Biofuels from Wastewater: State of the Industry

Fernando Sarmiento, P.E.
fsarmiento@greeley-hansen.com; 602-778-8475

August 31, 2011

GREELEY AND HANSEN

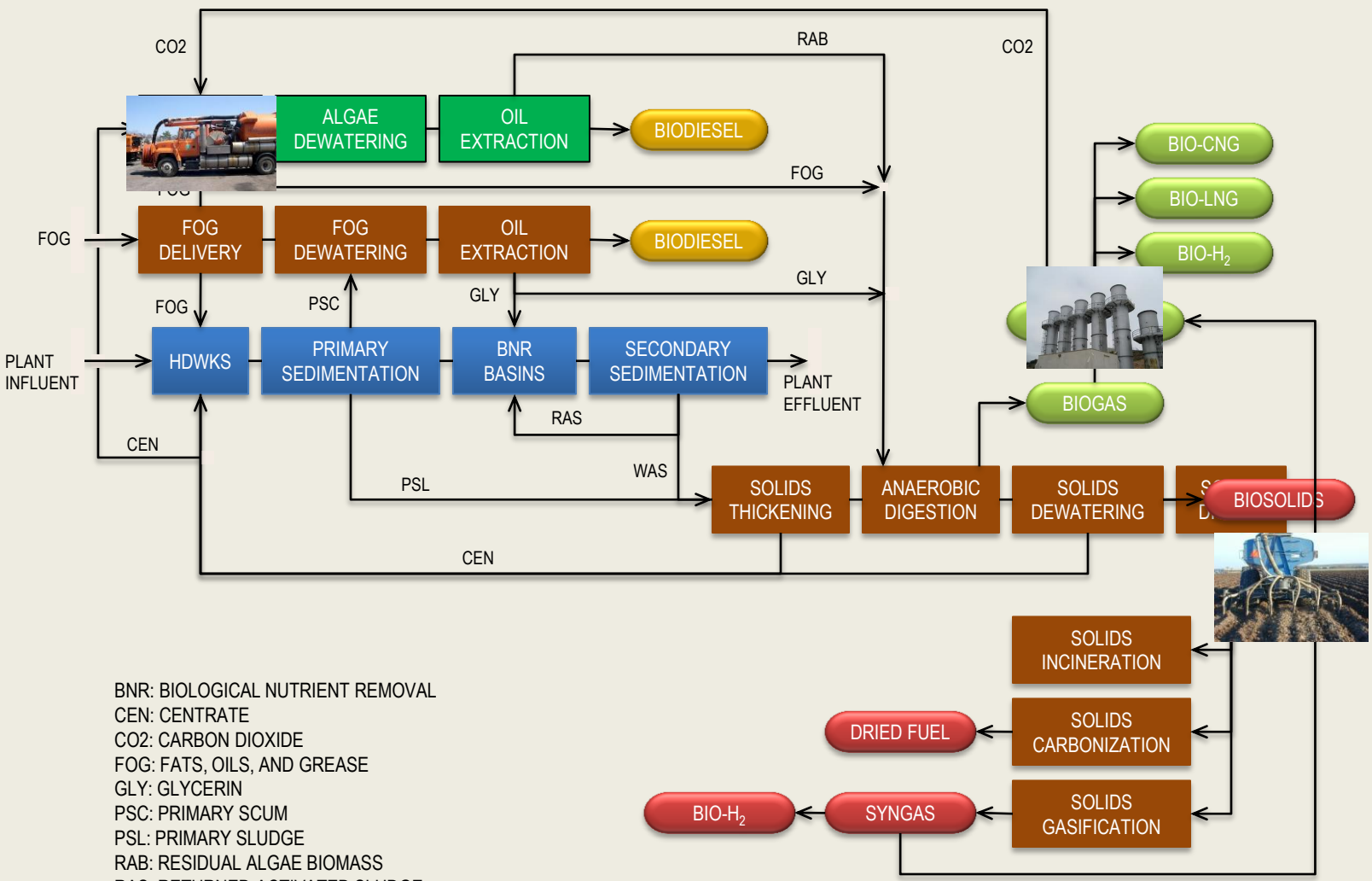
Presentation Overview

- Wastewater Treatment Plant
  - Conventional
  - Future
- Biofuels from Wastewater
  - Biogas (Digester Gas)
  - Biosolids (Dried Solids)
  - Biodiesel (FOG and Algae)
- Summary

Conventional WWTP

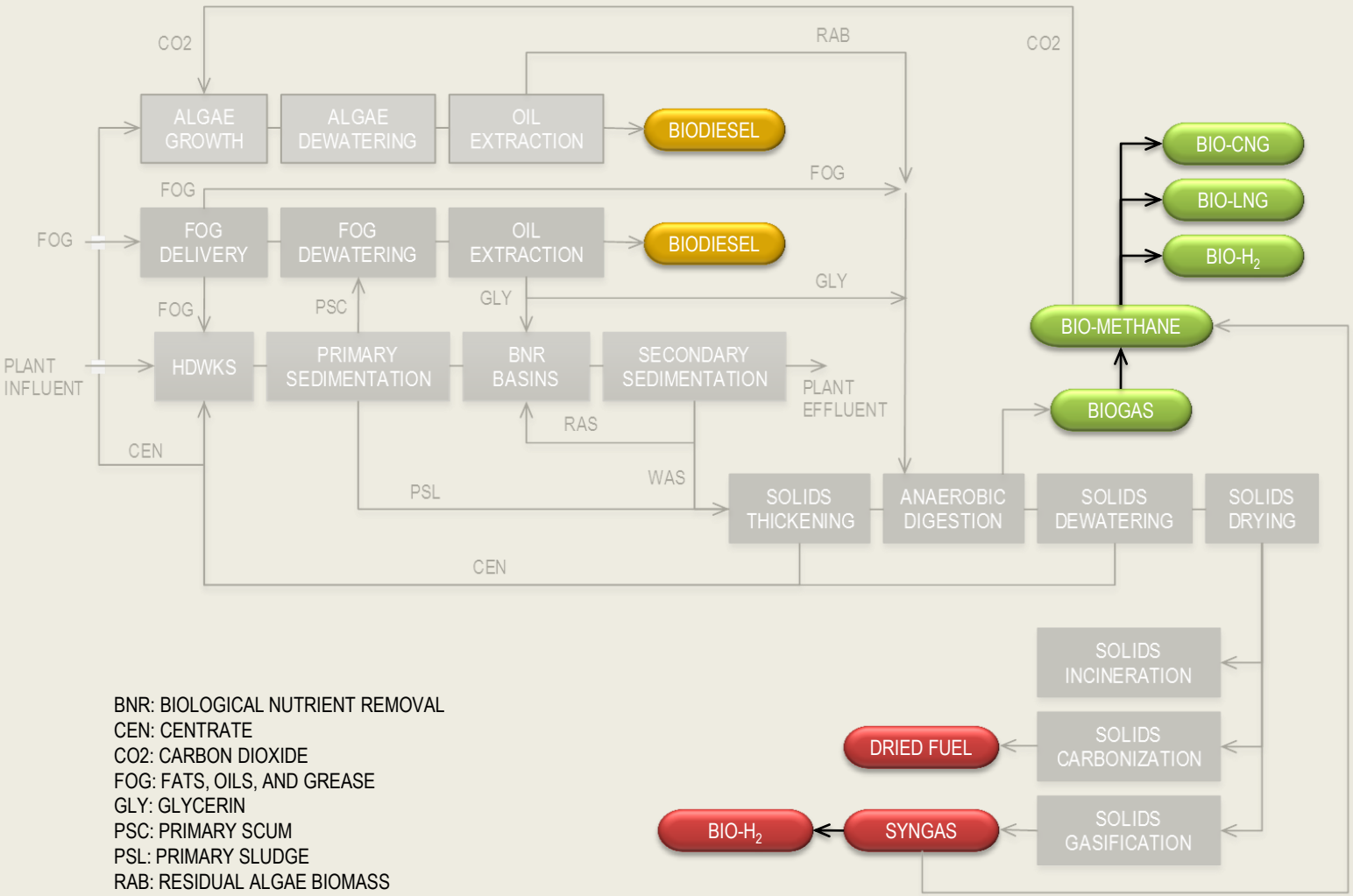
BNR: BIOLOGICAL NUTRIENT REMOVAL
CEN: CENTRATE
FOG: FATS, OILS, AND GREASE
PSL: PRIMARY SLUDGE
RAS: RETURNED ACTIVATED SLUDGE
WAS: WASTE ACTIVATED SLUDGE

Future WWTP…



BNR: BIOLOGICAL NUTRIENT REMOVAL
CEN: CENTRATE
CO2: CARBON DIOXIDE
FOG: FATS, OILS, AND GREASE
GLY: GLYCERIN
PSC: PRIMARY SCUM
PSL: PRIMARY SLUDGE
RAB: RESIDUAL ALGAE BIOMASS
RAS: RETURNED ACTIVATED SLUDGE
WAS: WASTE ACTIVATED SLUDGE

Future WWTP…



BNR: BIOLOGICAL NUTRIENT REMOVAL
CEN: CENTRATE
CO2: CARBON DIOXIDE
FOG: FATS, OILS, AND GREASE
GLY: GLYCERIN
PSC: PRIMARY SCUM
PSL: PRIMARY SLUDGE
RAB: RESIDUAL ALGAE BIOMASS
RAS: RETURNED ACTIVATED SLUDGE
WAS: WASTE ACTIVATED SLUDGE

Biofuels from Wastewater

- Dried Fuel
- Syngas
- Bio-Hydrogen

Dried Solids

WWTP Biofuels

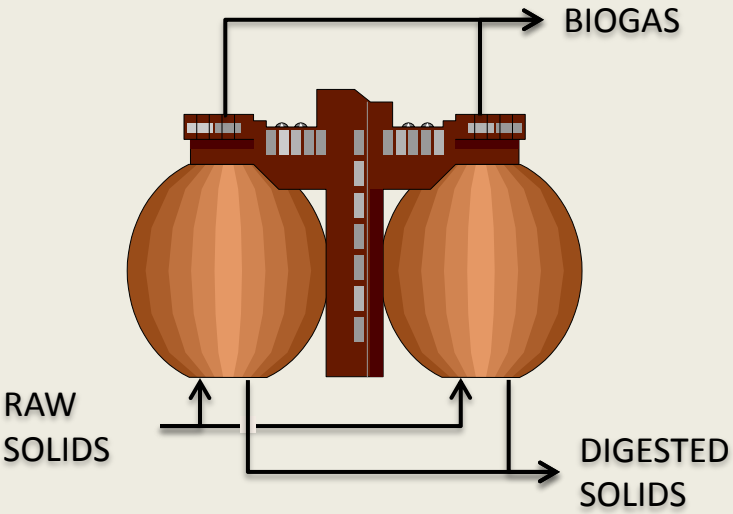
- Bio-Methane
- Bio-CNG
- Bio-LNG
- Bio-Hydrogen

Biogas

Biodiesel

- FOG-Based
- Algae-Based

Biogas – Background/Relevance



Anaerobic Digestion

Biodegradation of Volatile Content in Raw Solids

Biogas

CH_4: 60-65%

CO_2: 35-40%

<u>Traditional Uses</u>

- Flaring
- Process/Space Heating
- Power Generation
- Co-Generation (CHP)

Biogas – Background/Relevance

Biogas Heating Value	600 BTU/CF
Natural Gas (NG) Heating Value	1,000 BTU/CF
Typical WWTP Biogas Generation	1.0 CF/person/day
Typical Biogas Power Generation	2.2 watts/person

544 WWTPs > 5 MGD; w/ Anaerobic Digestion → 340 MW Potential Electricity Generation → 2.3M Tons CO_2 Annual Emissions Offset = 640,000 Acres of Forest

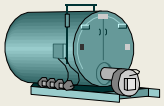
= 430,000 Cars CO_2 Emissions

Source: EPA Combined Heat and Power Partnership (CHPP), 2007

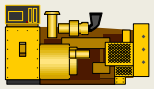
Biogas – What We Know

Traditional Uses

Flaring

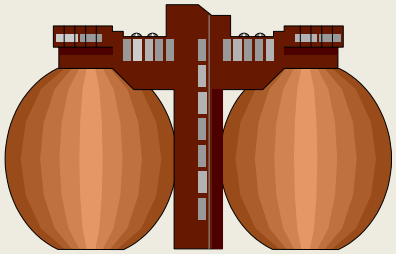


Heating



Co-Generation

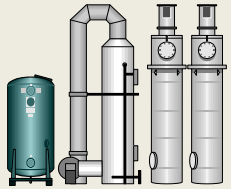
Anaerobic Digestion



BIOGAS

60-65% CH_4
35-40% CO_2
H_2S, Water,
Siloxanes

Biogas Cleaning



BIO-METHANE

95-98% CH_4

NG Pipeline Injection

Vehicle Fuel Use

- Liquid Scrubbing
- Granular Media Adsorption
- Iron Exchange
- Pressure Swing Adsorption (PSA)
- Membrane Separation

Uses Gaining Attention

NG Pipeline Injection

- United States
  - Standards Determined by Utility Owning NG Pipeline
  - Growing Interest Driven by Renewable Energy Credits and Self-Generation Incentives
- Europe
  - National Standards on Pipeline Quality Gas
  - Bio-Methane Injection Into NG Grid: 25% Annual Market Growth

Vehicle Fuel Use

BIO-METHANE

95-98% CH_4
NG Quality

BIO-CNG

2,500-5,000 psig
Storage/Fueling Facilities
Vehicle Conversion
GGE = 127 CF CNG

BIO-LNG

Cryogenic Process
Costs More to Produce
More Complex/Expensive Vehicles
GGE = 1.5 gallons LNG

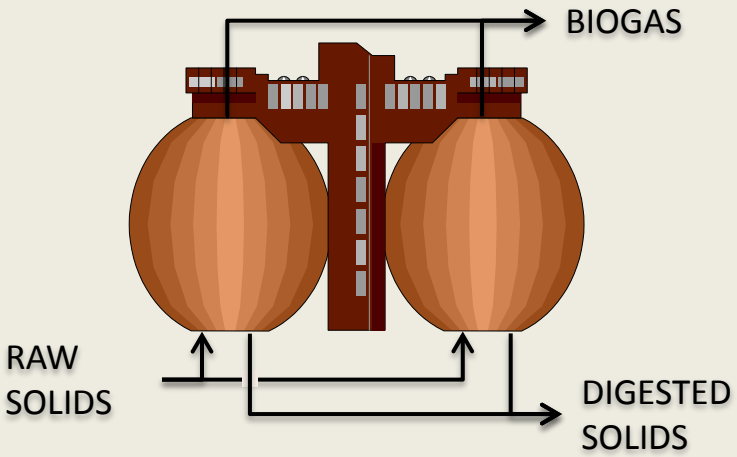
GGE=Gasoline Gallon Equivalent

- United States
  - No Known WWTP Bio-Methane Used as Vehicle Fuel
  - Five Known Landfills Using Bio-Methane to Fuel their Fleets
- Europe
  - Kristiantad, Sweden: About 340,000 CF/day of Bio-Methane Used as Vehicle Fuel in Public and School Buses
  - Lille Metropolis, France: Over 400 Bio-Methane Fueled Buses

Biogas – Future Directions

- Need to Better Understand Biogas Cleaning Technologies
  - Process Reliability
  - Relative Effectiveness
  - Treatment Costs
- More Work Required to Evaluate Vehicle Emissions When Using Bio-Methane
- Regional Initiatives
- Include Biogas as Renewable Energy Option in Federal and State Policies
  - Financing and Incentive Programs
  - Improved Public Perception and Awareness

Dried Solids – Background/Relevance



Raw Solids

Primary Sludge
Waste Activated Sludge

About 80% of Energy in Plant Wastewater Influent

Biosolids (Digested Solids)

Stabilized Solids (Pathogen and Vector Attraction Reduction)

About 45% of Energy in Plant Wastewater Influent

Wastewater Solids:
0.1-0.2 lb/person/day ➡ 7,100,000 dry tons/year

Source: EPA, 2004

Dried Solids – Background/Relevance

Dried Raw Solids Heating Value	8,000 BTU/lb
Dried Digested Solids Heating Value	4,500 BTU/lb
Coal Heating Value	10,000-15,000 BTU/lb

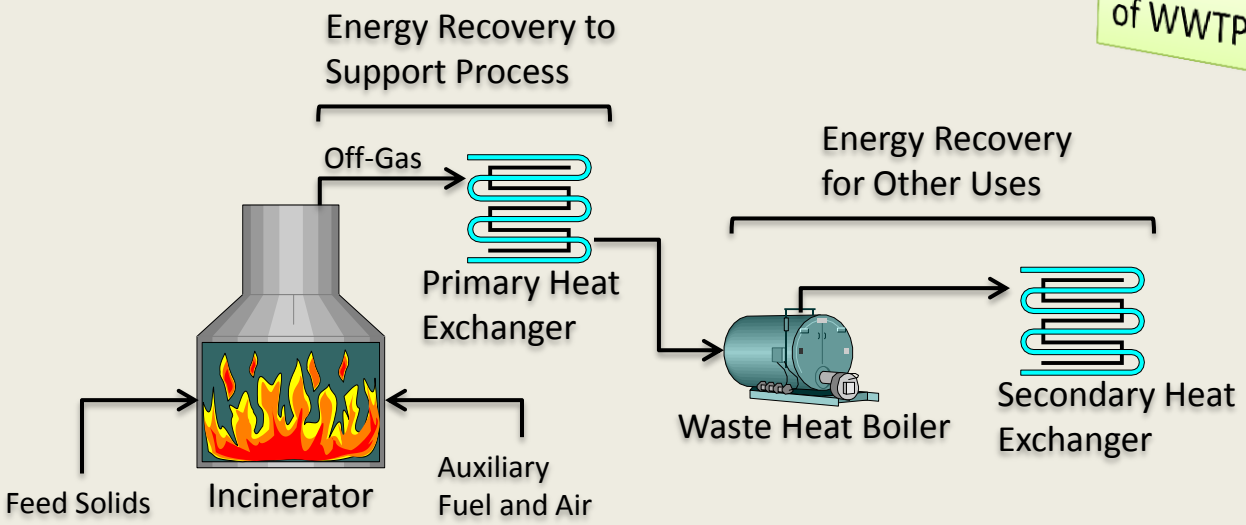
31 kWh Ave Daily Energy Use per Home ⟷ 13 lbs Biosolids Energy Equivalent

Source: Renewable Energy Resources: Banking on Biosolids, NACWA, 2010

Dried Solids – What We Know

Solids Incineration

Used by About 22% of WWTPS



Process Features

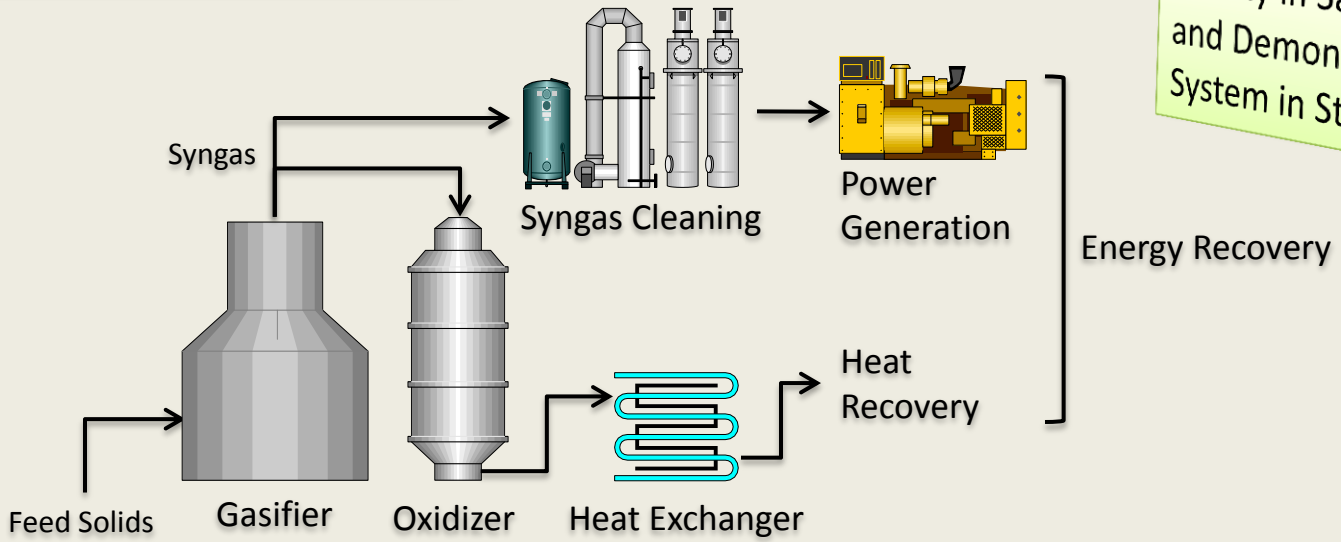
- Combustion with Excess Air
- Forms CO_2, Water, and Ash
- Significant Mass Reduction

Energy Recovery

- Heat Recovered from Off-Gas
- Support Process (Air Pre-Heating)
- Process/Space Heating Needs
- Power Generation (Steam Turbines)

Dried Solids – What We Know

Solids Gasification



Facility in Sanford, FL and Demonstration System in Stamford, CT

Process Features

- Oxygen-Starved Conditions
- High Temperatures (~1500 ^{o}F)
- Forms Syngas (Synthetic Gas)
- Syngas: CO and H_2

Energy Recovery

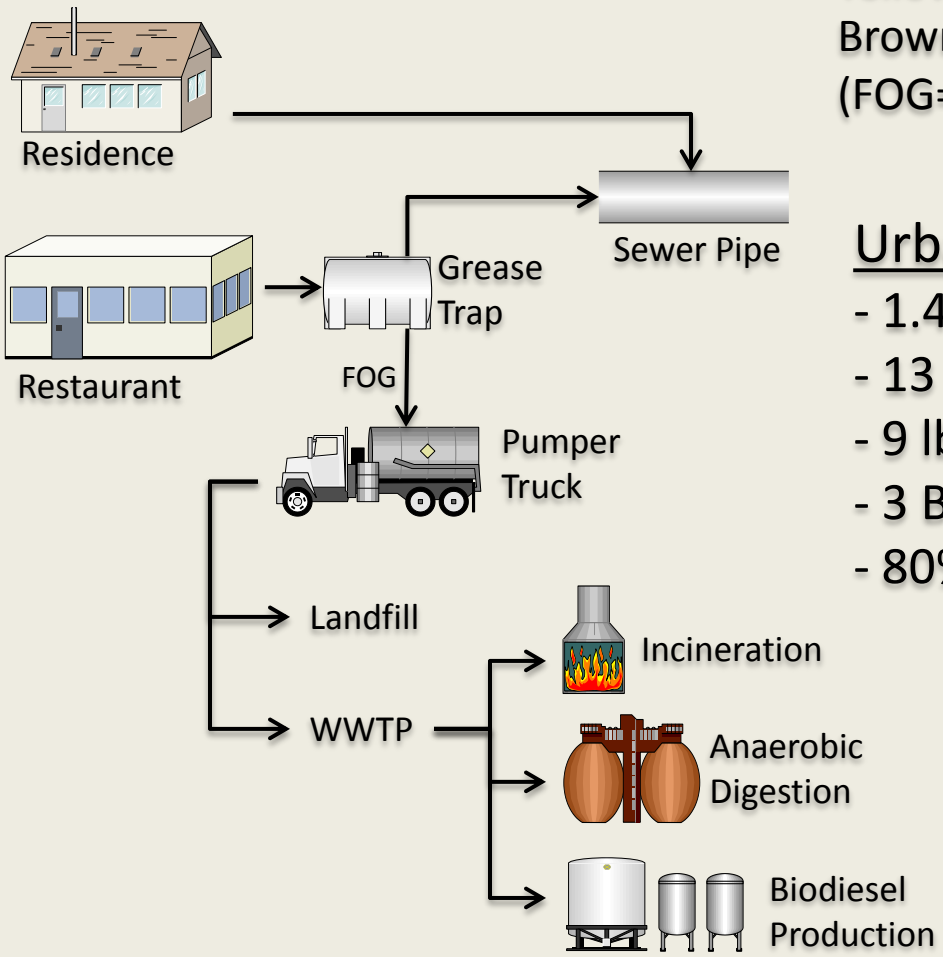
- Heat Recovery from Syngas Oxidation
- Process/Space Heating Needs
- Syngas Cleaning/Power Generation
- Early Stages of Implementation

Dried Solids – Future Directions

- Solids-to-Energy Likely to be Enhanced by
  - Development of Inter-Utility Partnerships for Implementation of Regional Facilities
  - Policies on Distributed Renewable Energy and Energy Recovery Projects
  - Rise of Industrial Energy Prices
- Development of Successful Track Record for Currently Operating Systems
- Include Biosolids as Renewable Energy Option in Federal and State Policies
  - Financing and Incentive Programs
  - Improved Public Perception and Awareness

Biodiesel – Background/Relevance

FOG-Based Biodiesel



Yellow Grease: Used Frying Oils
Brown Grease: FOG from Grease Traps
(FOG=Fats, Oils, and Grease)

Urban Areas

- 1.4 Restaurants/1,000 People
- 13 lbs FOG/person/year
- 9 lbs Yellow Grease/person/year
- 3 Billion gal Waste Oil/year (U.S.)
- 80% Sewer Spills Caused by FOG

Sources:
- Urban Waste Grease Resource Assessment, NREL, 1998
- EPA Biodiesel Partnerships, 2006

FOG-to-Biodiesel – What We Know

- Growing Use of FOG in Co-Digestion Applications (Biogas Production Enhanced)
- FOG-to-Biodiesel Technology is Currently Being Commercialized
- FOG-to-Biodiesel Projects at WWTPs
  - San Francisco Public Utility Commission (SFPUC), CA Pilot Facility: 100,000 gal Biodiesel/year
  - East Bay Municipal Utility District (EBMUD), CA
  - City of Pacifica, CA
  - Five Marin County Sanitary Districts, CA
  - Eastern Municipal Water District (EMWD), CA

Biodiesel – Background/Relevance

Algae-Based Biodiesel

CO_2

Water

Nutrients

Algae Growth System

Dewatering/ Separation

Algae Biomass

Oil Extraction Process

Early Stages of Development

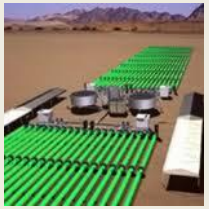
Biodiesel

Open Ponds

Large Surface Area and Shallow Water Depth

Photobioreactors

Enhanced Production per Volume and Surface Area



Potential in WWTPs

- Water and Nutrients in Plant Effluent and Centrate Sidestream
- CO_2 from On-Site Emissions and Bio-Methane Production
- CO_2 from Nearby CO_2 Emitters (Power Plants)

Algae-to-Biodiesel – What We Know

- Algae Industry Still in Early Stages of Development
- Water/Wastewater and Algae Industries Looking for Synergies
- Intense Research Ongoing
  - Private Entities
  - Universities (ASU, UofA)
- Federal Funding through the Department of Energy
- Algae-to-Biodiesel Projects at WWTPs
  - Hornsby Bend WWTP, Austin, TX
  - Rockaway WWTP, New York, NY
  - Erie WWTP, Erie, PA

Biodiesel – Future Directions

- Most Utilities Unaware of FOG-Related Sewer System O&M Costs
  - Need to Quantify Life-Cycle Cost of FOG and Savings from Beneficial Reuse
- FOG-to-Biodiesel Technologies to Overcome Challenges with “Brown Grease” Contaminants
- Commercialization of Algal Biodiesel
  - Reduce Costs and Real State Footprints
  - Identify Best Strains for Commercial Production
  - Development of Low-Cost Systems for Algae Harvesting, Dewatering, and Oil Extraction
- Pilot Studies and Demonstration Projects

Summary

- Biosolids and Residuals = Valuable Resources
- Biofuels from Wastewater
  - Digester Gas or Biogas
  - Dried Wastewater Solids
  - Biodiesel (FOG and Algae)
- Challenges for Energy Recovery
  - Technological
  - Financial
  - Legislative
  - Public Perception and Awareness
- Emerging Technologies Gaining Traction (Bio-Methane, Gasification, FOG-to-Biodiesel, Algae-to-Biodiesel)

Questions?

Fernando Sarmiento, P.E.
fsarmiento@greeley-hansen.com
602-778-8475