Leaders Innovation Forum for Technology

LIFT: Getting Involved 101 –

Featuring a Biosolids to Energy Project Example

WEF-WERF Webcast

April 20, 2016

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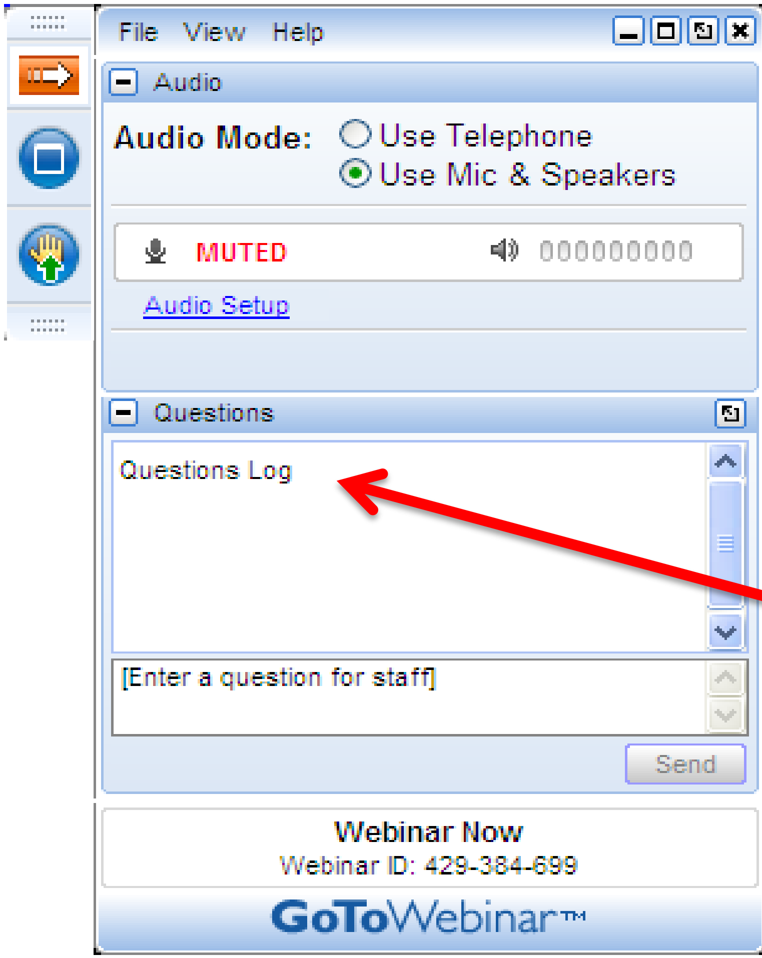
How to Participate Today



- **Audio Modes**
  - Listen using Mic & Speakers
  - Or, select "Use Telephone" and dial the conference (please remember long distance phone charges apply).
- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this web seminar.**

Today's Moderator

Jim McQuarrie
Chief Innovation Officer,
MWRD Denver, CO

Agenda
(Eastern Times)

1:00 **Welcome and Overview of Agenda**
Jim McQuarrie, MWRD Denver (Moderator)

Part 1: Overview of LIFT and How to Engage

1:05 **LIFT Programs and Activities**
Jeff Moeller, WERF

1:20 **Targeted Collaborative Research**
Allison Deines, WERF

1:25 **LIFT MA Toolbox**
Fidan Karimova, WERF

1:30 **Q&A**

Agenda (Cont.)

(Eastern Times)

Part 2: Example Collaborative Project

1:40 **Background**
Jeff Moeller, WERF

1:45 **Genifuel Hydrothermal Processing Bench Scale Evaluation**
Philip Marrone, Leidos, Inc.

2:05 **Hydrothermal Processing in Wastewater Treatment: Planning for a Demonstration Project**
Jim Oyler, Genifuel

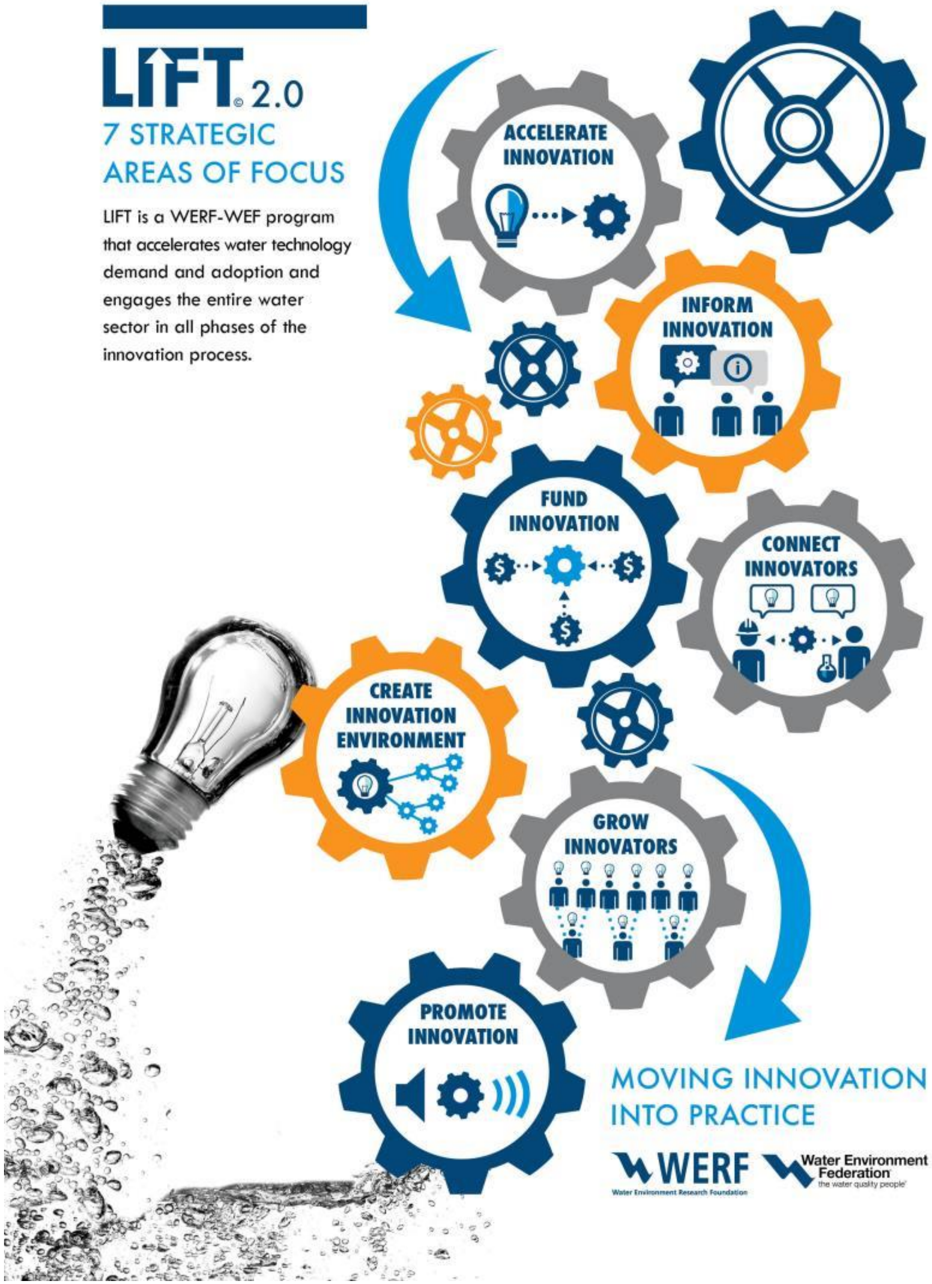
2:10 **Project Participant Perspectives**
Paul Kadota, Metro Vancouver

2:15 **Q&A**

2:30 **Adjourn**

Speaker

Jeff Moeller, P.E.
Director of Water Technologies, WERF
E-mail: jmoeller@werf.org
Web: www.werf.org/lift



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Program Components

1. Technology Evaluation Program
2. People and Policy
3. Communication
4. Informal Forum for R&D Managers

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Utility Technology Focus Groups

1	Shortcut Nitrogen Removal
2	P-Recovery
3	Digestion Enhancements
4	Biosolids to Energy
5	Energy from Wastewater
6	Collection Systems
7	Green Infrastructure
8	Small Facilities ⬅
9	Odor Control ⬅
10	Disinfection ⬅
11	Water Reuse ⬅
12	Intelligent Water Systems ⬅

⬅ New in 2016

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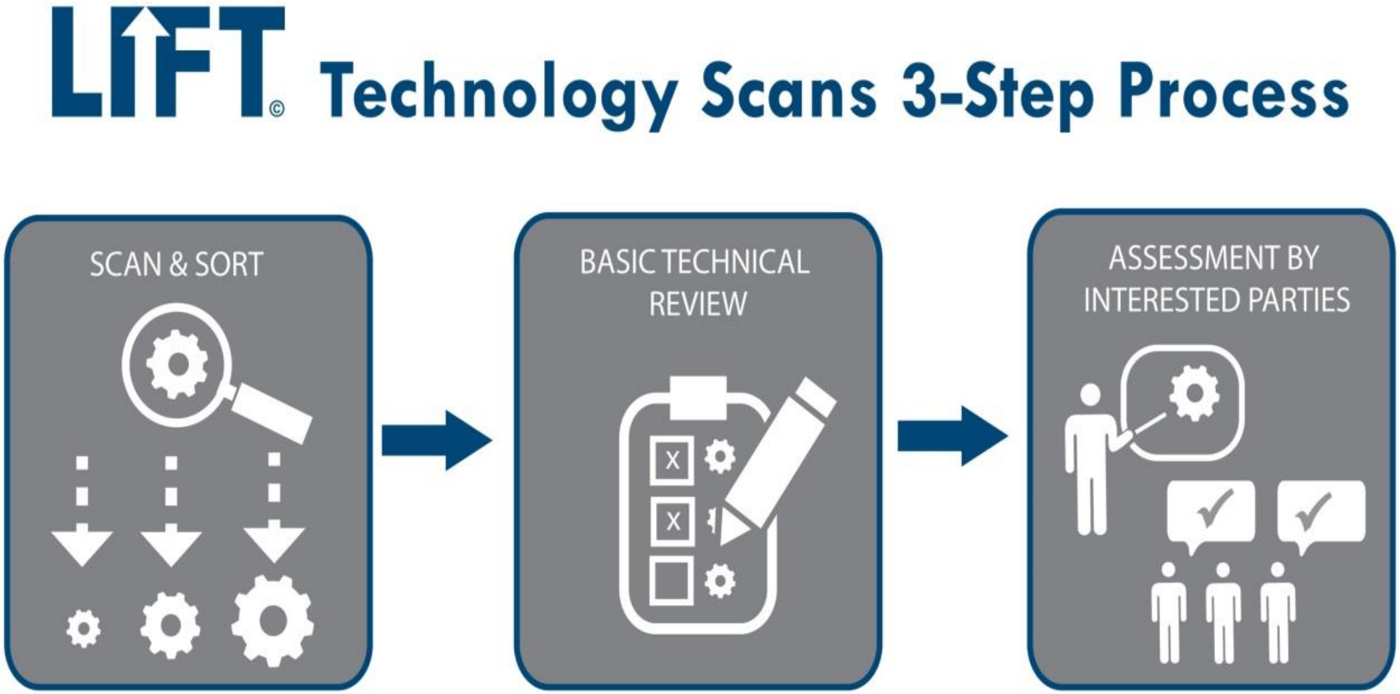
Technology Scans



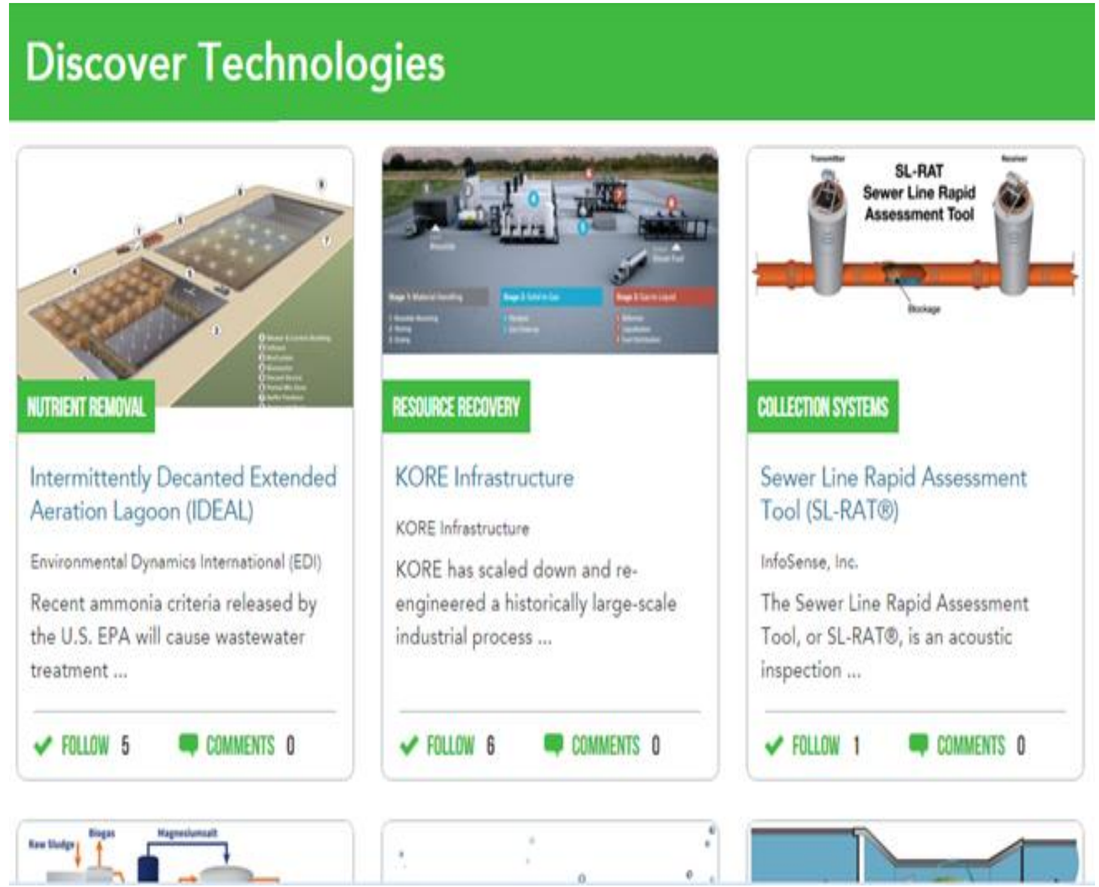
Upcoming Scan Presentation Series

April 26	**Collection Systems**	PICA Corp.	In-Line Inspection Tools
		Steel Toe Group	DIP System
		In-Pipe Technology Company	Pearl In-Pipe Technology/ BioConversion Solutions
May 17	**P-Recovery & Scale Prevention**	Ostara	Pearl
		Paques	Phospaq
		HydroFlow Holdings USA, LLC	Hydropath Technology
June 14	**Biosolids to Energy & Biofermentation**	SCFI Limited	AquaCritox
		Algae Systems, LLC	Direct conversion of wastewater sludge to oil via HTL
		ABS Inc.	Biofermentation
July 19	**Stormwater and Watersheds**	RainGrid, Inc.	Cistern Controller and Data Management Platform
		Blue Water Satellite, Inc.	Remote Sensing Solutions for Monitoring Water and Land
		C.I. Agent Storm Water Solutions, LLC	C.L.A.M.
		Parjana Distribution	Energy-Passive Groundwater Recharge Product

LIFT Link

Discover. Connect. Collaborate.

- Discover new technologies
- Connect with others with similar needs, technology interests, and desired expertise
- Collaborate on research and technology ideas, proposals, projects, demonstrations, and implementation



currently in beta, release expected summer 2016

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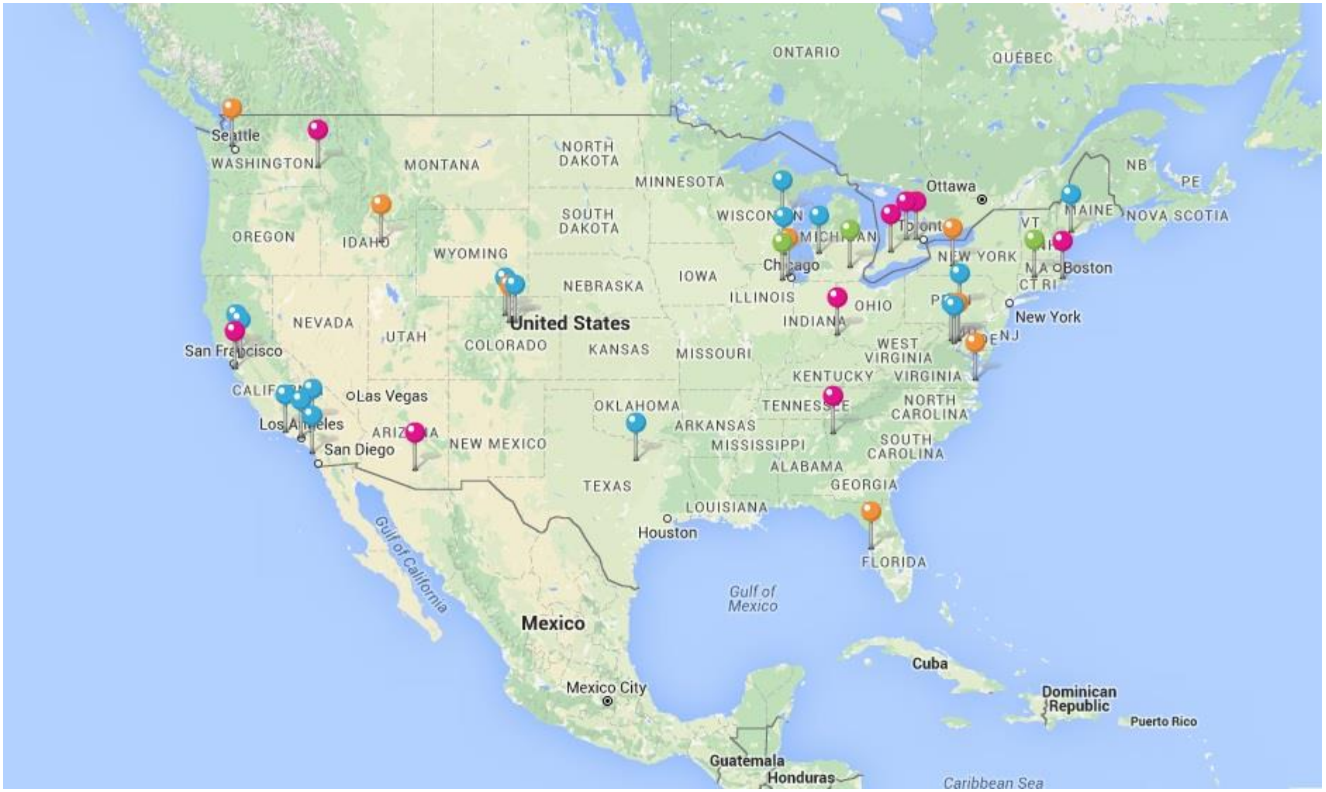
National Test Bed Network

www.werf.org/lift/testbednetwork



- Level 1: A university or research lab that can assist with bench-scale work but is not dedicated to piloting new technologies
- Level 2: A water resource recovery facility that is interested in innovation and willing to host a project, but does not have a dedicated test facility
- Level 3: A water resource recovery facility or research lab with a dedicated physical space available for piloting innovative water technology
- Level 4: A staffed facility dedicated solely to R&D/piloting of new technologies (can be housed at a functioning WRRF)

New Programs of Note

- Program to See and Visit New Technologies
- Program to Better Connect Utilities and Universities

New Projects of Note

- Fostering Research and Innovation within Water Utilities
- Guidelines for Utilities Wishing to Conduct Pilot Scale Demonstrations

Collaborations for RDD&D

Utilities

Universities

Consultants

NGOs

Others

Federal Agencies

Financers

Technology Providers

Agenda
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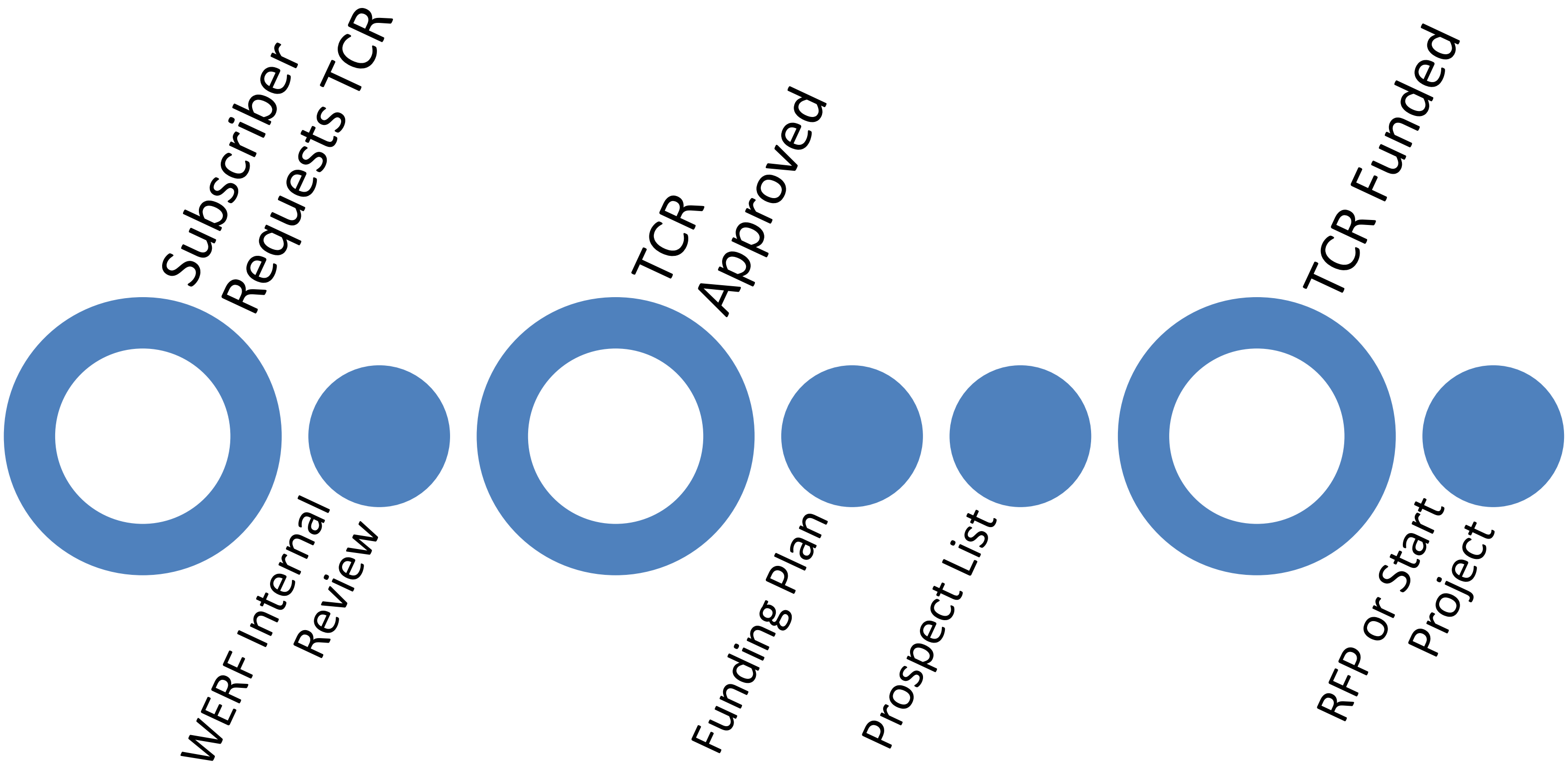
Speaker

Allison Deines
Director of Special Projects, WERF

Targeted Collaborative Research



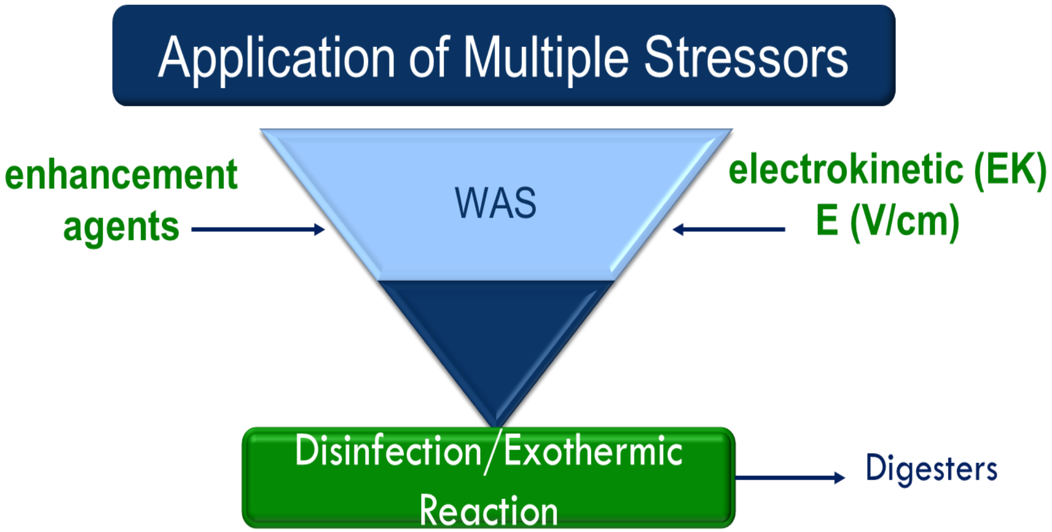
TCR Statistics

- Projects range in size from $25,000 to $300,000. Average project size is $50,000.
- Most common contribution is $5,000.
- 18 organizations gave in 2015.

WERF helps raise funds and provides financial and project management to support technology projects.

Bioelectro Technology

- Process to treat biosolids
- Low voltage gradient combined with additives
- Generates exothermic reaction
- Short detention time for disinfection <1.0 hr
- Heat generation for biosolids stabilization



Potential Benefits

- Small tankage required for pre-treatment
- Is effective for small, aerobic digesters
- Disinfects to Class A standards
- Exothermic reaction aids thermophilic digestion

E-beam Technology

Overall Objective: Obtain empirical data to evaluate the applicability of high energy eBeam technology to hydrolyze sewage sludge for enhanced biogas production

Specific Objectives

1. Identify the influence of eBeam dose and solids content on methane gas production
2. Identify chemical and biological properties of sludges processed with eBeam technology to identify by-products that have high commercial value

Potential Benefits

- Reduction in sludge viscosity
- Increased sludge loading rates
- Reduced sludge digester residence times
- Enhanced methane production
- Increased sludge de-waterability
- Class A biosolids
- Value-added sludge by-products

Final Thoughts

- The TCR program is set up to be flexible for WERF subscribers and technology providers.
- Projects are most successful when technologies have a utility champion.
- TCRs can support both bench-scale and pilot-scale research.

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Speaker

Fidan Karimova
Water Technology Collaboration Manager, WERF

WEF MA's

2015 Member Association WERF Supporters

- Alabama's Water Environment Association
- Arizona Water Association
- Atlantic Canada Water & Wastewater Association
- California Water Environment Association
- Chesapeake Water Environment Association
- Hawaii Water Environment Association
- Illinois Water Environment Association
- Kentucky-Tennessee Water Environment Association
- Mississippi Water Environment Association
- Missouri Water Environment Association
- Nebraska Water Environment Association
- New England Water Environment Association, Inc.
- New Jersey Water Environment Association
- New York Water Environment Association, Inc.
- North Dakota Water Environment Association
- Pacific Northwest Clean Water Association
- Pennsylvania Water Environment Association
- Rocky Mountain Water Environment Association
- South Dakota Water Environment Association
- Virginia Water Environment Association
- Water Environment Association of South Carolina
- Wisconsin Wastewater Operators' Association

LIFT MA Toolbox

LIFT MA TOOLBOX

LIFT, the Leaders Innovation Forum for Technology, is a WEF/WERF initiative that helps move new water technologies into practice quickly and efficiently. This toolbox outlines opportunities for WEF Member Associations (MAs) to connect with LIFT and to help expedite new technology adoption in their region. The toolbox pairs with MA leader training to help drive innovation in the water sector. Here are some ways MAs can jumpstart their efforts:

1. BECOME A LIFT AFFILIATE

MAs can participate in LIFT by establishing a committee on innovation and becoming a LIFT Affiliate. Affiliates work together through LIFT to share information and to collaborate on projects and initiatives of mutual interest and benefit, such as piloting and evaluating new technologies. Learn More >

> Download LIFT Affiliate Application (PDF)

2. CONNECT WITH LIFT LINK

LIFT Link is an online platform that serves as a highway for interaction among utilities, academia, consultants, investors, and innovative technology providers. Here, MA members can discover the latest technologies, connect with others on technologies of common interest, and collaborate on pilots and demonstrations. MA members can also learn about high-priority research and technology needs, find experts to help meet those needs, and more. Learn More >

> https://www.werf.org/lift/LIFT_Link.aspx

3. PARTICIPATE IN TECHNOLOGY SCANS

LIFT Technology Scans identify and evaluate innovative technologies to inform utility end users, funders, and advisors and to expedite early adoption of technologies. MAs can help identify promising technologies from their own networks to participate in the LIFT Technology Scan process. Learn More >

4. FOSTER INNOVATION WITHIN WATER UTILITIES

LIFT offers tools for MAs to help implement programs and activities that encourage the development or use of new technologies at water utilities. For example, utility-to-utility mentorship programs can play an important role in technology adoption, allowing smaller utilities to gain valuable knowledge from well-established facilities. Learn More >

5. CONNECT WITH TEST BEDS

MAs can work with local utilities and universities to integrate facilities from their region into a larger national test bed network. The network will help connect researchers and technology developers with appropriate facilities for technology pilots and demonstrations. Learn More >

6. LINK UNIVERSITIES & UTILITIES

MAs can leverage LIFT's network and ongoing activities to strengthen academic and utility connections. This provides greater opportunities for educational outreach, experiences, and utility-relevant research and will ultimately result in well-equipped future leaders. Learn More >

7. PROPOSE AN IDEA FOR LIFT

Additional ideas and initiatives are needed to better foster a culture of innovation in the water industry. MAs can help lead and implement this initiative. Contact the WERF or WEF representatives listed below to share thoughts and offer suggestions. Learn More >

FOR MORE INFORMATION OR TO LEARN MORE ABOUT HOW TO GET INVOLVED, CONTACT:

WERF
FIDAN KARIMOVA
fkarimova@werf.org

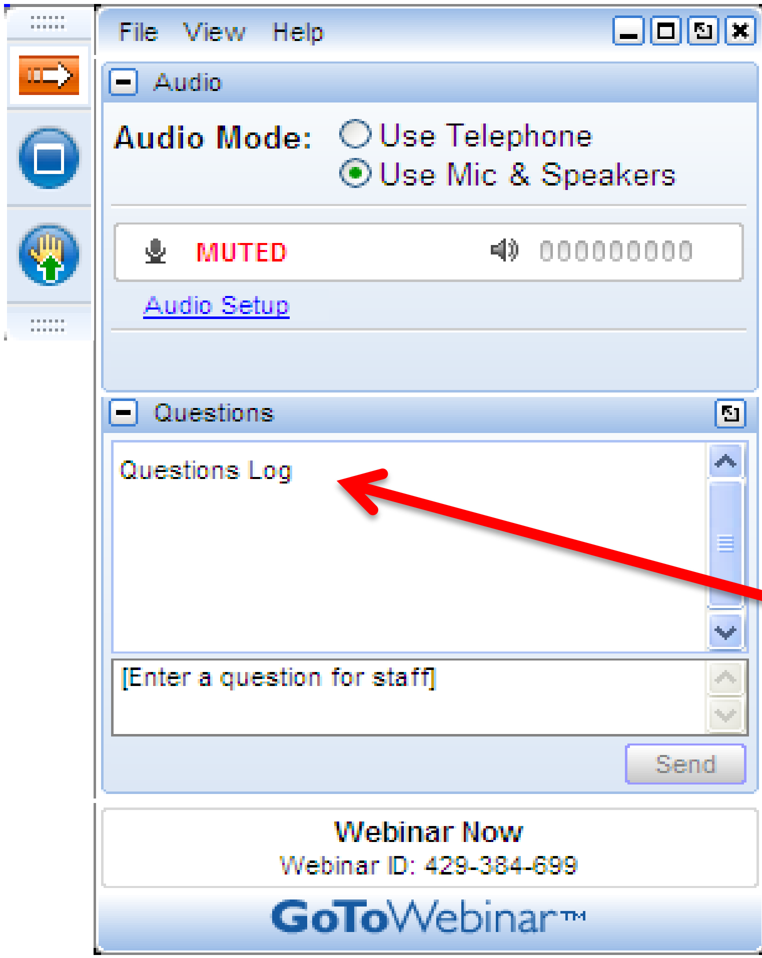
WEF
MARISA TRICAS
mtricas@wef.org

www. [LIFT AFFILIATES MAIN PAGE HERE] .org

"LIFT has provided a forum for bringing together the combined expertise and resources of many highly effective wastewater treatment agencies...which has facilitated more effective collaboration between agencies with similar goals."

BOB BUCHER
PROJECT ENGINEER,
KING COUNTY DEPARTMENT OF NATURAL RESOURCES AND PARKS

How to Participate Today



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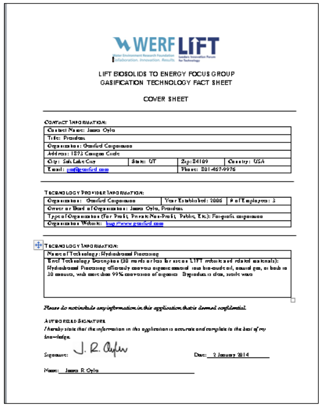
Project Background

- May 2013: LIFT B2E Focus Group Launched
  - Technology Matrix
  - WEFTEC 2013


LIFT BIOSOLIDS TO ENERGY FOCUS GROUP
GASIFICATION TECHNOLOGY FACT SHEET

COVER SHEET

State: UT | Zip: 84109 | Country: USA

- Jan 2014: Genifuel Fact Sheet
  - Expert Review

- Mar 2014: Genifuel B2E Focus Group Presentation

- April/May 2014: Calls w/ Genifuel & Interested Utilities
  - Project Concept Developed

Project Background (cont.)

- Summer/Fall 2014: Funding Assembled
  - City of Calgary
  - City of Orlando
  - City of Santa Rosa
  - Delta Diablo Sanitation District
  - Eastman Chemical Company
  - Melbourne Water Corporation
  - Metro Vancouver
  - Silicon Valley Clean Water
  - Toho Water Authority
  - US EPA
  - DOE (in-kind)

Project Background (cont.)

- June 2014: Request for Qualifications Issued

- Sept 2014: Leidos Selected

leidos

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Project Background (cont.)

- Sept/Oct 2014: PSC Formed
  - Mo Abu-Orf, AECOM
  - Bob Forbes, CH2M Hill
  - Angela Hintz, ARCADIS
  - Bryan Jenkins, University of California – Davis
  - Patricia Scanlan, Black & Veatch
  - Jeff Tester, Cornell University

Project Background (cont.)

- Oct 2014: Full Proposal
- Jan 2015: Revised Proposal
- Feb 2015: Project Kickoff
- April 2016: Project Completed


LIFT6T14

GENIFUEL HYDROTHERMAL
PROCESSING BENCH SCALE
TECHNOLOGY EVALUATION PROJECT

by:
Leidos, Inc.
550 Cochituate Rd.
Framingham, MA 01701
Principal Investigator: Philip A. Marrone

2016

WERF

Agenda (Cont.)
(Eastern Times)

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Speaker

Philip Marrone, Ph.D.
Senior Chemical Engineer,
Leidos, Inc.

Genifuel Hydrothermal Processing Bench Scale Technology Evaluation

LIFT: Getting Involved 101
WERF Project LIFT6T14
April 20, 2016

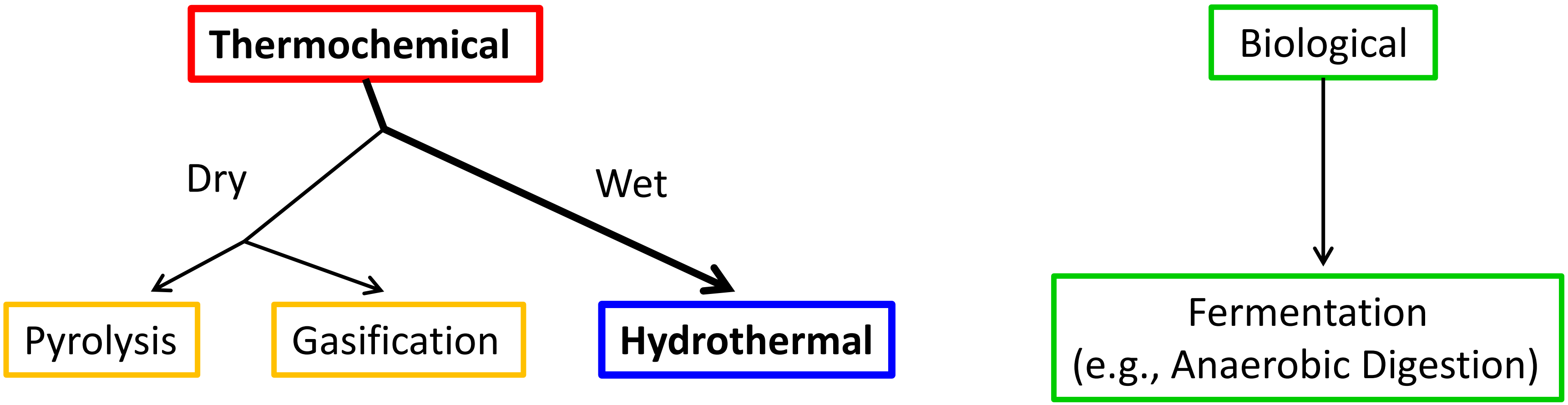
Philip A. Marrone
Leidos

Outline

- Introduction/Motivation
- Objectives
- Sludge Feed Procurement/Preparation
- HTP Test Equipment and Matrices
- HTP Test Observations
- Sampling and Analysis
- Test Results
- Summary/Conclusions
- Recommendations

Introduction

Sludge (organic biomass) Process Options:

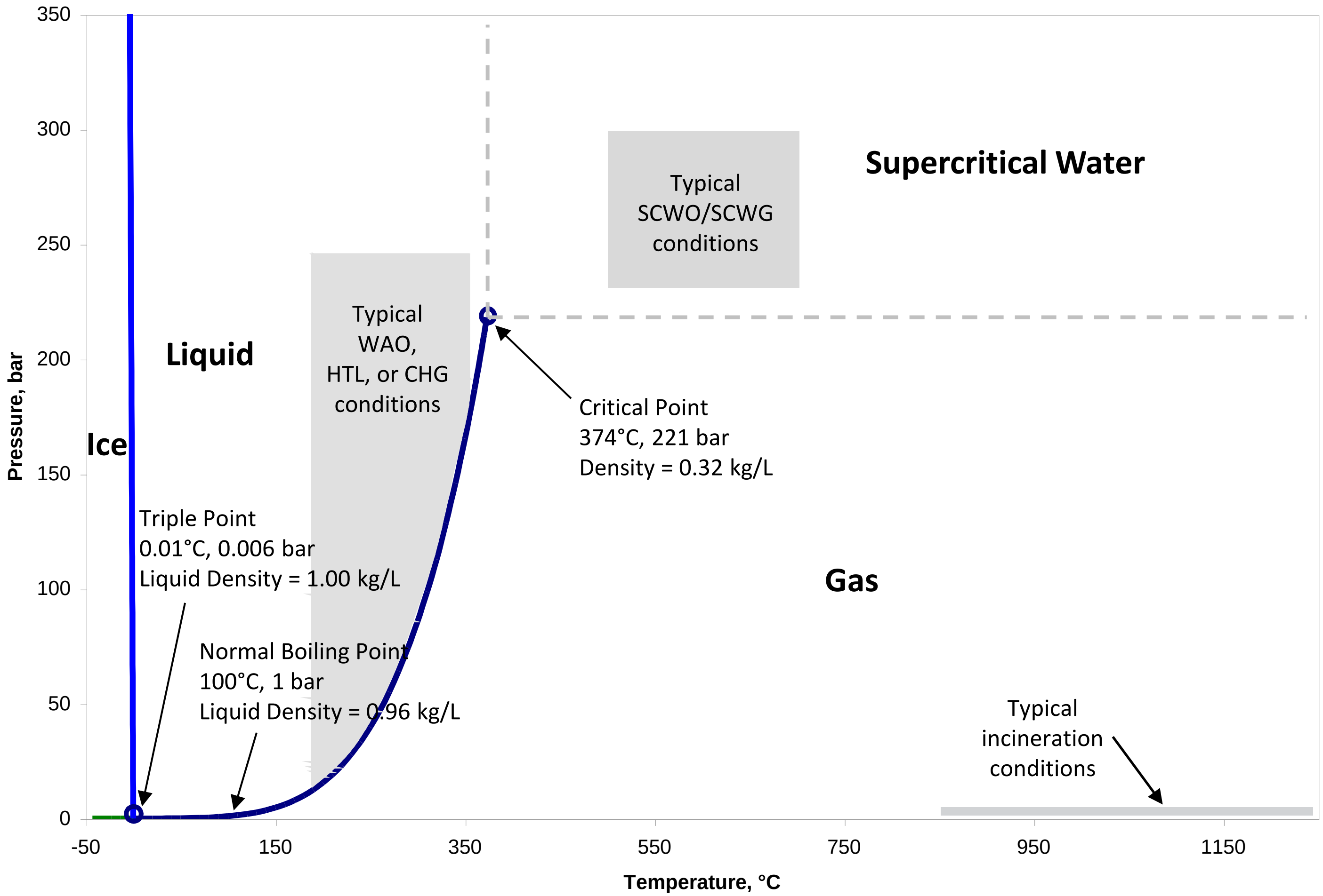


Introduction

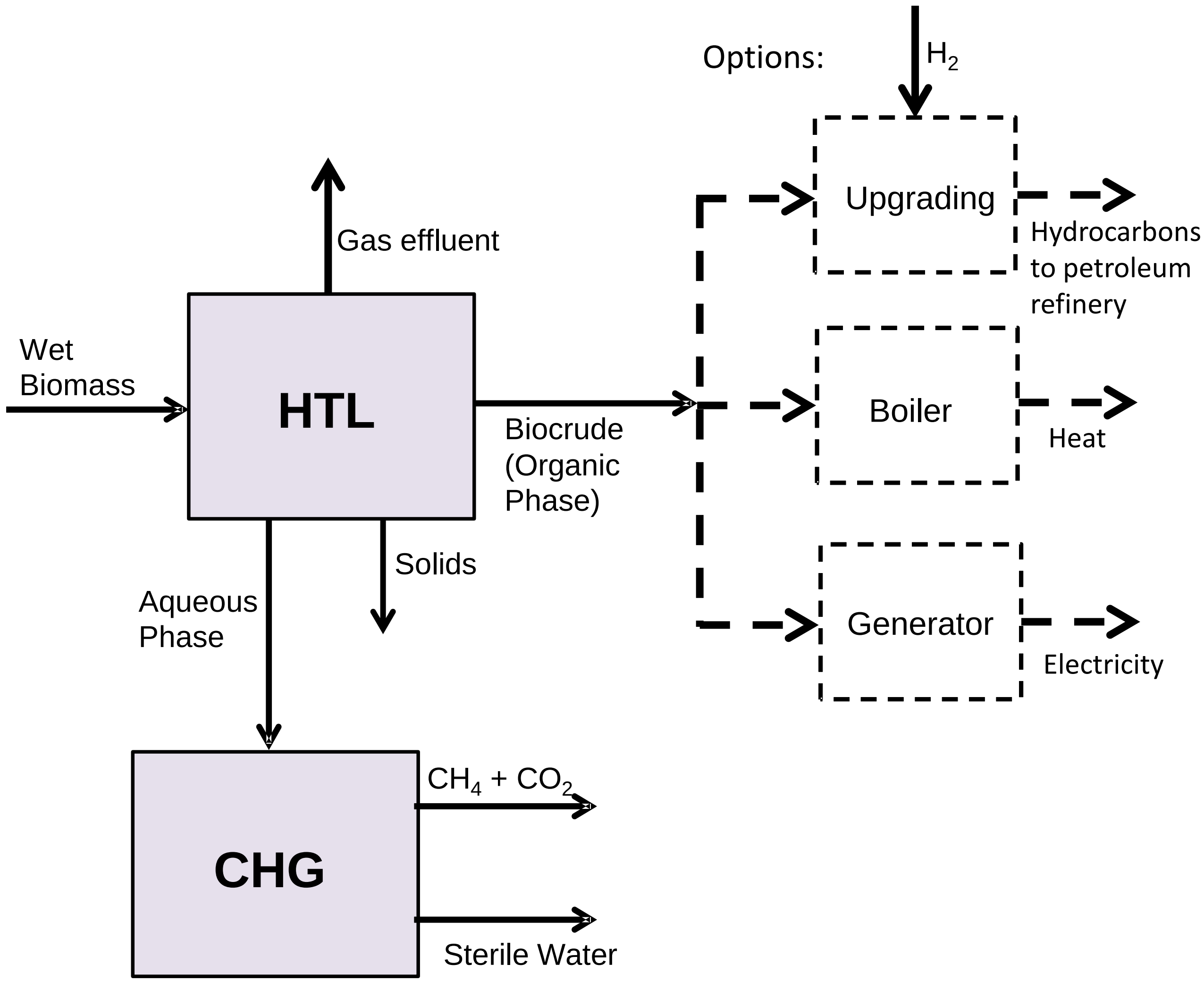
Types of Hydrothermal Processing:

Process	Oxidant?	Catalyst?	Water State	Product Phase of Interest
Hydrothermal Carbonization (HTC)	No	No	Subcritical	Solid
Hydrothermal Liquefaction (HTL)	**No**	**Possible**	**Subcritical**	**Liquid**
Catalytic Hydrothermal Gasification (CHG)	**No**	**Yes**	**Subcritical**	**Gas**
Supercritical Water Gasification (SCWG)	No	Possible	Supercritical	Gas
Wet Air Oxidation (WAO)	Yes	Possible	Subcritical	--
Supercritical Water Oxidation (SCWO)	Yes	Possible	Supercritical	--

Properties of Water



Genifuel Process



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Motivation

- **Advantages of Hydrothermal Processing (subcritical):**
    - Ideal for high water content feeds (e.g., lignocellulosics, manure, algae)
    - No drying (avoid heat of vaporization energy cost)
    - Utilizes all of biomass
    - Converts organic portion of feed to valuable fuel products

- **Wastewater Treatment Sludge:**
    - Byproduct of wastewater treatment process
    - Must be disposed (by landfill or land application) at cost to treatment plant
    - Anaerobic digestion reduces but does not eliminate solids

- **Limited previous research on HTL of wastewater treatment sludge**

Objectives

- **Overall:** Assess technical performance and potential viability of HTL-CHG process on wastewater sludge feed through proof-of-concept, bench-scale tests.

- **Specific:**

1. Determine sludge concentration that can be pumped.
2. Quantify the amount of biocrude and methane produced.
3. Characterize all feed and product streams.
4. Verify mass balance closure (total mass and carbon) to within 15%.
5. Analyze economic potential based on biocrude quality and current sludge handling data.
6. Assess areas of future work based on test observations and results.

Sludge Feed Procurement/Preparation

➢ **Sludge Types Tested:**
- Primary
- Secondary
- Post-digester (Digested Solids)

➢ **Sludge Provider:**

Metro Vancouver – Annacis Island WWTP

Annacis Island WWTP, Delta, BC, Canada

➢ **Sludge Preparation:**

Sludge	Initial Solids Conc.	Dewatering Method	Autoclave Conditions	Solids Conc. At Shipment	Dilution at PNNL	Final Solids Conc.
Primary	4.5 wt%	Filter press (40 psi for 20 min; 300 μm filter), followed by hand press	Yes (121°C for 5 hrs)	26.0 wt%	Yes	11.9 wt%
Secondary	3.9 wt%	55 L Dewatering bags for 48 hrs	Yes (121°C for 5 hrs)	10.9 wt%	No	10.0 wt%
Digested Solids	28 wt%	None	None	28 wt%	Yes	16.4 wt%

Sludge Feed Procurement/Preparation

Primary (11.9 wt % solids)

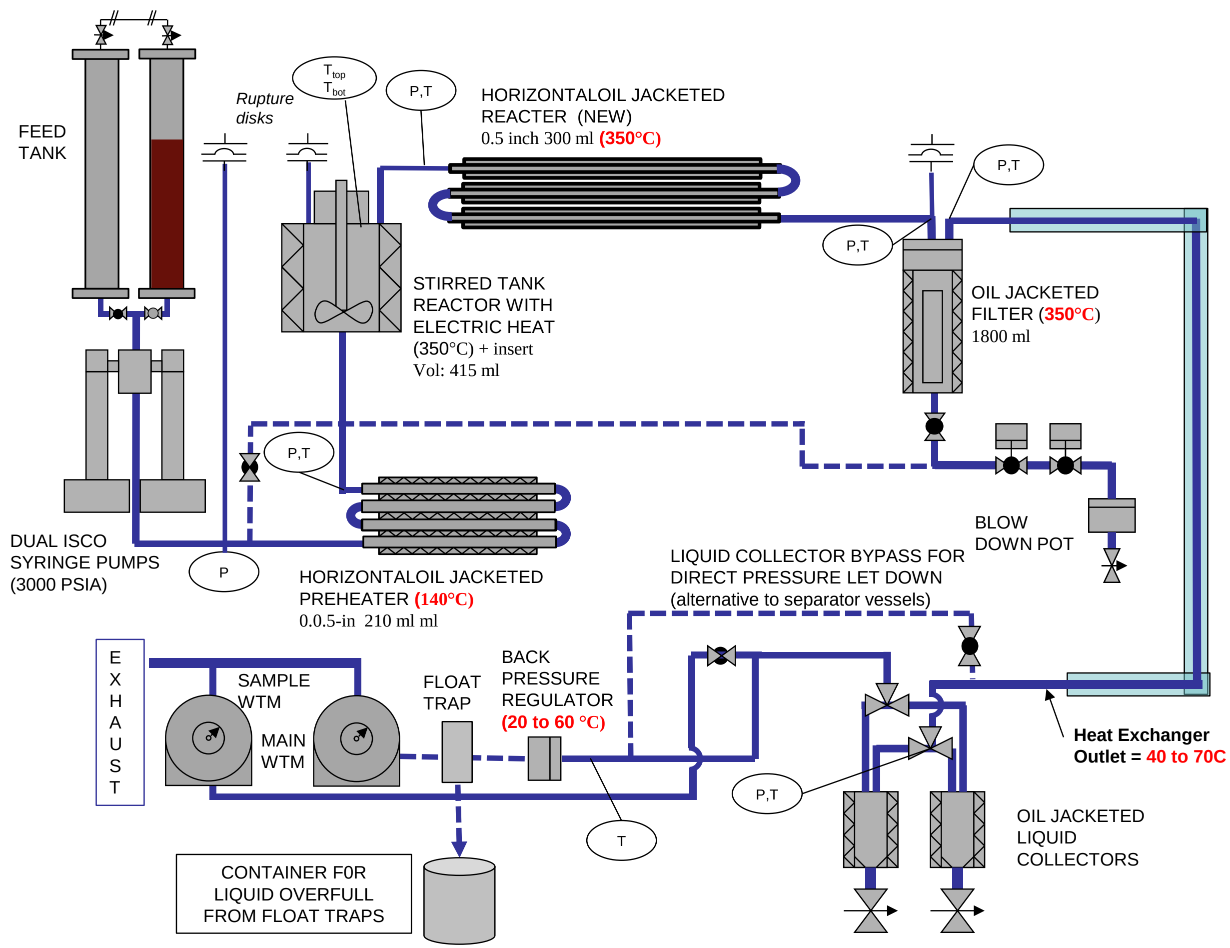
Secondary (10.0 wt% solids)

Sludge Feeds

Post-digester (16.4 wt % solids)

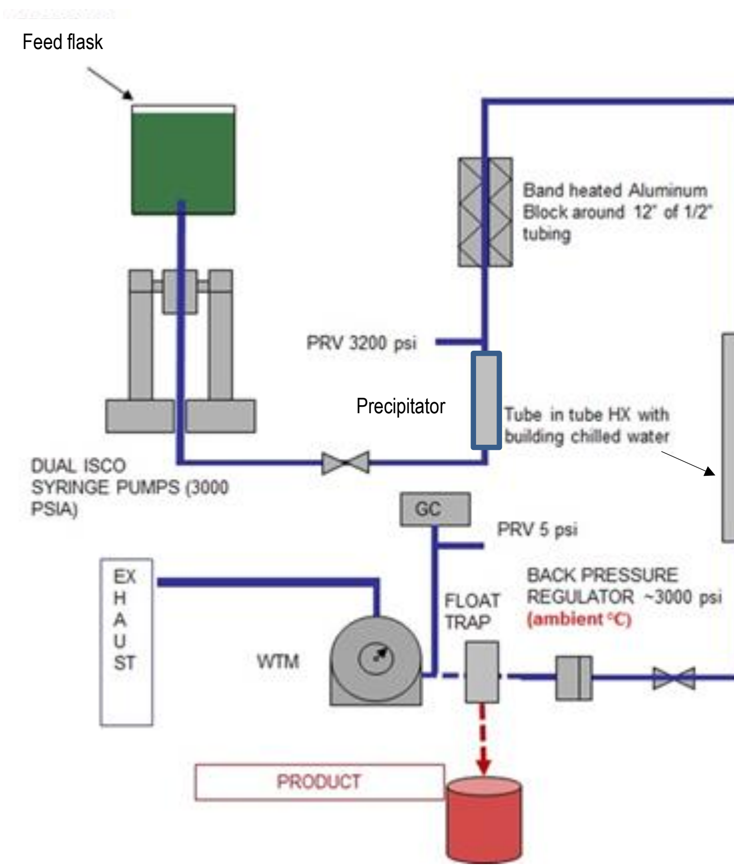
Hydrothermal Processing Tests - Equipment

PNNL Bench-scale HTL System

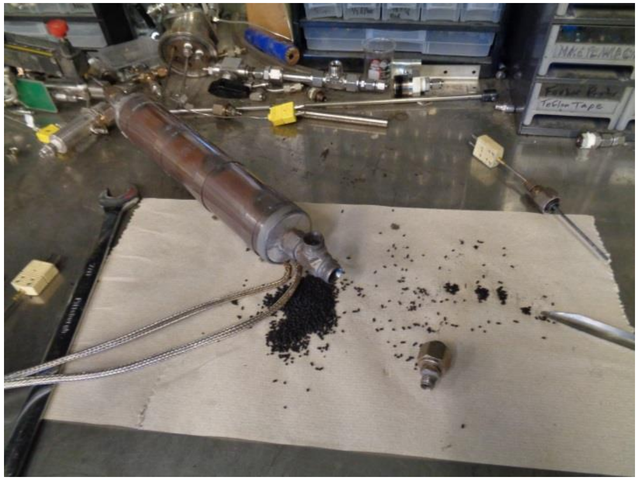


Hydrothermal Processing Tests - Equipment

PNNL Bench-scale CHG System



Precipitator and Reactor



Ru catalyst

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Hydrothermal Processing Tests – Test Matrices

- **HTL:** 1 test per sludge feed types (post-digester test repeated):

Sludge Feed	Feed Conc. (wt% solids)	Feed Flow Rate (L/hr)	Reaction Temperature (°C)	Avg. System Pressure (psig)	Liquid Hourly Space Velocity (hr^{-1})	Mean Residence Time (min)	Test Duration			No. of Steady State Liquid Samples (Set-asides)
							Total Feed (hrs)	Baseline steady state (hrs)	RLD steady state (hrs)	
Primary	11.9	1.5	318-353	2948	2.1	18	7.4	2.0	1.5	3
Secondary	9.7	1.5	276-358	2919	2.1	19	7.5	2.0	1.0	3
Digested Solids	16.0	1.5	332-358	2906	1.2	30	7.2	2.7	1.5	4

- **CHG:** 1 test per each HTL combined steady state aqueous phase product:

HTL Aqueous Effluent Feed Source	Feed Flow Rate (mL/hr)	Avg. Reactor Temperature (°C)	Avg. System Pressure (psig)	Reactor Residence Time (min)	Test Duration (hr)		Sulfur Removal (Raney Ni) (g)	Catalyst (Ru on graphite) (g)
					Total Feed	Steady State		
Primary	39.7	347	3023	15	49.3	20.6	8.05	10.71
Secondary	43.8	346	2883	15	45.4	35.9	8.19	11.82
Digested Solids	41.2	348	2959	15	31.4	25.4	8.98	11.65

Hydrothermal Processing Tests – Observations

HTL steady state liquid effluent

Separated biocrude

Solids from filter vessel

CHG aqueous feed (far left) and liquid effluent samples

CHG aqueous effluent

Analytical Approach – Laboratories & Methods

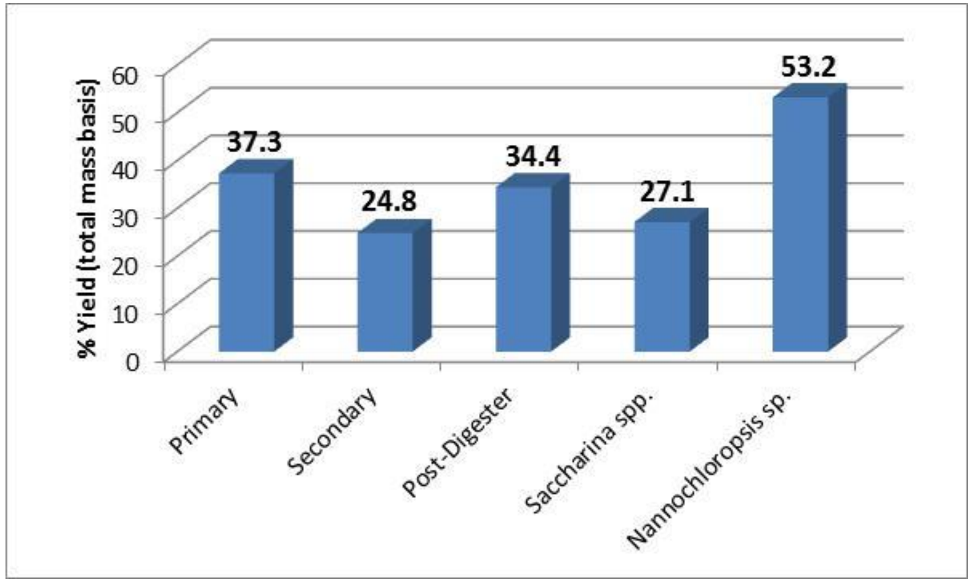
PNNL HTL Laboratory (BSEL-156)	
• Ammonia and Chemical Oxygen Demand (COD)	• Hach Kits
• Ash, Dry Solid Content, Filtered Oil Solids, Moisture, Weight	• Gravimetric Determinations
• Light Hydrocarbons and Permanent Gases (HTL Samples)	• In-line INFICON Micro GC with a Thermal Conductivity Detector (TCD)
• Light Hydrocarbons and Permanent Gases (CHG Samples)	• Off-line GC with a TCD
• pH	• pH meter
• Density and Viscosity	• Gravimetric or Anton Paar Stabinger Viscometer

PNNL Analytical Laboratory (BSEL-166)	
• Anions	• Ion chromatography
• Dissolved Organics	• High Performance Liquid Chromatography (HPLC) Refractive Index Detection (RI)
• Metals	• Inductively Coupled Plasma (ICP) – Optical Emission Spectrometry (OES)

Off site Laboratories	
• Elemental Analysis	• ALS Environmental Laboratory in Tucson, AZ, ASTM Methods
• Total Acid Number	• ALS Environmental Laboratory in Tucson, AZ ASTM Method D3339
• Total Organic Carbon	• ALS Environmental Laboratory in Jacksonville FL, EPA Method 9060
• Siloxanes	• Atmospheric Analysis and Consulting, Ventura, CA, EPA TO-15

Test Results - Biocrude

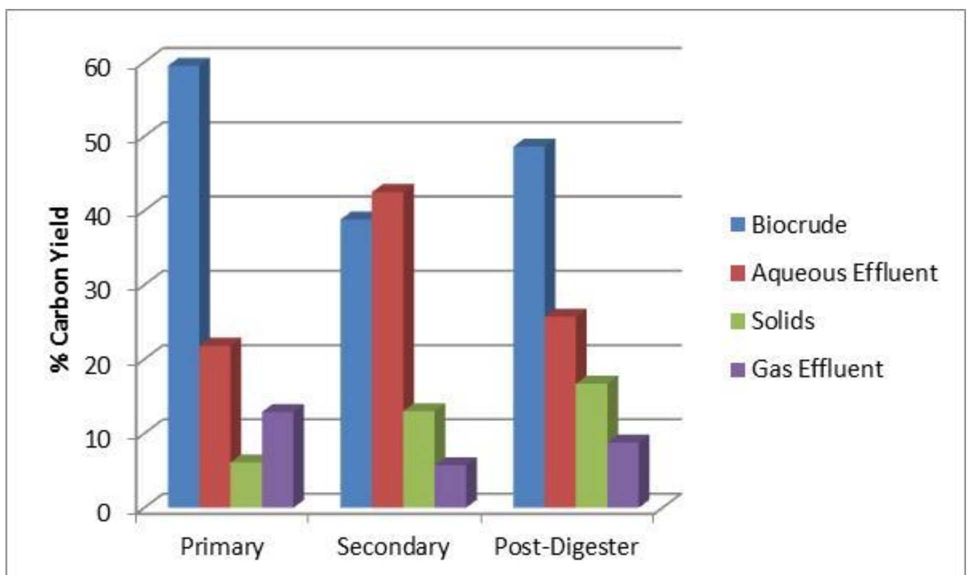
HTL Biocrude Yield (total mass basis)



Algae data for comparison from other PNNL studies (Elliott et al., 2013 and Elliott et al., 2014)

All yield values are normalized per appropriate mass balance

HTL Carbon Yields



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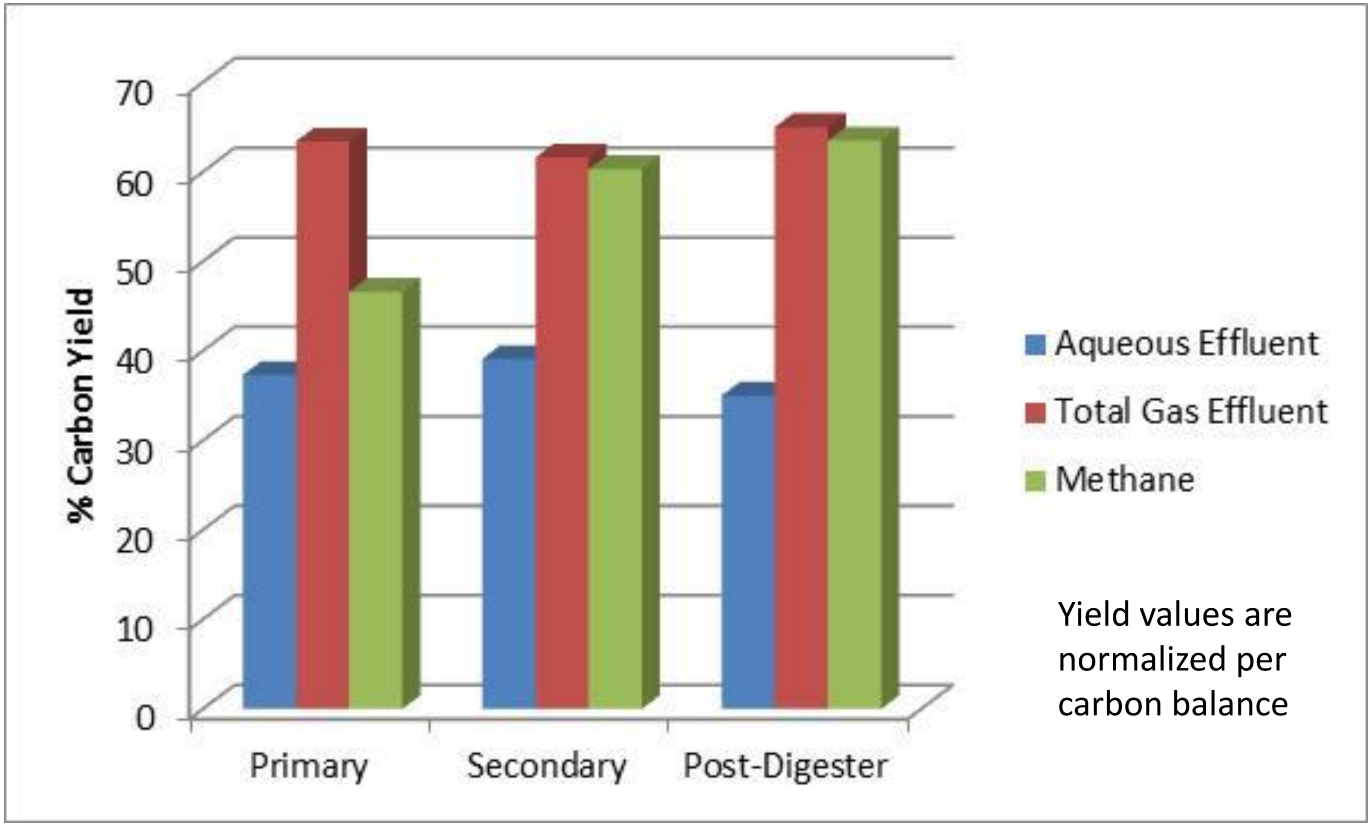
Test Results - Biocrude

HTL Biocrude Quality

Data	Biocrude from Sludge			Biocrude from Algae	
	Primary	Secondary	Post-Digester	*Saccharina spp.*	*Nannochloropsis sp.*
wt% Carbon (dry)	76.5	72.5	78.5	79.4	79.2
wt% Hydrogen (dry)	10.1	8.7	9.51	8.0	10.0
H:C molar ratio	1.6	1.4	1.4	1.2	1.5
wt% Oxygen(dry)	8.1	6.5	6.21	8.3	5.7
wt% Nitrogen(dry)	4.3	5.1	4.46	4.1	4.7
wt% Sulfur (dry)	0.63	0.90	1.16	0.3	0.5
wt% Ash (dry)	0.38	6.3	0.21	Not determined	Not determined
wt% Moisture	13.0	1.0	13.5	9.2	7.8
TAN (mg KOH/g)	65.0	44.8	36.0	36	Not determined
Density (g/ml)	1.000	0.985	1.013	1.03	0.95
Kinematic viscosity (cSt)	571	624	1160	1708	205
Heating Value (MJ/kg)	37.8	34.8	38.0	-	-

Test Results - Methane

CHG Carbon Yields



CHG gas effluent comprised mostly of methane

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Test Results - CHG Aqueous Effluent

- **Organic Removal**

COD (units in ppm)

Sludge Feed	HTL Feed	Post-HTL	Pre-IX	Post-IX	Post-CHG
Primary	187,000	41,000	40,800	20,300	54
Secondary	153,000	73,000	72,300	21,700	25
Digested Solids	203,000	48,200	49,900	23,700	19

> 99% reduction in COD over HTL-CHG process

- **Sulfate / Catalyst Performance**

	Total Sulfur (ppm)	
	Raney Ni	Ru/C
Primary	4100	1700
Secondary	16,000	3400
Digested Solids	9900	1410

Ru Catalyst active at end of each CHG test (52-85 hrs exposure), but total sulfur concentrations on catalyst indicate poisoning per PNNL (> 1000 ppm)

Water Quality

Analysis	Regulatory Limit*	CHG Effluent
BOD cBOD	< 60 ppm < 15 ppm	√ (< 26 ppm)**
Total N	< 2 ppm	X (> 1100 ppm)
Total P	< 0.2	√ (< 1 ppm)

CHG effluent may be capable of meeting regulatory requirements for discharge except for nitrogen

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Test Results - CHG Gas

Siloxanes

- Found in biogas; silica formed in combustion is abrasive and insulating
- Analyzed gas effluent for 7 specific siloxanes and 2 precursors by laboratory used by Silicon Valley Clean Water WWTP

Feed	Test	Siloxane Conc.
Primary	HTL	All < 263 ppb
Post-Digester	HTL	All < 2886 ppb
Primary	CHG	All < 22.7 ppb except trimethylsilanol = 43.3 ppb
Secondary	CHG	All < 43 ppb
Post-Digester	CHG	All < 40 ppb

- Gas engine fuel specifications:
  - GE Jenbacher - < 3 ppm
  - MWM Caterpillar - < 800 ppb
- All CHG gas siloxane concentrations met engine specs
- Si partitions mostly into aqueous phase effluent

Test Results - HTL Solids

	Primary	Secondary	Post-digester
Sludge Feed (g/hr)	1541	1499	1570
Sludge Ash (wt%)	7.5	16.2	28.0
HTL Solids (g/hr)	17.4	29.8	88.9
HTL Solids Ash (wt%)	64.4	64.5	73.3
HTL Solids Weight Reduction (%)	99	98	94

- **Post-digester sludge generated the highest amount of solids and %ash**
- **HTL process results in high solids reduction relative to sludge feed weight**

Summary/Conclusions

- Biocrude and methane successfully generated from all 3 sludge types.
- Secondary sludge results possibly affected by equipment issues, low solids content, autoclaving, and inherent nature of sludge.
- Mass balance closure within ± 15% achieved for all total mass and carbon balances but one.
- 94 samples for a total of ~2,500 analytical data results with adequate precision and accuracy.
- No difficulties experienced pumping sludge feeds; potential to process at higher conc.
- Biocrude quality appeared comparable to that from other biomass feeds (e.g., algae), was ~ 80% of heating value of petroleum crude, and needs to be upgraded.
- Had > 99% COD reduction in effluent and 94-99% solids reduction relative to feed.
- Siloxane concentrations in the CHG product gas were below engine limits.
- The CHG aqueous effluent is capable of meeting regulatory limits except total N.
- The CHG Ru/C catalyst and Raney Ni guard bed performed well, but S poisoning occurred.

The overall results of this proof-of-concept test program are sufficiently promising to justify further investigation of the HTL-CHG technology for application to sludge.

Recommendations

- Determine the HTL optimal sludge feed concentration for each sludge type and a representative combination of primary and secondary sludge.
- Perform long-term operation tests on a single, integrated HTL-CHG system at pilot-scale that is representative of the equipment and design that would be installed at a WWTP.
- Develop and demonstrate an better temperature control and an effective method to remove sulfate species from HTL effluent to avoid poisoning of the downstream CHG catalyst.
- Determine the CHG ruthenium catalyst replacement frequency.
- Perform an energy balance on an integrated, representative pilot-scale system.
- Perform a burner or small engine test with biocrude produced from sludge.
- Perform a TCLP test on HTL solids to determine proper classification for disposal.
- Identify trace organic contaminants in feed and determine fate after HTL-CHG processing.
- Characterize dewatered sludge filtrate for plant recycle.
- Identify interested WWTP facilities and perform a detailed site-specific economic analysis and GHG reduction analysis to assess the economic viability for installation of HTL-CHG.

Agenda (Cont.)

(Eastern Times)

Part 2: Example Collaborative Project

1:40 **Background**
Jeff Moeller, WERF

1:45 **Genifuel Hydrothermal Processing Bench Scale Evaluation**
Philip Marrone, Leidos, Inc.

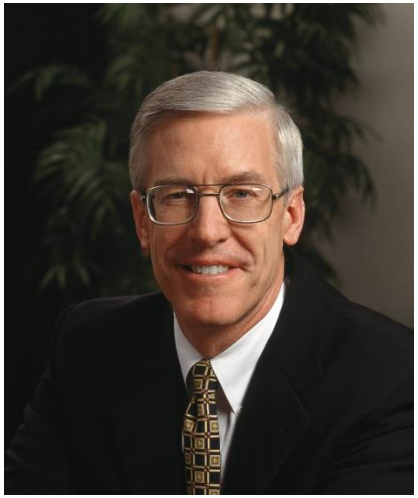
2:05 **Hydrothermal Processing in Wastewater Treatment: Planning for a Demonstration Project**
Jim Oyler, Genifuel

2:10 **Project Participant Perspectives**
Paul Kadota, Metro Vancouver

2:15 **Q&A**

2:30 **Adjourn**

Speaker



Jim Oyler
President,
Genifuel

Hydrothermal Processing in Wastewater Treatment

Planning for a Demonstration Project

Paul Kadota
metrovancouver

James Oyler
Genifuel CORPORATION

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Overview

- This presentation shows a proposed project to scale-up a Hydrothermal Processing (HTP) system at a Water Resource Recovery Facility (WRRF)
- The demonstration project follows a key recommendation of the LIFT Report
- The sponsor is Metro Vancouver (MV)

Metro Vancouver's Interest in HTP

- Metro Vancouver saw HTP pilot project as a way to explore 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

The Scaled-Up System

- The Metro Vancouver system is based on a pilot-scale HTP system that has recently completed commissioning
- The Metro Vancouver system will be 5x larger than the recently completed system
- Will install in two stages—oil formation in Stage 1, followed by oil + gas in Stage 2.

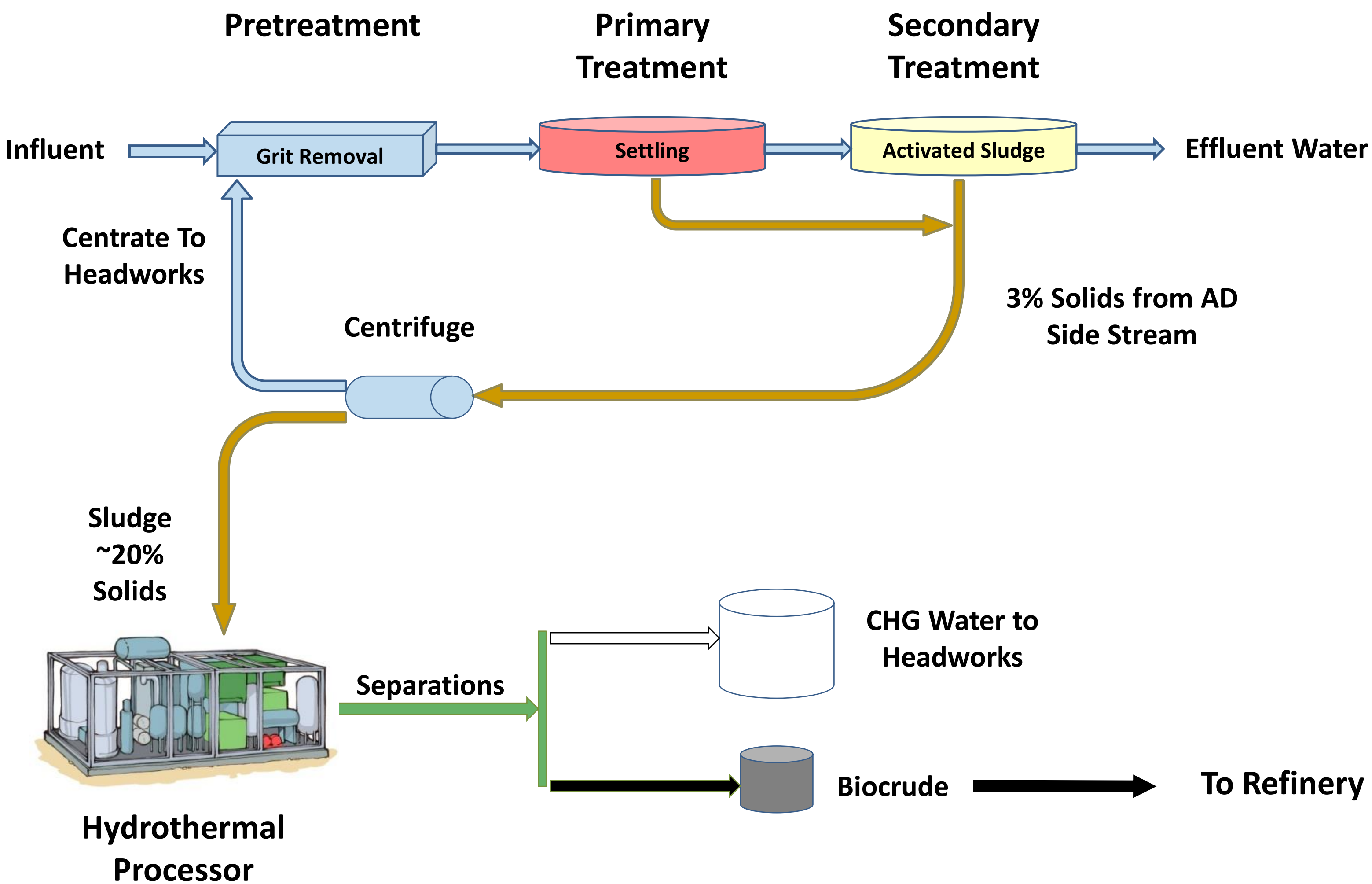
Recently Commissioned HTP System

Annacis Island Plant

HTP Will Process Undigested Solids

- Combined stream of primary and secondary solids (secondary is Waste Activated Sludge)
- Combined stream will be taken as a side stream from the digester feed
- Centrifuge will be used to increase solids from 3% to 20%
  - Undigested cake at 20% solids feeds the hydrothermal system
  - Centrate returns to headworks

Proposed HTP Implementation at Metro Vancouver



HTP Size Compared to AD Alternative

MEASURE	HTP	AD
Area occupied	6,727 ft^2 (625 m^2)	15,327 ft^2 (1424 m^2)
Building Height	20 ft (6.1m)	48 ft (14.6 m)

- *HTP footprint is 44% of AD*

GHG Reduction (CO_2 emissions)

ITEM	HTP	AD
Avoided Emissions via HTL Biocrude	860 t/y	N/A
Avoided Emissions via Methane	190 t/y	350 t/y
Total CO_2 Avoided	1,050 t/y	350 t/y

- *HTP reduces CO_2 emissions 3x more than AD*

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20-Year Cost (Net Present Value)

MEASURE	HTP (USD $000)	AD (USD $000)
Capital Expense	**$5,805**	**$5,346**
Operating Expense	**$237**	**$444**
Revenue	**$124**	**$26**
20-Year Net Cost*	**$7,305**	**$11,126**

- ***Outcome of analysis is case-specific***
- ***In this example, HTP cost is 34% less than AD***

* Interest = 7%; OpEx Annual Increase = 3.5%; Oil and Gas Annual Price Increase = 4%

Additional Benefits of HTP

- HTP is thermochemical; does not rely on organisms that can cause 'upsets'
- Protects against escalating sludge disposal cost
- Low retention time, complete sterilization, odor compounds are reduced
- HTP destroys organics such as pesticides, pharmaceuticals, flame retardants
- Ammonia and phosphorus can be recovered

Conclusions

- Pilot project will provide valuable data and experience with hydrothermal processing
- Follows recommendation from LIFT program
- Successful project can form basis of large scale implementation
- A potentially disruptive technology for the wastewater industry

Agenda (Cont.)

(Eastern Times)

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Speaker

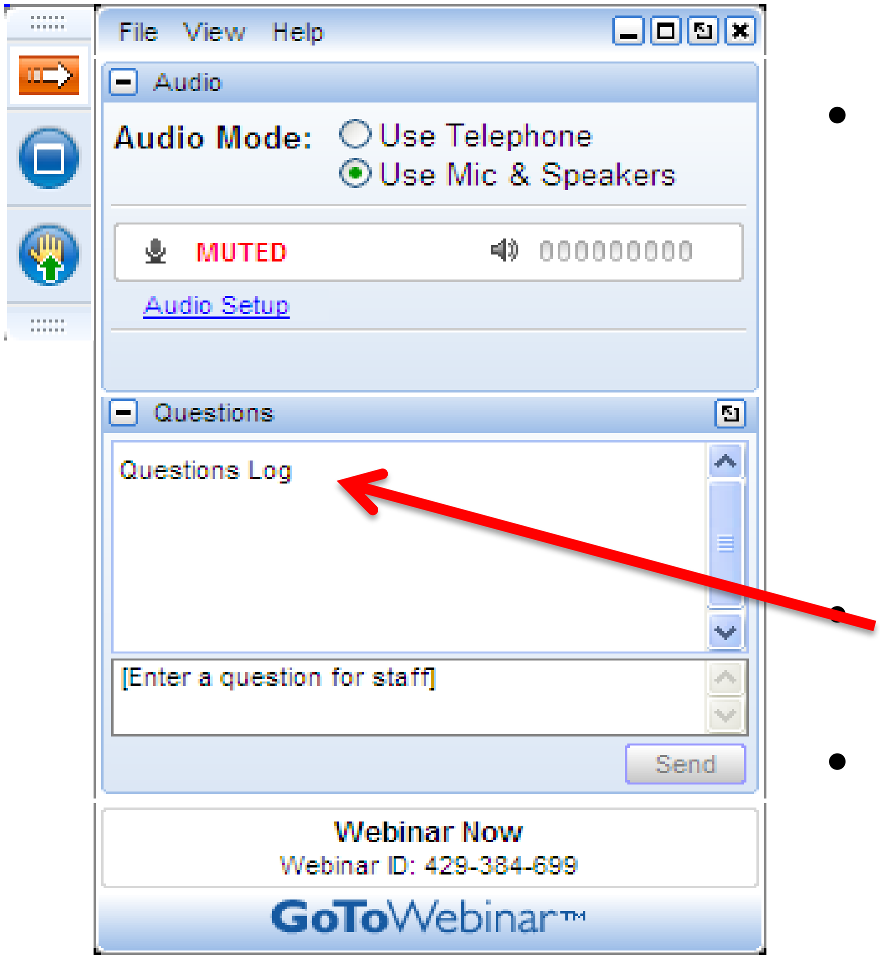
Paul Kadota

Program Manager,

Metro Vancouver

Metro Vancouver's Involvement and Experience

How to Participate Today



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- **Submit your questions using the Questions pane.**
- **A recording will be available for replay shortly after this web seminar.**

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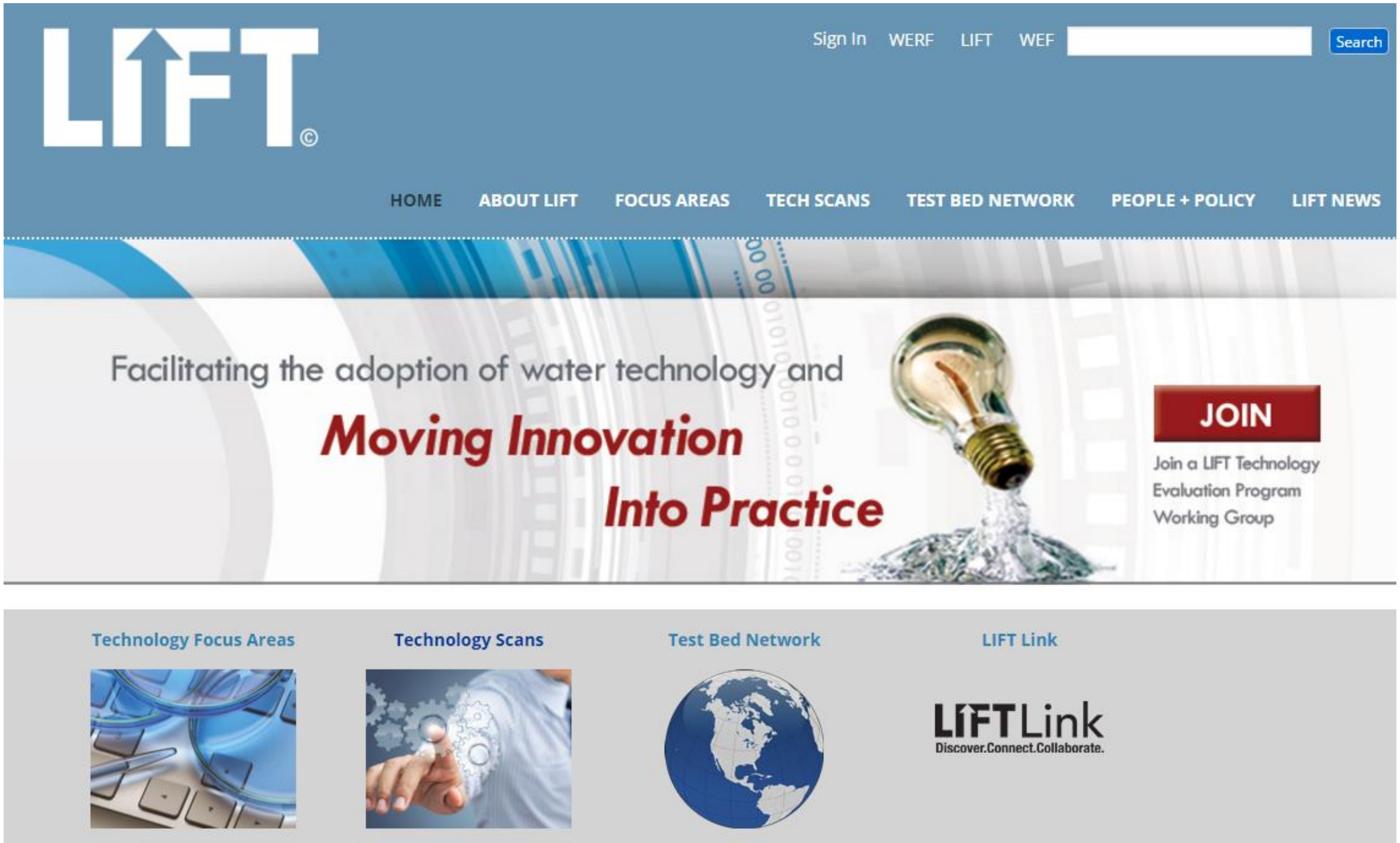

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Thank You