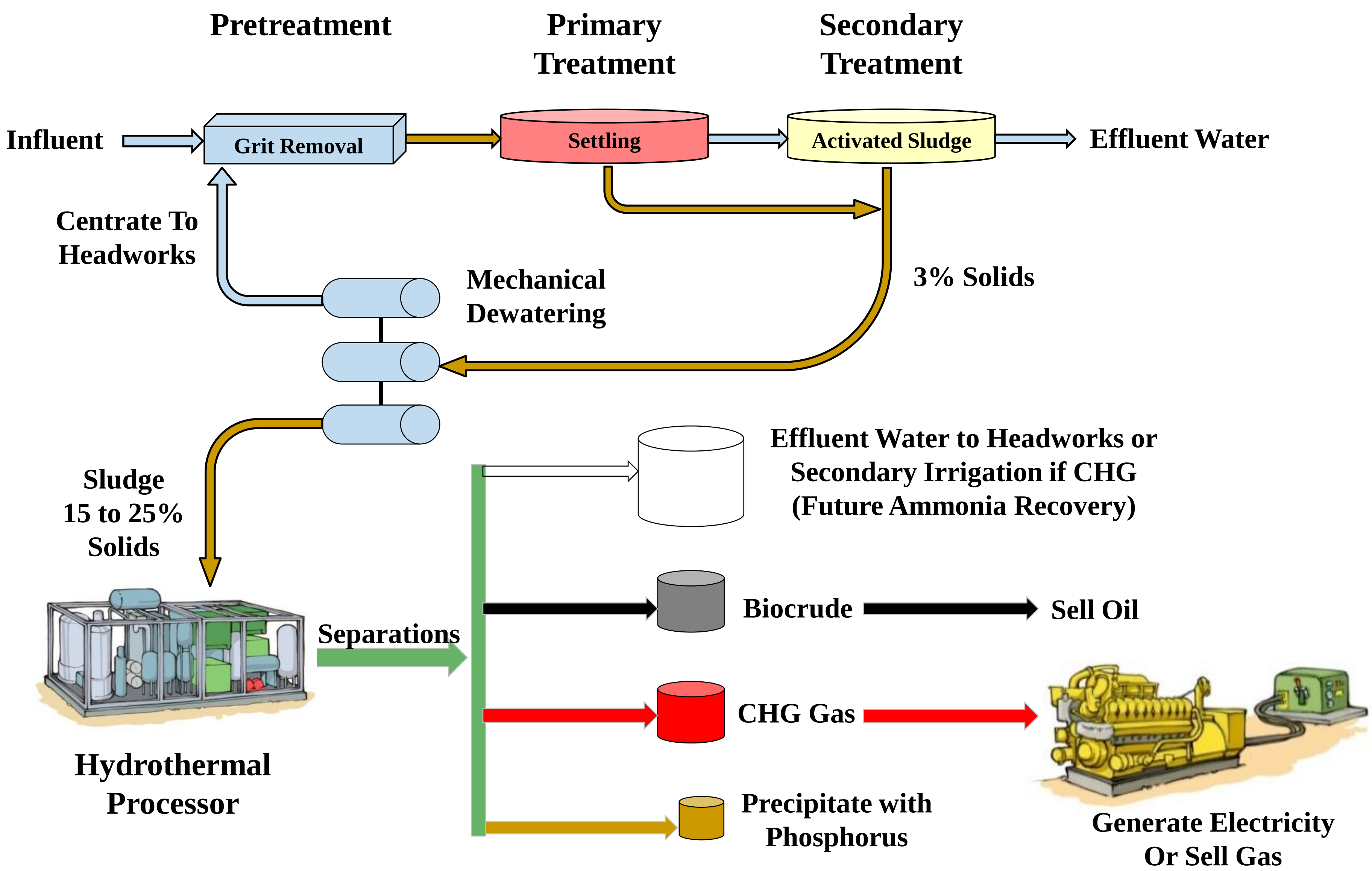
➢ **Solids management, P capture, valuable products, lower emissions, high efficiency, small size and incentives provide value to the plant owner**

An Installed HTP System and Outputs

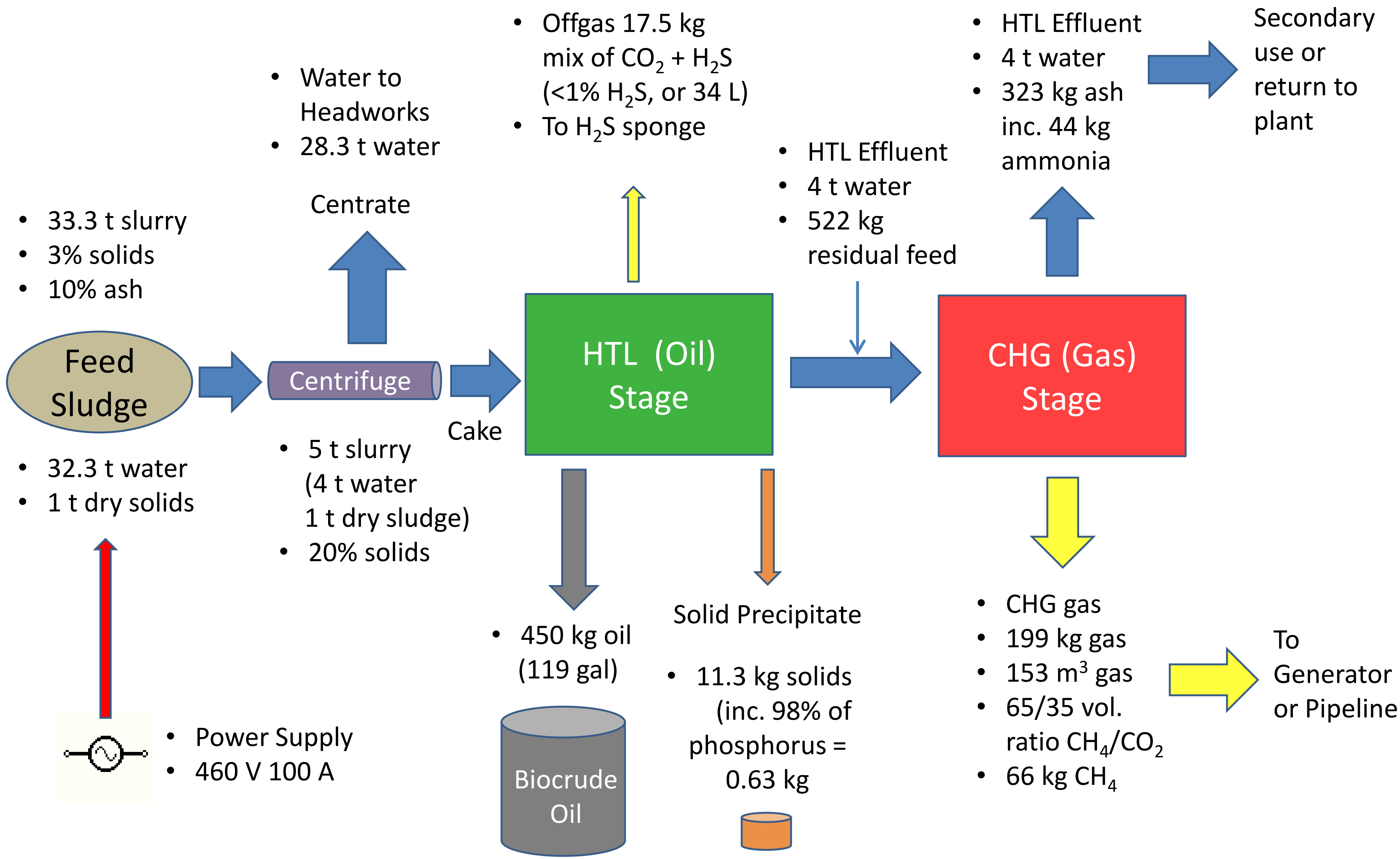
HTP Oil

Effluent
Water

Wastewater Process Flow with Hydrothermal Processing

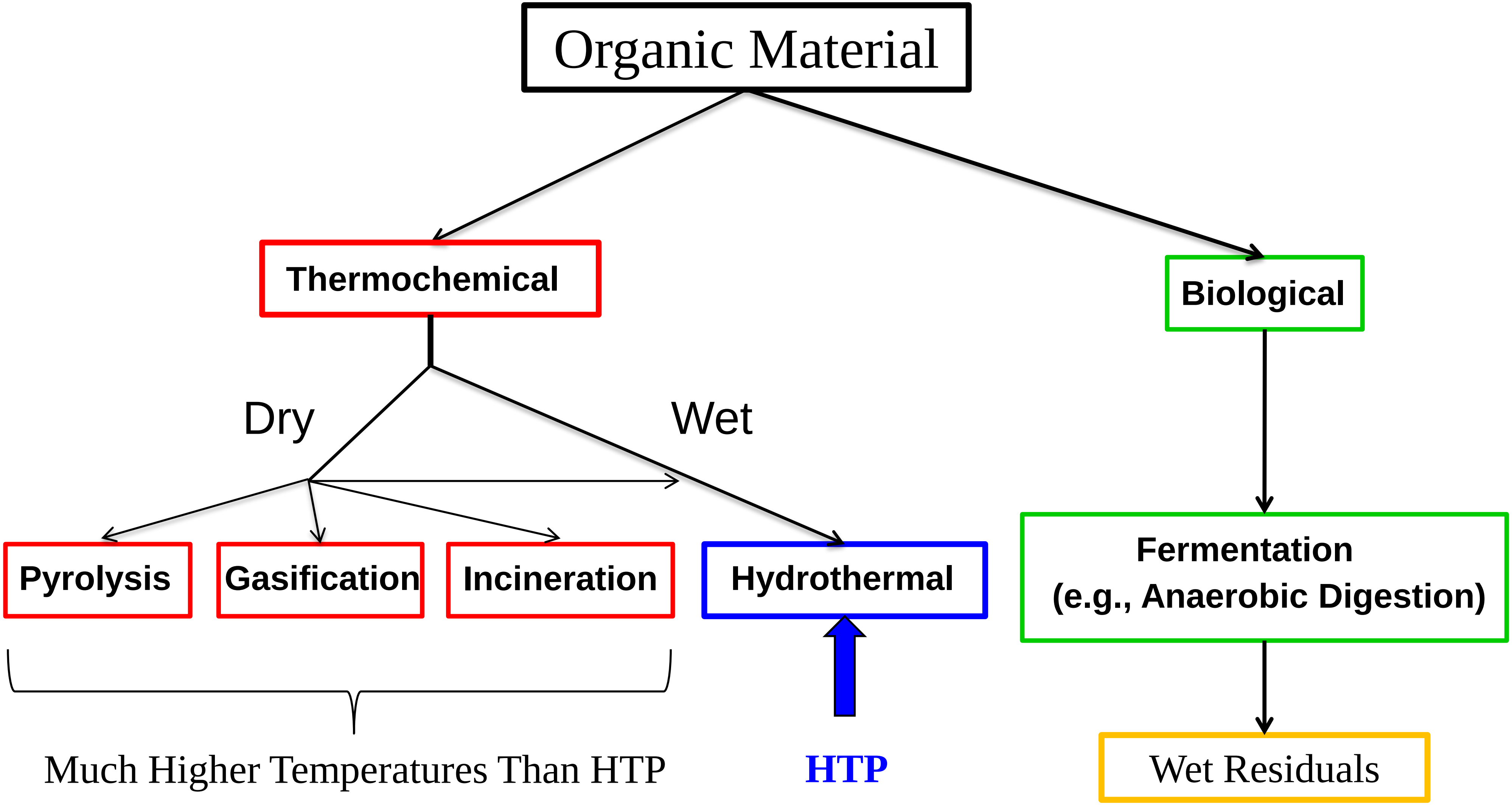


System is Well-Characterized:
Mass Flow Diagram for 1 t/d dry (equivalent) solids*



*All units metric unless shown otherwise. Mass unit of t/d = 1000 kg/day

Comparison to Other Technologies

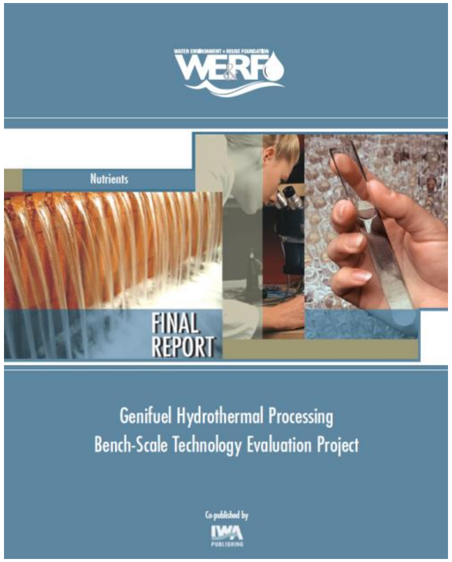


Comparison to Other Technologies (cont.)

TECHNOLOGY	COMPARISON
Anaerobic Digestion	• AD app. 2x footprint of HTP • HTP one hour vs. 20-30 days for AD • HTP 80% to 120% more fuel energy • AD leaves 40-50% of feedstock as biosolids; HTP none
Thermal Hydrolysis (e.g. CAMBI)	• Pre-process for AD, not a conversion process • Increases yield and decreases time for AD • Increased methane needed for CAMBI, little net gain
Incineration	• Eliminates solids • Limited resource recover—some heat and some ash • Expensive to eliminate regulated air emissions
Pyrolysis or gasification	• Very high temperature can create reliability problems • Low yield and low quality if pyrolysis oil is produced • Produces syngas rather than methane—lower specific energy

The LIFT Study of HTP by WERF

- **The LIFT study produced a 185-pg. third-party report by Leidos, Inc.**
- **The report was reviewed by utilities and industry experts…**



Available free from WERF

… and recommended installation at a utility

Continuing Improvements in HTP

- **Pacific Northwest National Laboratory, which ran the LIFT test, ran additional tests with Detroit sludge, and installed major new test equipment**

Medium-Scale HTP System

Oil Upgrading System

Genifuel

Results from Wastewater Sludge Tests*

Measurement	Value
Oil as % feedstock solids (mass/mass)	35% to 45%
COD of effluent water after gasification	<60 mg/L
Feedstock carbon recovered into fuels	85%
% of output fuel energy needed to run the system	14%
Siloxane and H_2S levels in CHG gas	Negligible
Ammonia level in CHG water, before removal	1% to 1.5%
Complex molecules remaining (pesticide, pharma)	Negligible
Operating conditions	350°C, 200 bar
Preferred solids concentration	20% solids in water; range 15 to 25%

** Sludge samples from Metro Vancouver and Detroit*

Genifuel

Metro Vancouver’s Interest in HTP

- **After working on LIFT, Metro Vancouver saw the HTP pilot project recommendation as a way to gain experience with solutions to key issues**
  - Rising cost of solids management and increasing distance to disposal sites
  - High cost of installing AD at smaller sites
  - New technology for future system upgrades to improve process and reduce cost
  - A pathway to meet environmental goals for lower emissions and greater energy recovery

Metro Vancouver’s (MV) Project

- The MV system will process 10 metric t/d of sludge at 20% solids
- Serves satellite site with population of 30,000
- Initially oil only (875 L/d) , with gas later
- Commission late 2018

Annacis Island System Site

Genifuel

Analysis of MV Project—HTP vs. AD

MEASURE	VALUE
Footprint	HTP is 44% of AD
GHG Reduction	HTP reduces GHG 3X as much as AD
20-year NPV* Cost	HTP is 55% of AD Cost

*NPV = Net Present Value

Genifuel

HYPOWERS Is the Next New Project

- HYPOWERS is a two-phase project partly funded by Dept. of Energy for demonstration with wastewater
- Size is planned at 20 metric tons/day, or 60,000 pop.
- Host facility is Central Contra Costa Sanitary District ("Central San"), east of San Francisco

Central San System Site

Genifuel

About Central San

- 145 Sq. Mile Service Area
- >480,000 Population Served
- >1,500 Miles of Sewer
- 19 Pump Stations
- 1 Treatment Plant
- Average Flow: 32 Million Gallons Per Day (MGD)
- Solids: ~200 Wet Tons Per Day

Genifuel

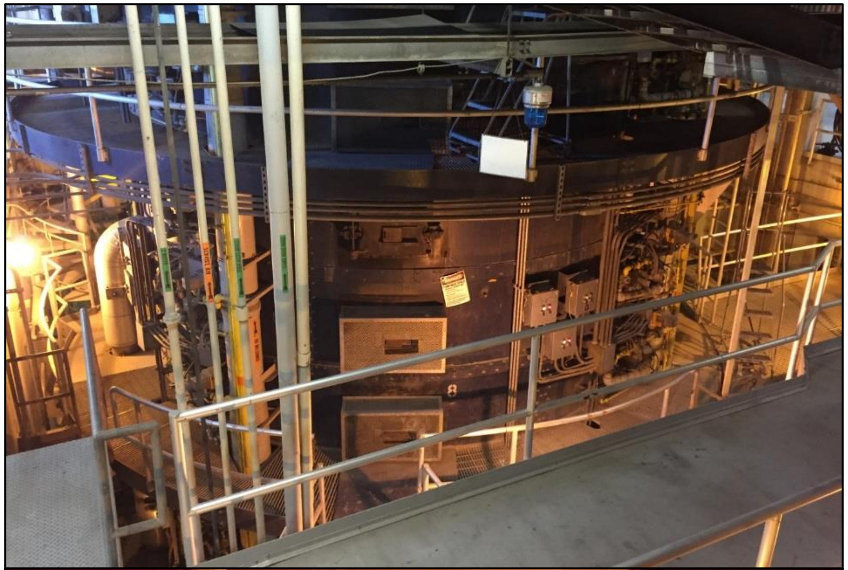
Central San Embarked on a Comprehensive Wastewater Master Plan

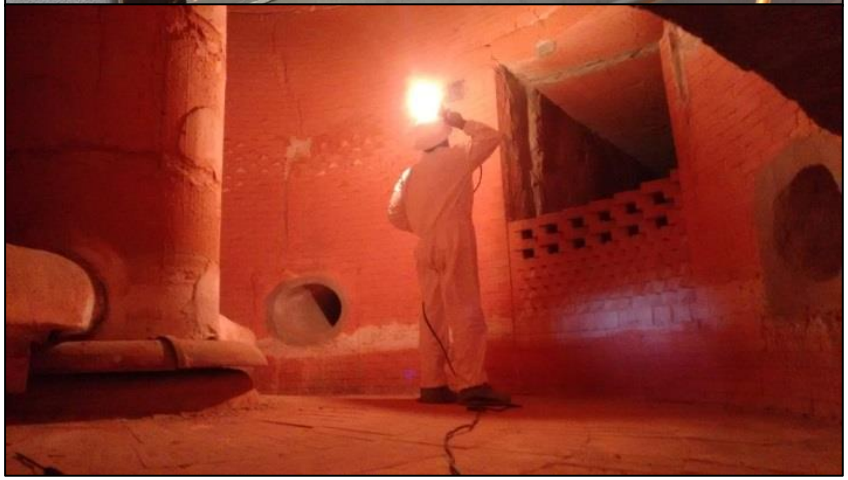
Aging Infrastructure	Capacity
Regulatory	Sustainability

Genifuel

Existing Solids Handling System

- 1980s Waste to Energy
- Furnaces in Good Condition
- Support Equipment & Building Requires Upgrades
- Emissions Controls Improvements Needed
- Regulatory Risks
- Plans to De-couple Waste Heat Recovery System from Secondary Aeration Blowers



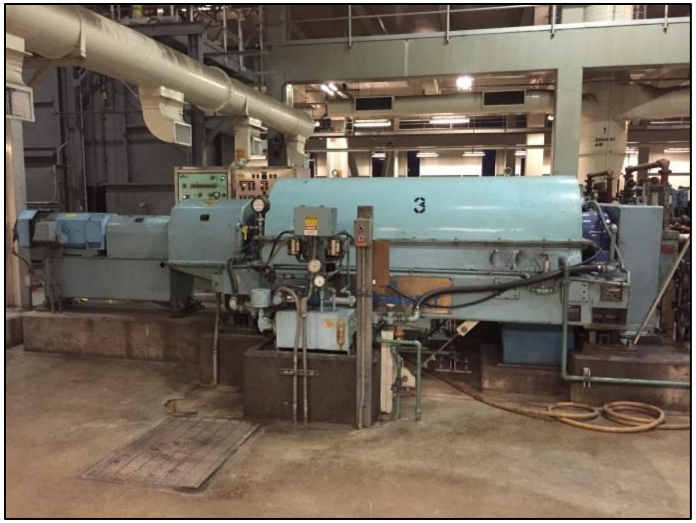


Genifuel

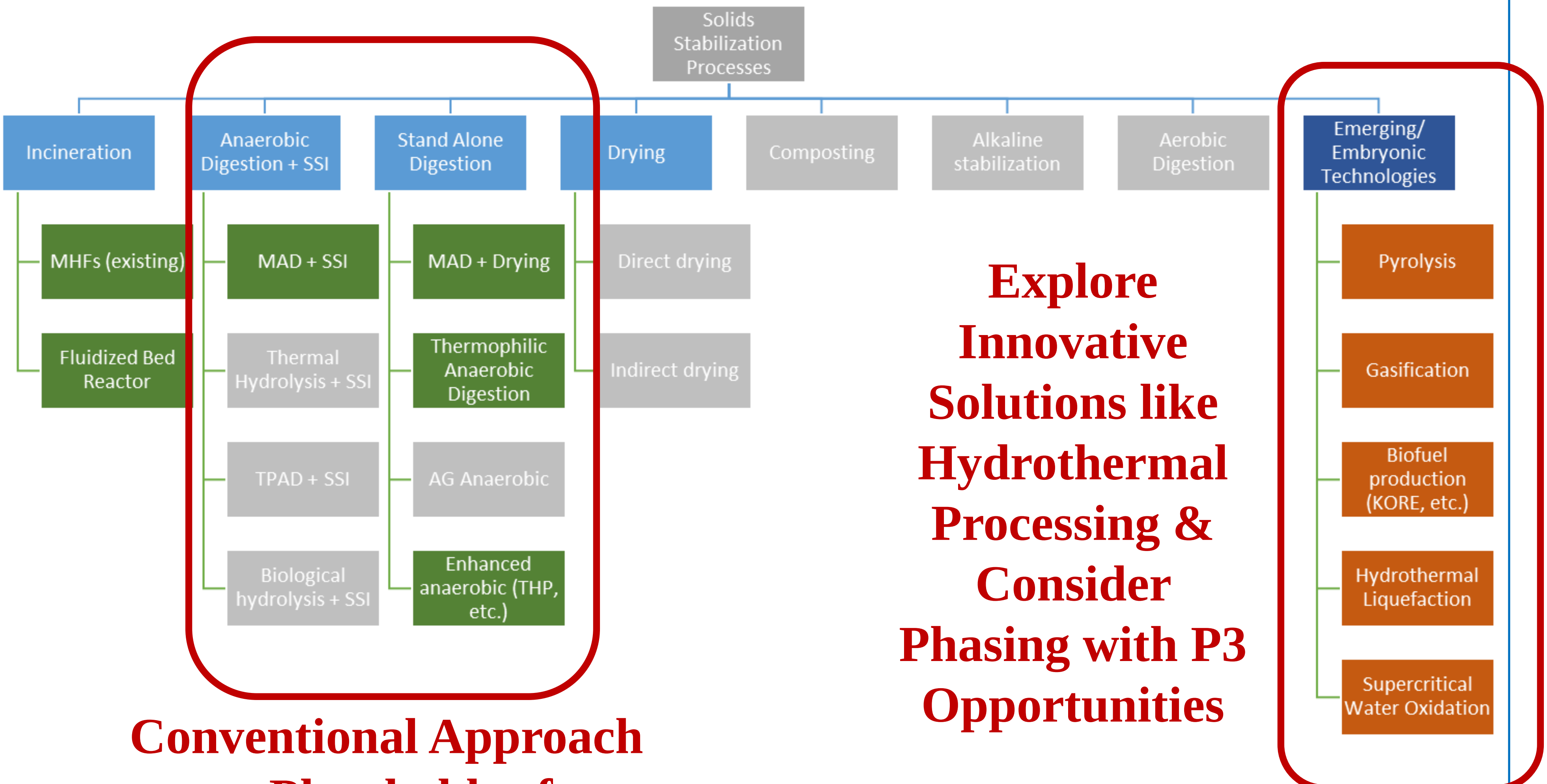
Solids Handling Goals

- **Continue with Furnaces**
  - Near-Term Upgrades
  - Address Vulnerabilities

- **Plan for Furnace Replacement (Possibly in Phases)**
  - Strive for Net Zero Energy
  - Reduce Greenhouse Gas Emissions
  - Embrace Innovation



Universe of Alternatives

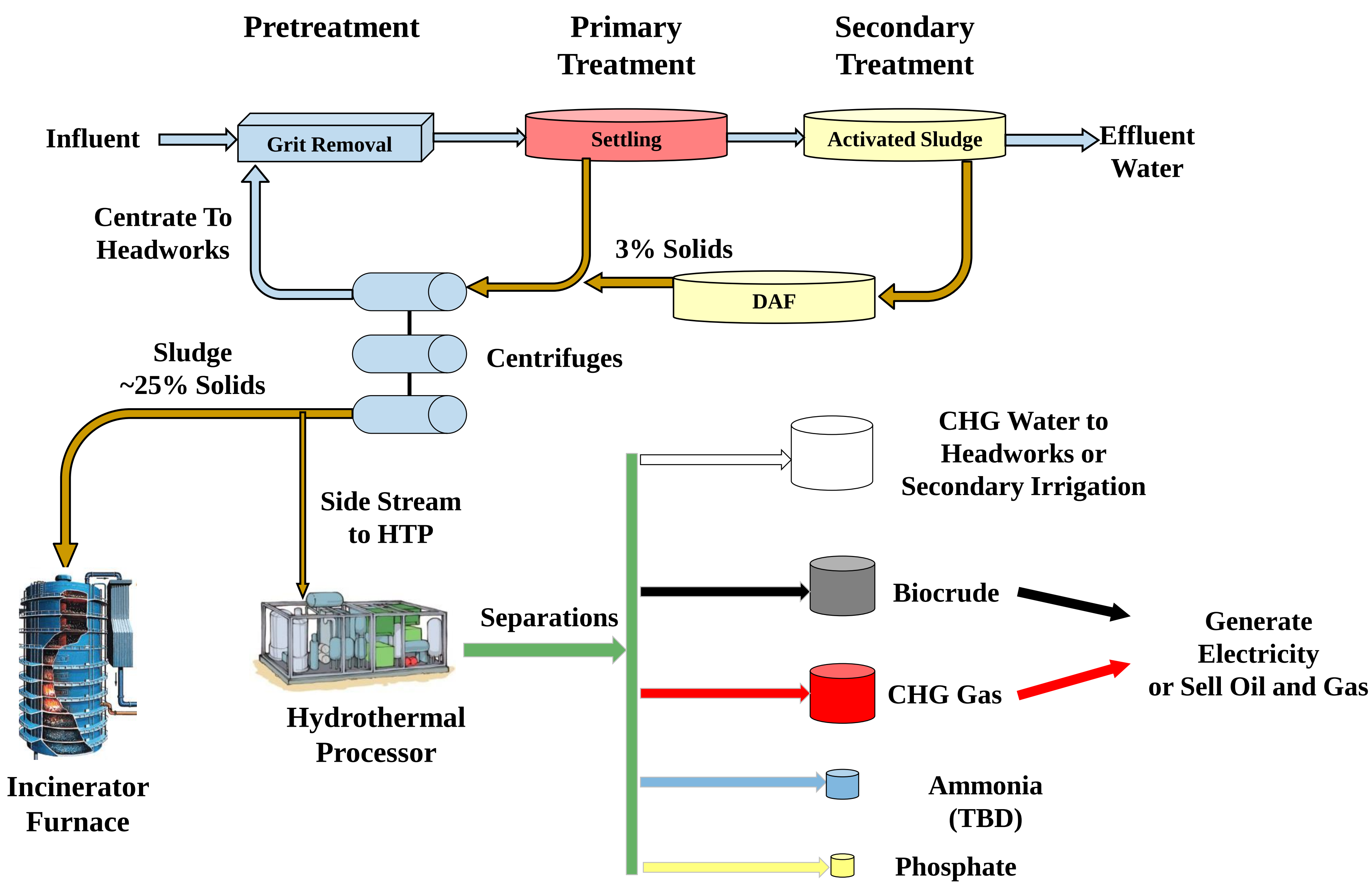


Explore Innovative Solutions like Hydrothermal Processing & Consider Phasing with P3 Opportunities

Conventional Approach as a Placeholder for Master Planning

Genifuel

Central San Process Flow with Hydrothermal Processing



The HYPOWERS Team

Water Environment & Reuse Foundation (WE&RF)

Pacific Northwest National Laboratory

Genifuel Corporation

Merrick & Company

Central Contra Costa Sanitary District

metrovancouver

SoCalGas — A Sempra Energy utility

MicroBio Engineering (μBIO)

TESORO

Brown and Caldwell

Central Contra Costa Sanitary District — 70 Years, 1946–2016

Equipment Installation for HTP

- **HTP system is skid-mount and factory-built**
  – Shipped to site by truck
  – May be containerized for sea shipment
- **Site installation requires pad, utilities (electricity, water, drain), and cover (roof or building)**
- **Need supply of sludge or biosolids**
  – Sludge can be delivered by pipe, biosolids likely not
  – Sludge will need to be dewatered to 20% (range 15-25%)
- **Need disposition of effluent water and storage tank for oil (weekly pickup)**
- **Odor control simple because very small amounts**

Genifuel

Conclusion

- **Only hydrothermal process with both liquefaction and gasification in same system**
- **Optimized process produces high quality outputs**
  - Oil—no char, low oxygen
  - Gas—H_2S and siloxanes below detection limit
  - Water—no organisms or pharmaceuticals
- **Unique process step automatically captures phosphorus for direct conversion to fertilizer**
- **Successful scale-up now at small commercial size**
- **More than $50 million invested in R&D by both government and private parties**
- **All IP owned or licensed exclusively to Genifuel**

Genifuel

Hydrothermal Processing in Wastewater Treatment

Thank you!

Genifuel

Additional Slides

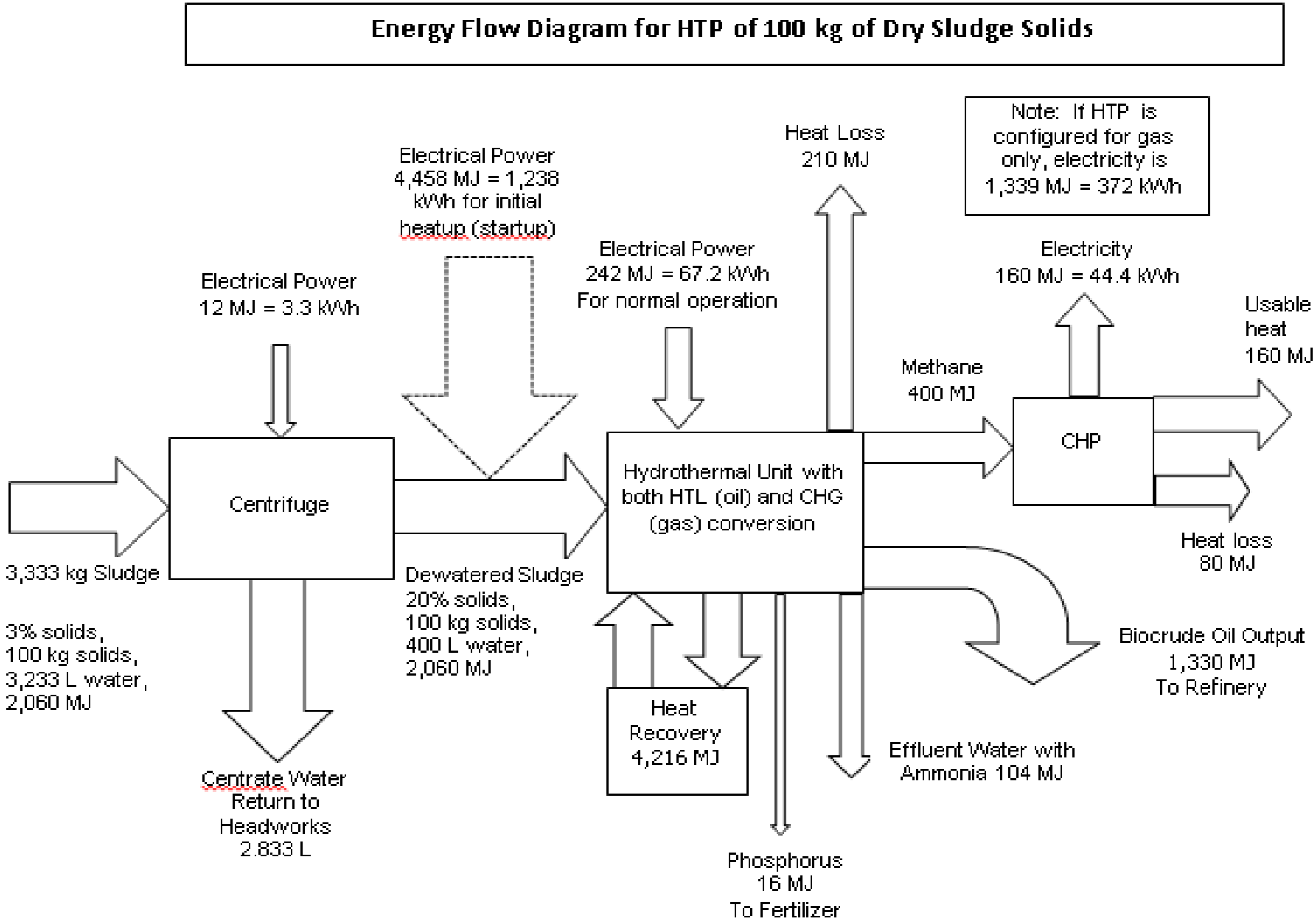
James Oyler, President—Brief CV

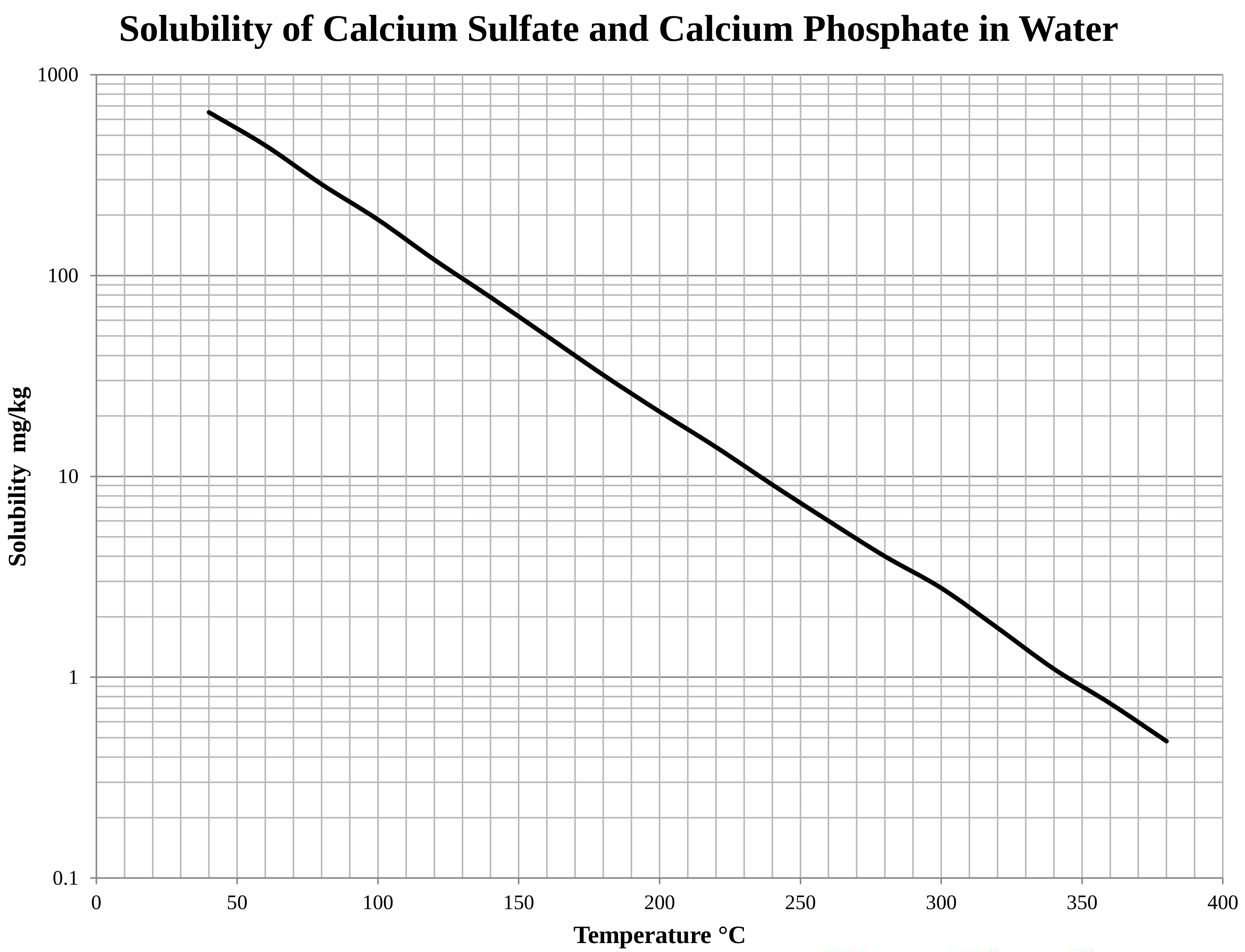
- Built and managed energy practice for Booz, Allen & Hamilton, worldwide consultants (1972-1976)
- Sector President for Harris Corporation, a Fortune 500 Company (1976-1993)
- President and CEO for E&S, a NASDAQ technology company sold to Rockwell Collins (1994-2006)
- BSEE 1967, M.A. Cambridge University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

Conclusion

- **Successful testing with wastewater solids has created significant learning for equipment design, expected performance, and cost reduction**
- **Critical next step is to demonstrate continuous 24/7 operation at operating wastewater utility**
  - Current longest operation is app. three months
  - Planned projects at MV and Central San
  - Sharing of data and results with wastewater industry
- **Will need new investment for operations**
- **Would like utility partner in UK/Europe for demonstration plant**

System is Well-Characterized: Energy Flow Sankey for 100 kg/d dry solids




Solubility of Calcium Sulfate and Calcium Phosphate in Water
1000
100
10
1
0.1
Solubility mg/kg
0
50
100
150
200
250
300
350
400
Temperature °C