Anaerobic Digestion and Waste to BioEnergy Conversion Opportunities

Abhijeet P. Borole, Ph.D.

Biosciences Division

Oak Ridge National Laboratory, Oak Ridge, TN

borolea@ornl.gov

March 9, 2012

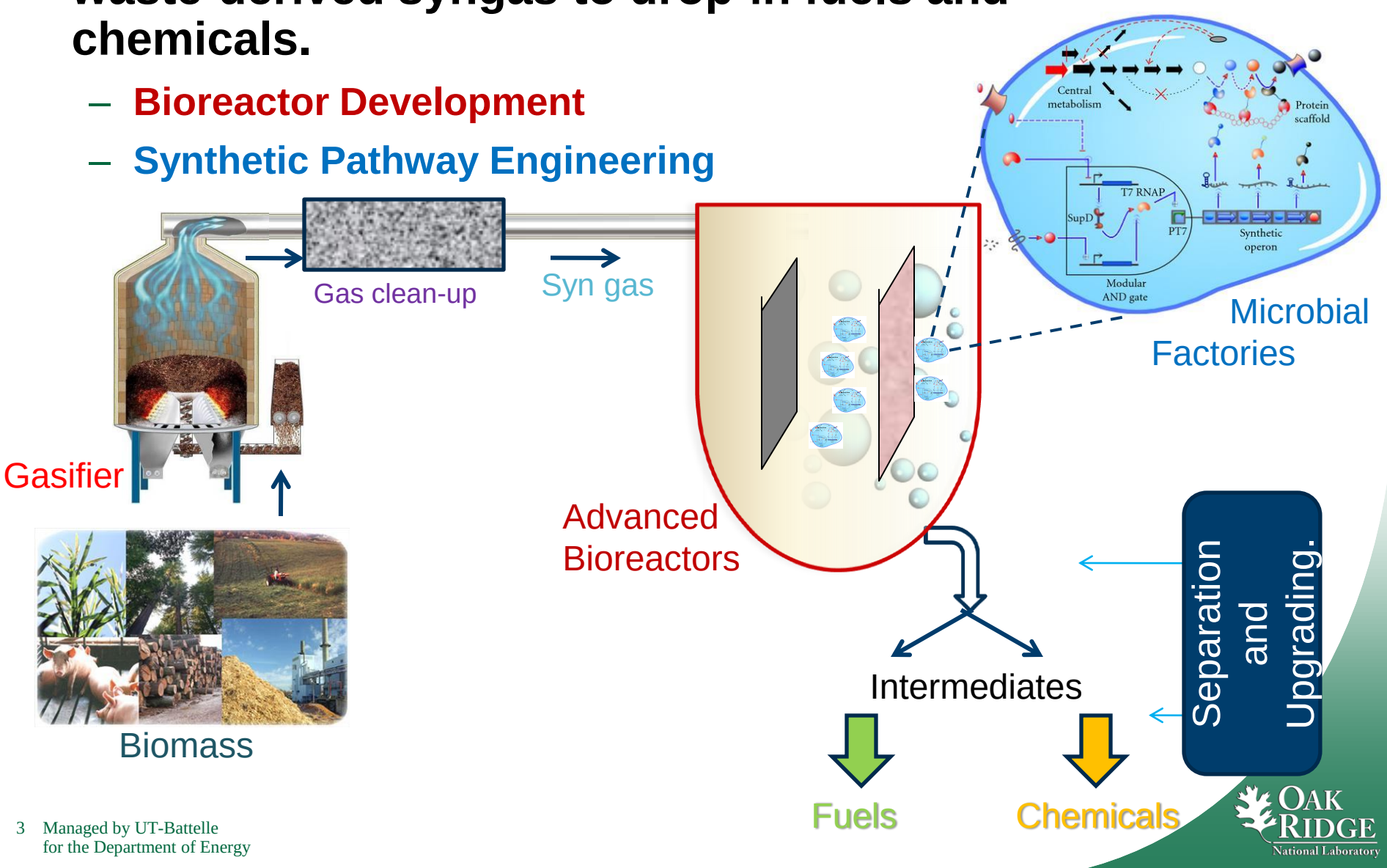
Purpose

- **Potential for biogas production in TN.**
  - **Scope for application of anaerobic digestion**
  - **Benefit assessment**
  - **Economic incentives**
  - **Need for implementation leaders**

- **Waste to bioenergy R&D in my lab at ORNL**
  - **Waste to syngas to biofuels**
  - **Wastewater treatment**
    - **Bioelectricity production**
    - **Biohydrogen production**

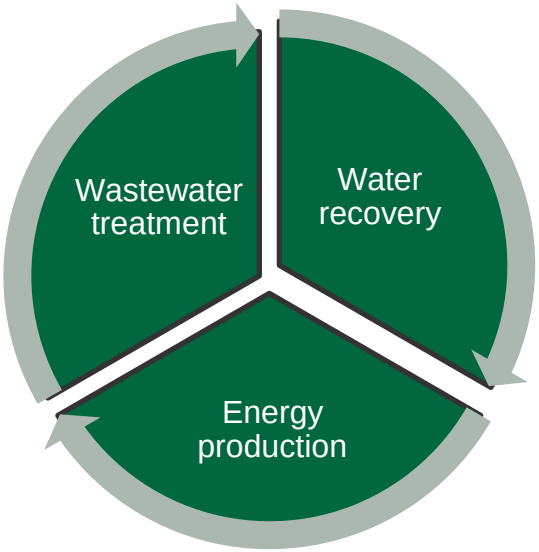
Waste/Biomass - Syngas - Biofuels

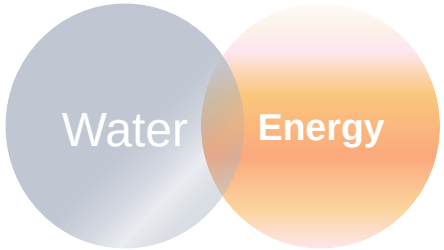
- **Develop technology for conversion of biomass and waste-derived syngas to drop-in fuels and chemicals.**
  - **Bioreactor Development**
  - **Synthetic Pathway Engineering**

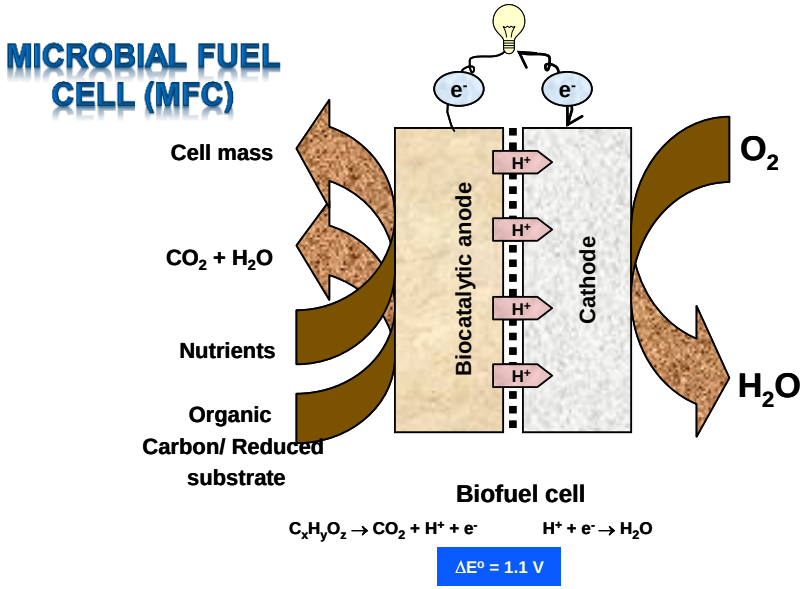


Biological fuel cells

- **Fuel cells using microbes as catalysts to produce electricity**
  - **Sustainable source of energy**
    - **Derived from : organic waste / biomass (vs. hydrogen in conventional fuel cells)**
    - **Regenerable catalyst**
    - **Product: CO_2 (C neutral), water**
    - **Water recovery and reuse**
    - **Potential for hydrogen production instead of electricity**







[2]Borole, et.al., 2009, **J. Power Sources**., Integrating Engineering Design Improvements with Exoelectrogen Enrichment Process to Increase Power Output from Microbial Fuel Cells, 191, p520.

Biofuel cell applications

- **Municipal wastewater treatment**
- **Food industry wastewater**
- **Biorefinery wastewater**
- **Produced water from oil and gas operations**

Produced water from oil and gas drilling

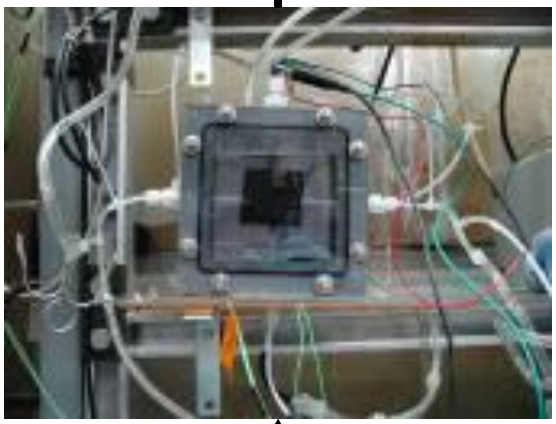
Borole, A.P., 2010. Microbial fuel cell with improved anode, US Patent 7,695,834. UT-Battelle, USA.

Borole, et.al., 2009, **Biochem. Engg**. **J.**, Improving power production from acetate-fed microbial fuel cells via enrichment of exoelectrogenic organisms in continuous flow systems, 48, p71-80.

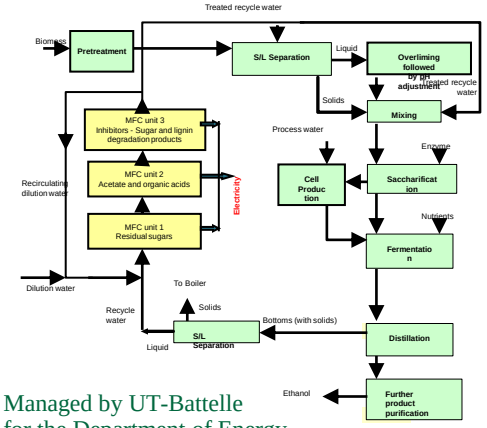
Biorefinery application

Bioelectricity
or
Hydrogen

+ Clean water

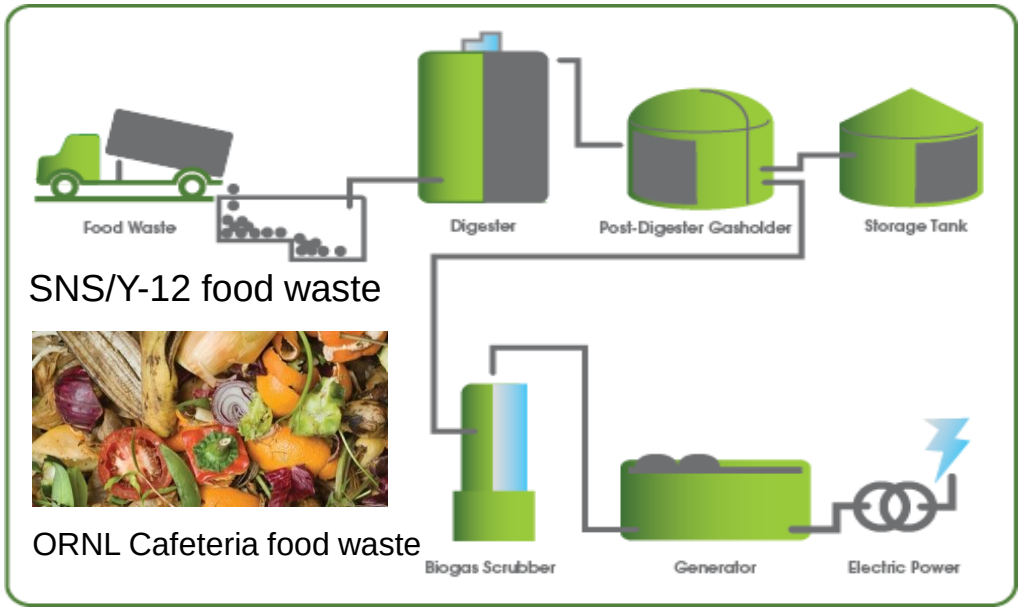


Process water with BOD



Application time frame: on the 5 yr horizon.

Near term applications:
Food waste to Biogas – ORNL cafeteria



SNS/Y-12 food waste

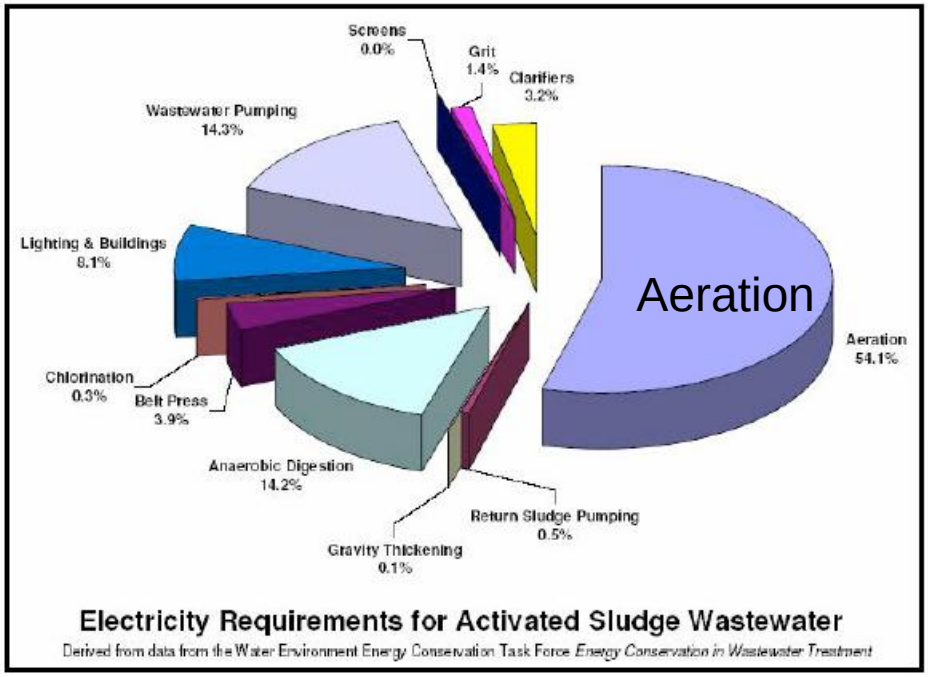
ORNL Cafeteria food waste

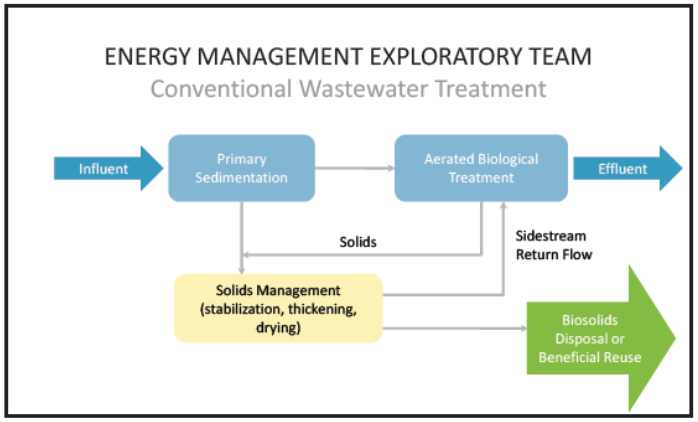
Campus anaerobic digester application not feasible due to low volume. Is it possible to do cumulative waste treatment?

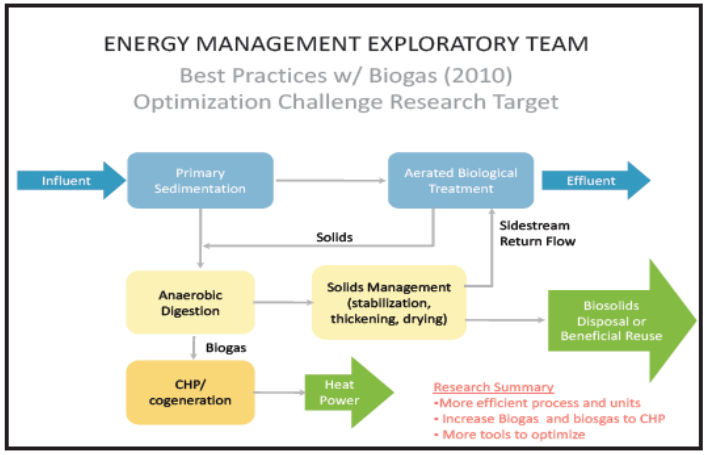
SUSTAINABLE CAMPUS INITIATIVE

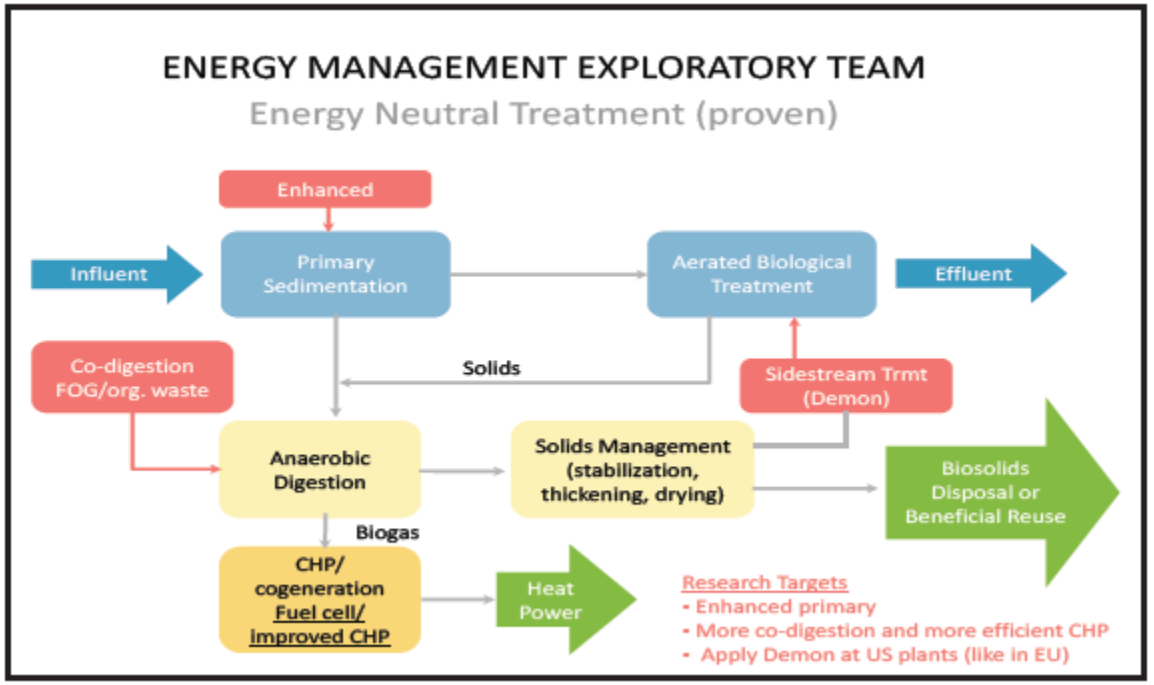
Water Environment Research Foundation study

- **Energy Management Exploratory Team**
  - **DOE National Lab liaison**
  - **EPA, EPRI, WWTP leaders, WW treatment consultants and industry engineers and scientists.**
- **Wastewater contains up to 9-times more energy than that needed to operate a WWTP .**
- **Identified potential energy efficient technologies to make WWTP energy-neutral.**
- **WWTPs use 4% of total energy consumption in US.**


Screens
0.0%
Grit
1.4%
Clarifiers
3.2%
Wastewater Pumping
14.3%
Lighting & Buildings
8.1%
Aeration
Aeration
54.1%
Chlorination
0.3%
Belt Press
3.9%
Anaerobic Digestion
14.2%
Return Sludge Pumping
0.5%
Gravity Thickening
0.1%
Electricity Requirements for Activated Sludge Wastewater
Derived from data from the Water Environment Energy Conservation Task Force Energy Conservation in Wastewater Treatment


ENERGY MANAGEMENT EXPLORATORY TEAM
Conventional Wastewater Treatment
Influent
Primary Sedimentation
Aerated Biological Treatment
Effluent
Solids
Sidestream Return Flow
Solids Management (stabilization, thickening, drying)
Biosolids Disposal or Beneficial Reuse


ENERGY MANAGEMENT EXPLORATORY TEAM
Best Practices w/ Biogas (2010)
Optimization Challenge Research Target
Influent
Primary Sedimentation
Aerated Biological Treatment
Effluent
Solids
Sidestream Return Flow
Anaerobic Digestion
Solids Management (stabilization, thickening, drying)
Biosolids Disposal or Beneficial Reuse
Biogas
CHP/ cogeneration
Heat Power
Research Summary
•More efficient process and units
• Increase Biogas and biosgas to CHP
• More tools to optimize


ENERGY MANAGEMENT EXPLORATORY TEAM
Energy Neutral Treatment (proven)
Enhanced
Influent
Primary Sedimentation
Aerated Biological Treatment
Effluent
Co-digestion FOG/org. waste
Solids
Sidestream Trmt (Demon)
Anaerobic Digestion
Solids Management (stabilization, thickening, drying)
Biosolids Disposal or Beneficial Reuse
Biogas
CHP/ cogeneration Fuel cell/ Improved CHP
Heat Power
Research Targets
- Enhanced primary
- More co-digestion and more efficient CHP
- Apply Demon at US plants (like in EU)

Anaerobic Digestion application in TN

- **Total 95 counties in TN**
- **Of these only ~ 6-7 WWTP's have anaerobic digestion (AD):**
  - **Jackson, Monterey, Memphis, Nashville, Lenoir City, Bristol and Kingsport .**
- **Issues for implementing ADs:**
  - **Need for biogas cleanup**
    - **Water and siloxane removal**
  - **Connecting with distributors**
  - **Managing existing regulations**

'Show me the money – **TODAY**'

- **Positive factors:**
  - **TVA Green power switch - biogas inclusive?**
  - **Upcoming water shortage and recycle needs.**
  - **Degrading wastewater infrastructure and need for billions of $$ of investment (report released by AWWA – Feb 2012).**

Information - courtesy of Brett Ward, TREED)

EPA report on implementing AD-CHP at WWTPs (2011)

- **While many WWTPs have implemented combined heat and power (CHP) , the potential still exists to use CHP more based on technical and economic benefits.**
  - **As of June 2011, CHP systems using biogas were in place at 104 WWTPs, representing 190 megawatts (MW) of capacity. CHP is technically feasible at 1,351 additional sites and economically attractive (i.e., payback of seven years or less) at between 257 and 662 of those sites**
- **The cost to generate electricity using CHP at WWTPs ranges from 1.1 to 8.3 cents per kilowatt-hour (kWh) depending on the CHP prime mover and other factors.**
  - **Current retail electric rates range from 3.9 to over 21 cents per kWh, so CHP can have clear economic benefits for WWTPs.**
- **On a national scale, the technical potential for additional CHP at WWTPs is over 400 MW of biogas-based electricity generating capacity and approximately 38,000 MMBtu/day of thermal energy.**
  - **This capacity could prevent approximately 3 million metric tons of carbon dioxide emissions annually, equivalent to the emissions of approximately 596,000 passenger vehicles.**
- **Each million gallons per day (MGD) of wastewater flow can produce enough biogas in an anaerobic digester to produce 26 kilowatts (kW) of electric capacity and 2.4 million Btu per day (MMBtu/day) of thermal energy in a CHP system.**

http://www.epa.gov/chp/documents/wwtf_opportunities.pdf

Analysis for the state of California

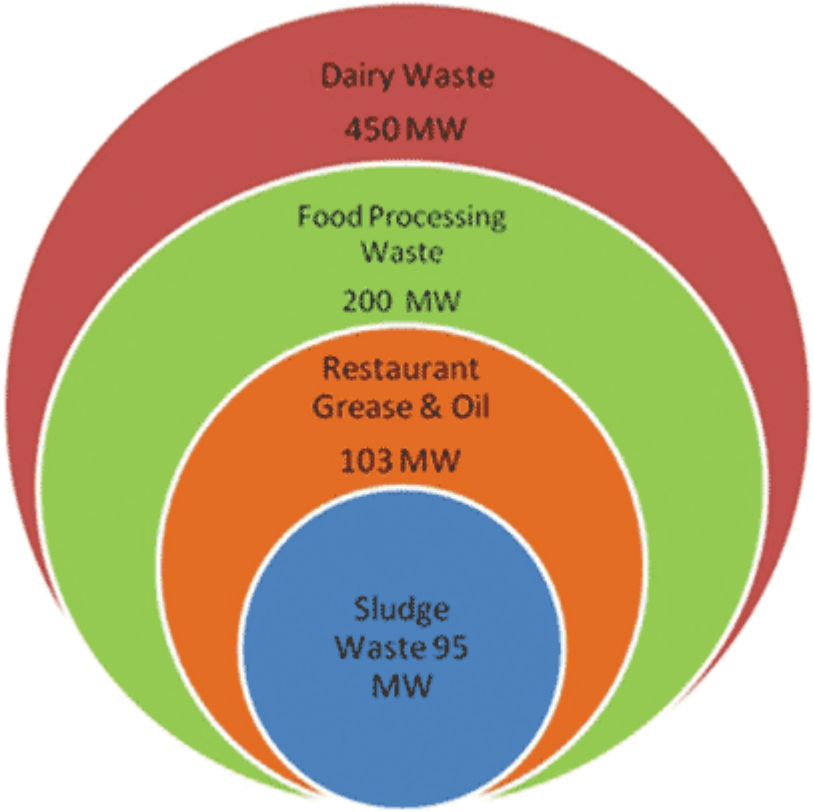
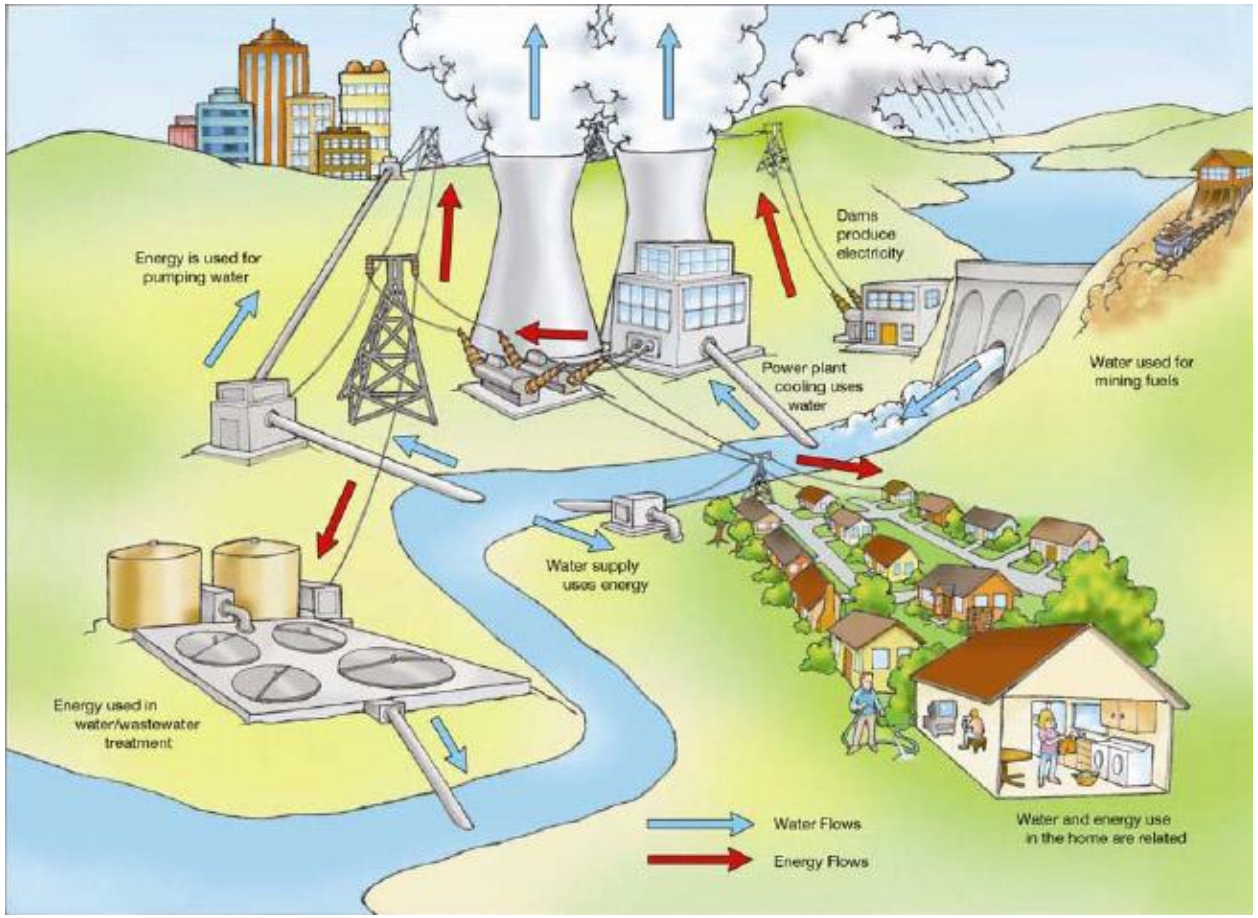
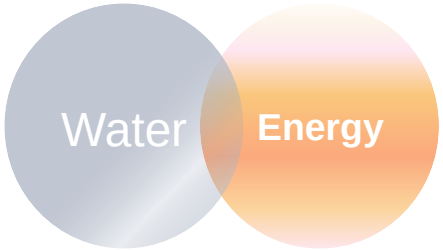


Figure 1. Cumulative market potential for WWTP CHP through sludge co-digestion of multiple bio-waste streams in California Source: Co-digestion of Dairy Manure/Food Processing Waste and BioSolids/Food Processing Wastes to Energy, California Energy Commission Report 500-2007-015. March 2008

What can we do?

- Need for a thorough analysis of TN's potential to implement AD
- AD-derived electricity for TN ~ $ 0.14/kWh
  - An incentive of $ 0.04/kWh for biogas can remove one barrier (via Green power switch program?)
  - Need for capital investment – TN Clean Energy Grants, EPA, USDA programs?
  - Availability of companies to take the initiative and implement AD? (e.g., Process Unlimited Intl, Inc. – Josh Pendergrass; Quasar (Ohio), others?)
  - Policy changes to promote water-related green energy production
- Need for action!
  - Why should we do it?
    - Create local jobs
    - Not so cool / new technology? Potential applications in food industry, farms, biorefineries, etc. as of yet unrealized.
    - Water security/shortage issues
    - Wastewater infrastructure renewal needs
    - Potential path to development of hybrid AD-microbial fuel cell (direct waste to electricity) technologies – further improvement in energy efficiency, potentially by a factor of 2 (ORNL R&D).





Nexus

- **Most forms of energy production require water**
  - **Nuclear Energy, Coal power plants, Oil refineries (production operations, cooling needs), etc.**
  - **Bioenergy production (Biorefineries)**
- **Also, water production requires energy**
  - **Making water production energy-neutral is the first step towards water and energy security**

Acknowledgements

- **Warren Nevad – Thanks for the opportunity**
- **ORNL Sustainability Initiative**
- **WERF – Lauren Fillmore – Pushing for new developments and energy efficiency in wastewater treatment.**