Flexible Distributed Energy & Water from Waste for the Food & Beverage Industry

DE-FC26-08NT05870

GE Global Research, GE Water, GE Intelligent Platforms, Sentech

2009-2012

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Executive Summary

WWT for Food & Bev Industry using anaerobic & aerobic bioprocess

Project Team

GE Global Research Center
- Advanced monitoring and controls

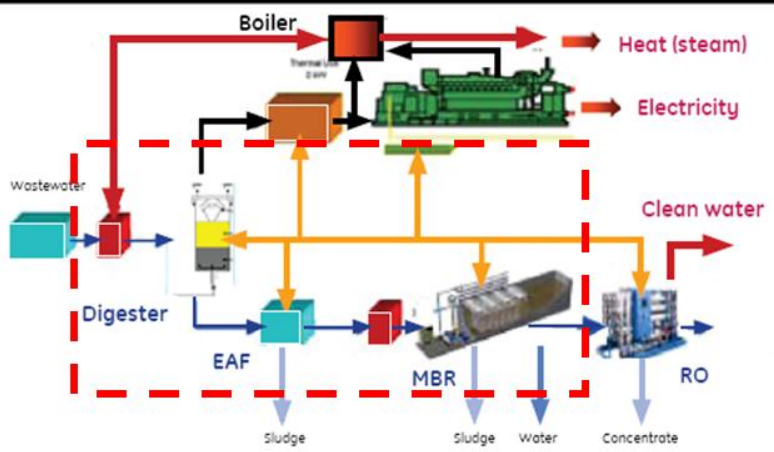
GE Water & Process Technologies
- Water processing technology and commercialization

GE Industrial Platforms
- Controls platform

Sentech
- Consulting (SB)

Consulting
- Prof. P. McCarty
- Prof. L. Angenent

3-yr. $3.2MM program focused on Robust and Flexible Waste to Value Plant for food and beverage industry



- System level monitoring, control and optimization using predictive dynamic models
- Early detection and mitigation of process upsets
- Development (Phase 1) and Pilot-plant demonstration (Phase II)

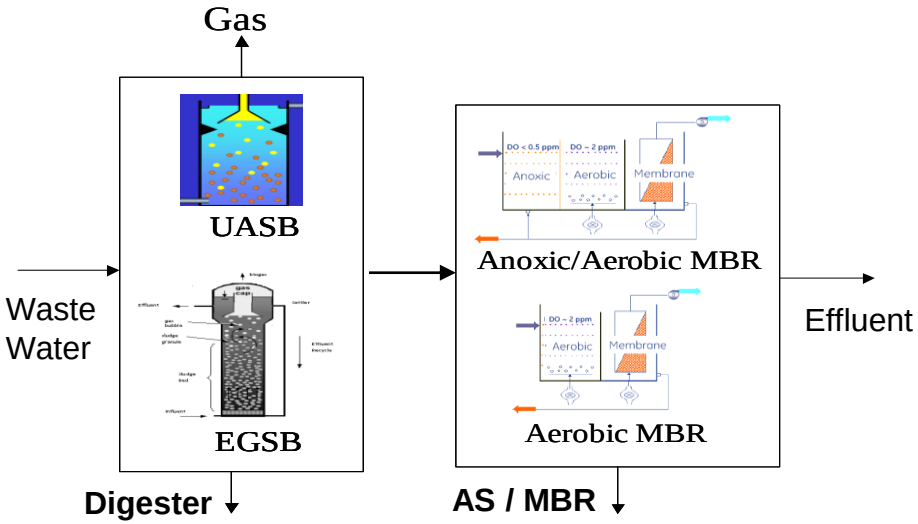
Anticipated Benefits for target food & beverage industry

- 5-10% increased biogas generation
- Improved water for discharge or potential reuse
- 10% or more reduction in op ex
- 90% reduction in upsets

- **Phase 1 - Develop online monitoring and supervisory controls to improve integrated system performance & reliability** (completed)
  - General model-based real-time monitoring using real & virtual online sensors
  - Supervisory controls to mitigate upsets, improve performance and reduce op ex
- **Phase 2 - Demonstrate technology in a pilot plant** (18 months)
  - ABI Brewery in Van Nuys, CA, Waiting for DoE approval

Online Monitoring & Controls for Increased Performance & Reliability

Project Objective

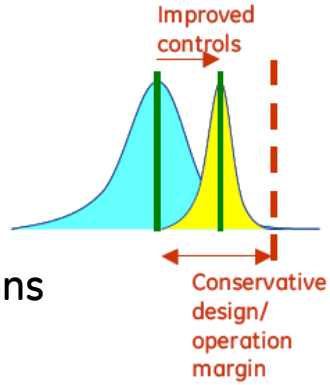


Scope:

- Wastewater treatment with anaerobic digester (AD) & Active Sludge (AS)/Membrane bioreactor (MBR)
- **Immediate focus on brewery** – high COD, easily digestible, large plants
- **Applicable to other F&B segments**

Current operation is conservative, inefficient & non-robust

- Relies of manual supervision and operation with limited understanding



Objective - Improve overall system reliability & performance

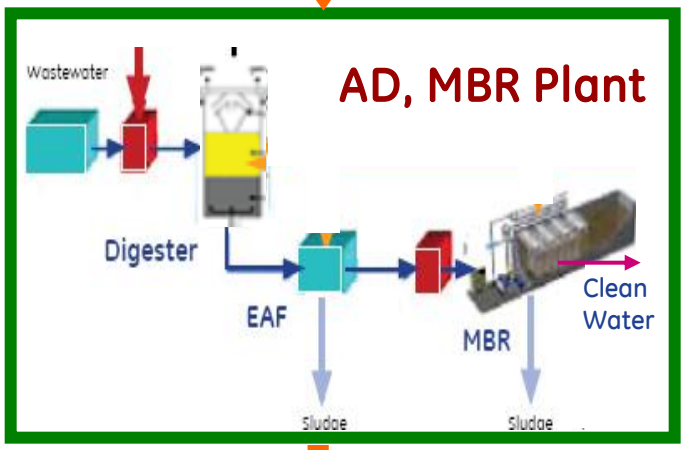
- **Optimize performance to close to entitlement** for wastewater feed variations
  - Increase biogas production – enhance COD reduction
  - Meet/improve discharge water quality (COD, NH_3, NO_3)
  - Reduce chemical & energy (aerobic) usage – reduce op ex
- **Ensure reliable operation** – Maintain stable operation in presence of variations
- **Automate monitoring and controls** – improve operation consistency
  - Reduced operator load, reliance – advance from "offline, once/day" to "online, real-time"

State of the Art

- **Current practice relies heavily on manual supervision & operation**
  - Limited bio-process operation knowledge and automation
- **Digester operation**
  - Key parameters monitored once-per-day : sample collection & lab analysis
    - COD (soluble/total), VSS, TSS, Alkalinity, (VFA)
  - Simple manual/automatic controls
    - Flowrates, nutrient dosing, alkali dosing – pH : under ratio/PI control
- **Activated Sludge/Membrane Bio-reactor (MBR) operation**
  - Key parameters monitored once-per-day - sample collection & lab analysis
    - COD (soluble/total), VSS, TSS, MLSS, MLVSS, (Alkalinity)
  - Simple manual/automatic controls
    - Flowrates, nutrient dosing, alkali dosing – pH, aeration-DO : under ratio/PI control
    - Sludge discharge (wasting) done manually – to regulate MLSS
    - Periodic membrane cleaning through back pulse, aeration, chemicals
- **Conservative operation to avoid upsets - inefficient operation**
- **Manual correction during upsets based on operator experience**

Technical Approach

Control Actuation
- Flows/recycle
- Chemicals
- Blowers, …



3. Act

Supervisory Control
- Improved control of AD & MBR units
- Early detection of upsets & corrective action
- Optimize for min chemical, energy use

1. Sense

Online Sensors
- flow, pH, T
- TOC/TIC
- Gas comp., flow
- DO, TMP, NH_3, NO_3

Model validation
- Lab AD expts
- Plant operation data

2. Analyze

Model-Based Inferential Sensing of KPI
- Alkalinity, VFA, biomass, …

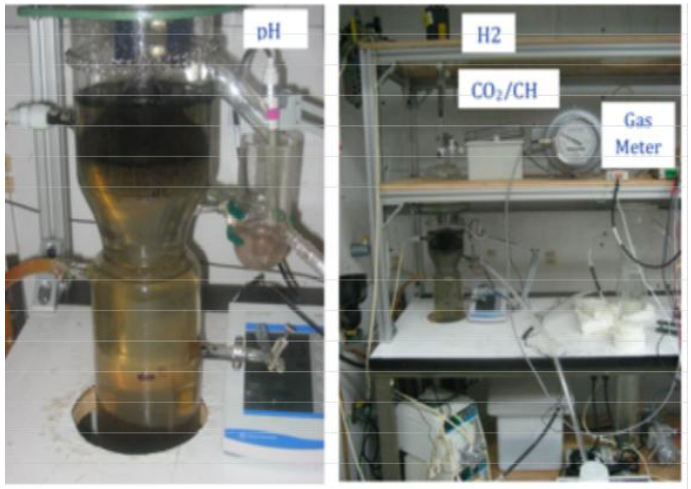
Control Relevant Model
- Physics based & simple
- Flexible/adaptive for different waste & process

Automation to advance from "offline" to "online"

Technical Approach

General model development & validation

- **Simplified, flexible/adaptable dynamic model for general wastewater**
  - COD (OC) , IC balance, alkalinity-pH
- **Pre-acidification + Digester**
  - Validate against lab and brewery plant data
- **Anoxic + Aerobic + Membrane separation**
  - Validate against industrial MBR plant data



5-liter UASB digester expt. with synthetic brewery wastewater

Online monitoring

- **New online sensors**

GE sensor

Online TOC/TIC
(GE Water)

Third party sensors

Infrared CH_4, CO_2 sensor
(Edinburgh Instruments)

Ion-selective NH_3, NO_3 sensor
(e.g., Advanced Sensor Technologies, Inc)

- **Model-based estimation (virtual sensing) of important parameters**
  - Real-time dynamic model simulation matched to online sensors to infer unmeasured variables

Supervisory control

- Improved pH control – stability, efficiency
- Improved coordination of PA & AD – COD conversion, biogas generation
- Improved coordination of anoxic & aerobic – aeration & chemical saving, regulate effluent water quality

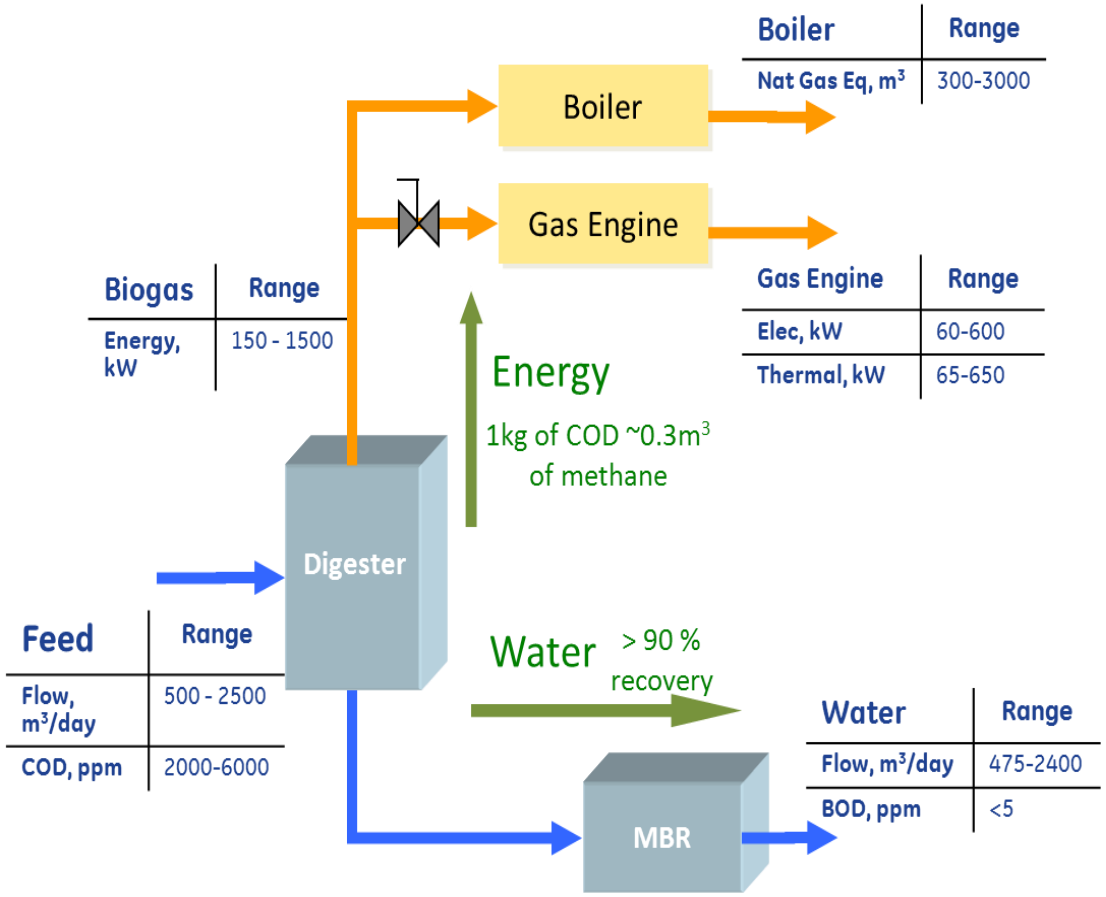
Measure of Success

- **Initial Implementation at AB InBev Plant (Phase 2)**
  - Demonstrate improved process operation – robust & efficient
  - Success criterion – significant customer value
    - Improved stability and robustness against bioprocess upsets
    - Improved COD conversion and biogas generation
    - Improved and consistent effluent water quality
    - Reduced op ex – chemical alkali dosing
- **Commercialization and implementation at other WWT sites**
  - Translate to other AB InBev sites, and other breweries (North America/global)
  - Translate to other F&B waste water treatment plants with anaerobic and/or aerobic bioprocesses
- **Potential extension of monitoring & controls solution to upstream bioprocesses** – e.g. fuel ethanol fermentation

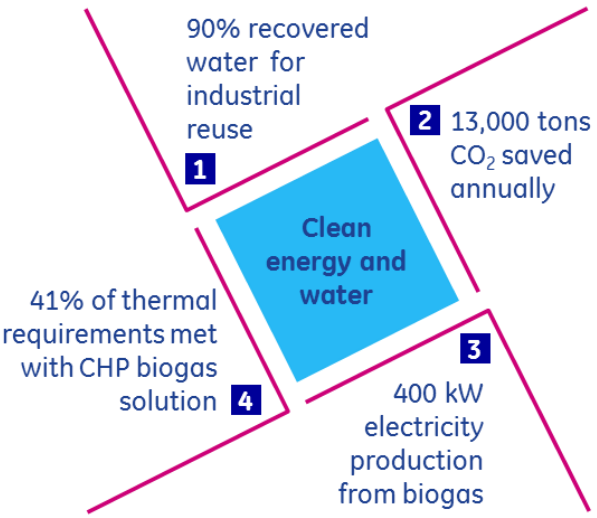
Benefits – Energy/Environmental Savings

Waste Water Treatment (WWT) plant for F&B industry

Recovers Valuable Energy & Water (potential reuse)



Improves environmental performance



CASE –Brewery: 640,000 GPD waste water flow rate using a CHP solution

Benefits – Economic Benefits

- **Benefits due to Monitoring & Controls Solution**
  - Increased biogas yield ~ 5-10% to offset natural gas use
  - Reduced operating cost
    - 10% or more reduction in chemical alkali for pH
    - 10% or more reduction in aeration energy use
  - Improved and consistent effluent water quality – reduced disposal cost, potential reuse
  - *Avoid severe upsets/shutdowns (causing expensive re-seeding and/or upstream plant shutdown in extreme cases)*
  - Savings estimate: >$200K/yr benefit to average customer
    (~1-2MM gall/day with ~3000-5000 ppm COD)

Project Management & Budget

Total Program Duration & Budget

- **Phase 1 - $2.0MM ($1.4MM DoE + $0.6MM Cost Share) - 2009 - 2010**
- **Phase 2 - $1.0MM ($0.5MM DoE + $0.5MM Cost share) - 18 months**

Program Milestones

Phase 1 – completed

- F&B WWT monitoring & control requirements (customer reviews)
- AD and MBR model development and validation with lab/plant data
- AD and MBR monitoring & control technology development and lab/simulation testing

Phase 2 – starting

- Define goals for pilot plant demonstration (3 months)
- Install sensors, PLC, update models and algorithms (12 months)
- Demonstrate and document improvements vs. goals (18 months)

Project Budget (for Phase 2)				
	FY11	**FY12**	**FY13**	**FY14**
DOE Investment	$200.2K	$302.6K		
Cost Share	$200.2K	$302.6K		
Project Total	$400.4K	$605.2K		

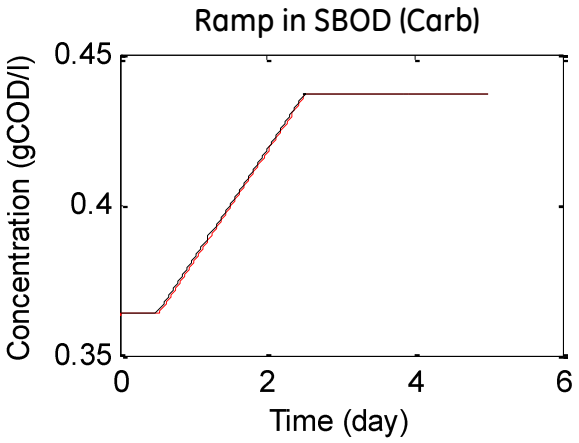
Proposal assuming Apr 2011 start date
Delayed start will push program into FY13

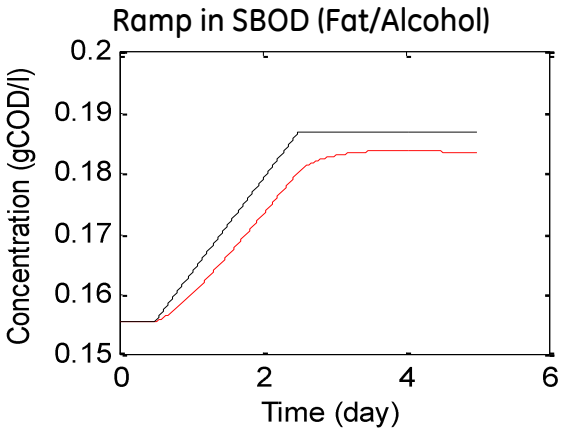
Results and Accomplishments

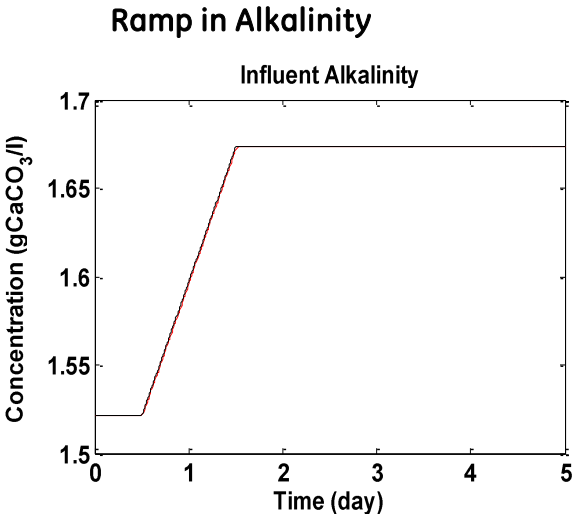
- **Monitoring & controls technology development – Phase 1 (complete)**
  - Developed and validated AD & MBR models using lab-scale and plant operation data
  - Online monitoring using sensors and model-based estimation for AD & MBR – simulation with validated models, lab AD perturbation experiment
  - Improved control for AD and MBR – simulation with validated models
  - Models and monitoring/control algorithms implemented on GE IP PLC and validated
  - Stage 3 review with DoE completed
- **Pilot plant demonstration of monitoring & controls – Phase 2 (starting)**
  - AB InBev brewery wastewater treatment in PA + AD process
  - Implement monitoring & controls technology and demonstrate improved process robustness and efficiency

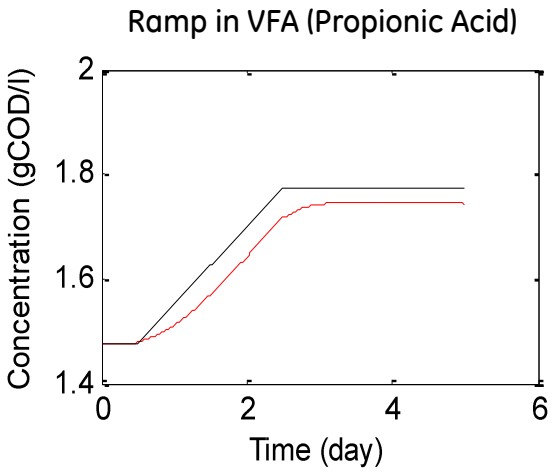
Results and Accomplishments (contd.)

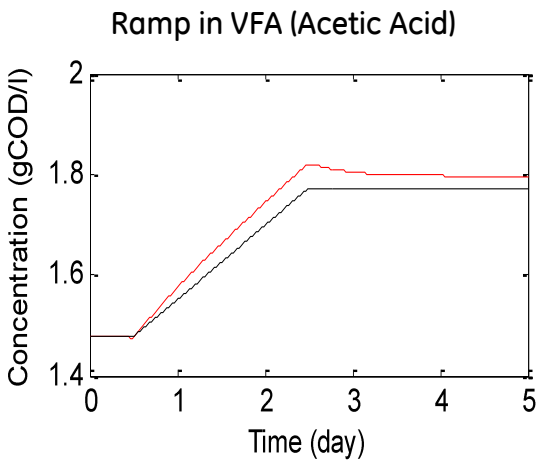
- **Example of online monitoring in digester – unknown changes in waste water feed composition**





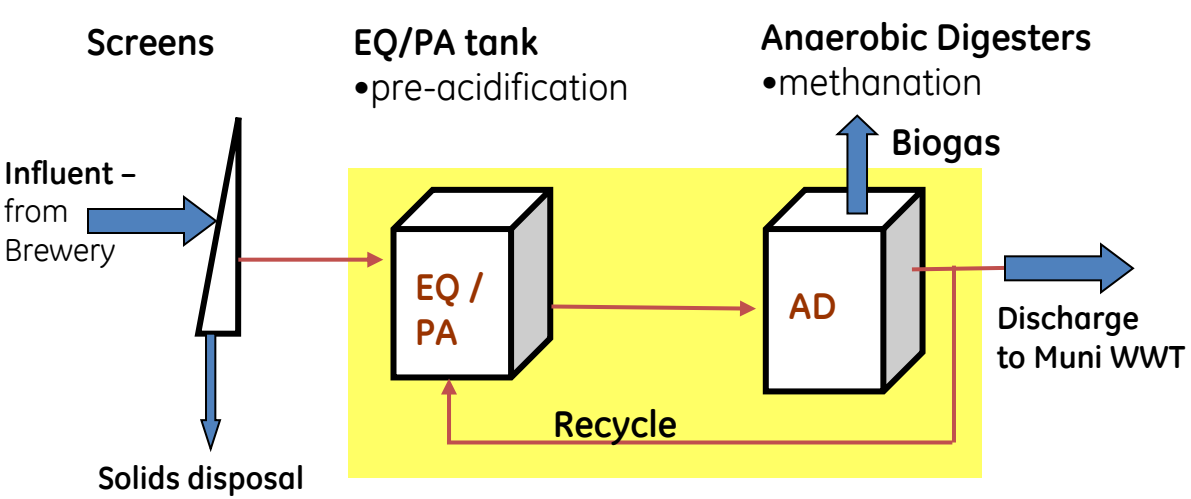






Similar online monitoring results for MBR

Path Forward – Phase 2

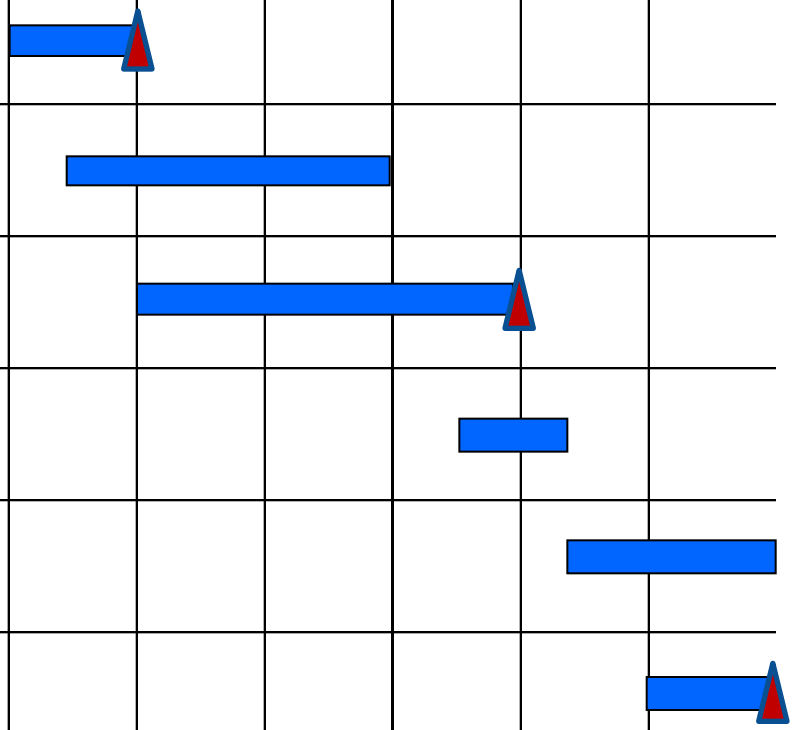


- **Pilot Implementation – ABI Brewery wastewater treatment plant, Van Nuys, CA**
  - Full-scale plant treating ~1.5-2 MM gallons/day brewery waste water
- **Challenges/Opportunities for improved monitoring & control**
  - Weekday/weekend variation due to brewery production
  - Biomass growth/retention
  - Increase in COD conversion, biogas generation
  - Improve effluent quality (COD, TSS)
  - Improve pH regulation and chemical saving
- **Successful demonstration at L.A. plant can be translated to other N.A./global locations**

Phase 2 – Aim & Timeline

- Implement developed monitoring & controls technology on pilot plant and demonstrate full-scale plant application and operation benefits
- Plan for Phase 2 demonstration (18 months) – awaiting DoE approval to start

Task	Q1	Q2	Q3	Q4	Q5	Q6
Gather Process Info, Data, Establish Baseline, Specify Goals						
Install Sensors, PLC, collect operation data						
Update Model and Monitoring/Control algorithms, Implement on PLC						
Test in Open-loop (monitoring) mode, update algorithms						
Test in Closed-loop (control) mode, update algorithms						
Document Benefits vs. Goals						

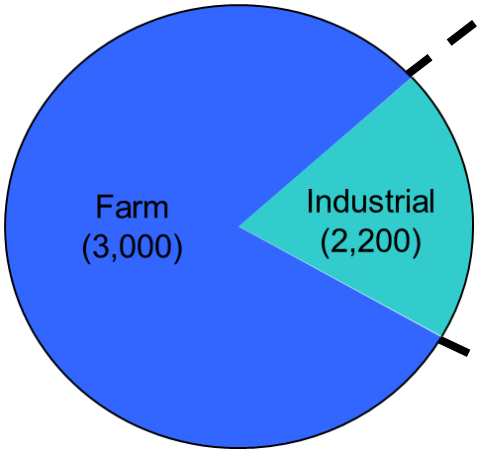


- Commercialization after Phase 2 completion

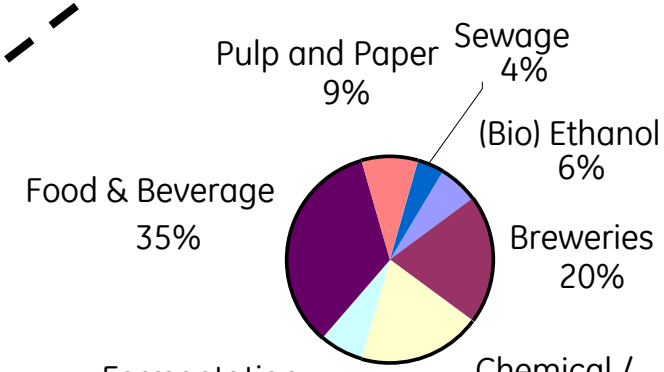
Market & Commercialization

Market Opportunity

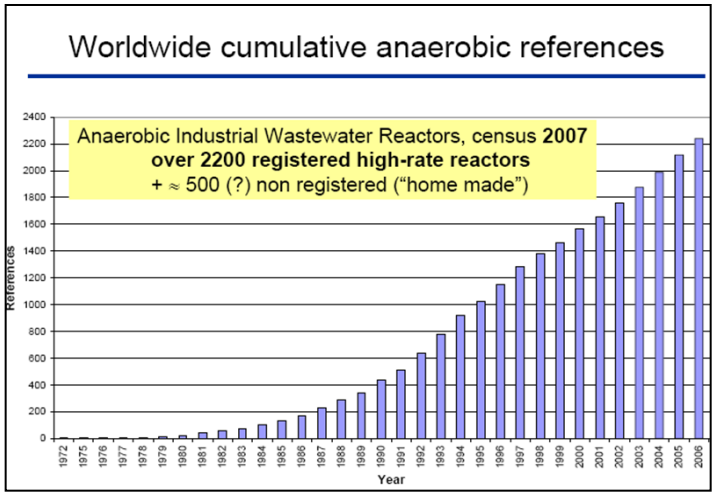
WW AD Installations (5,000+)

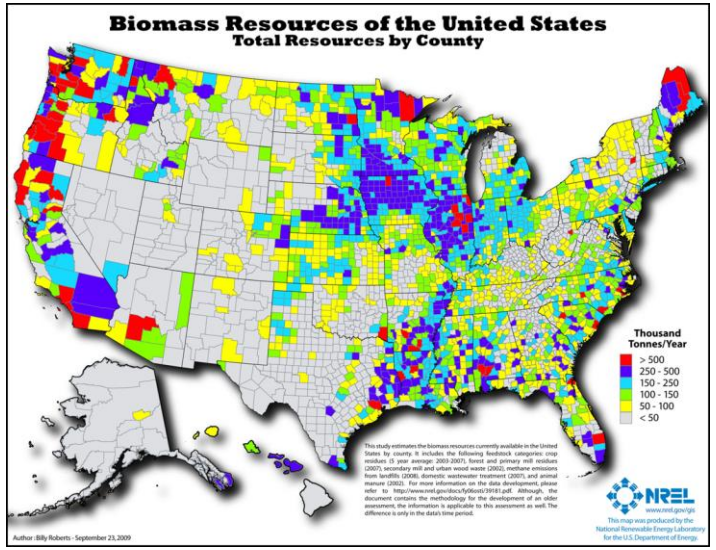


F&B Key Industrial Market



Source: Biothane (approx 500 installations)





- Small scale / Low flows
- Limited water reuse potential
- No commercialization resources

Not Attractive

- Larger flow/ Centralized
- More consistent waste
- Higher organic loading
- Tougher regulations

F&B….Focus where experience exists

Commercialization - Value Proposition

Overcoming the Limits of Current Practice

Irrefutable value Proposition

By offering a turnkey solution, companies within the Food & Beverage industry will be able to address three key needs not commercially available today:

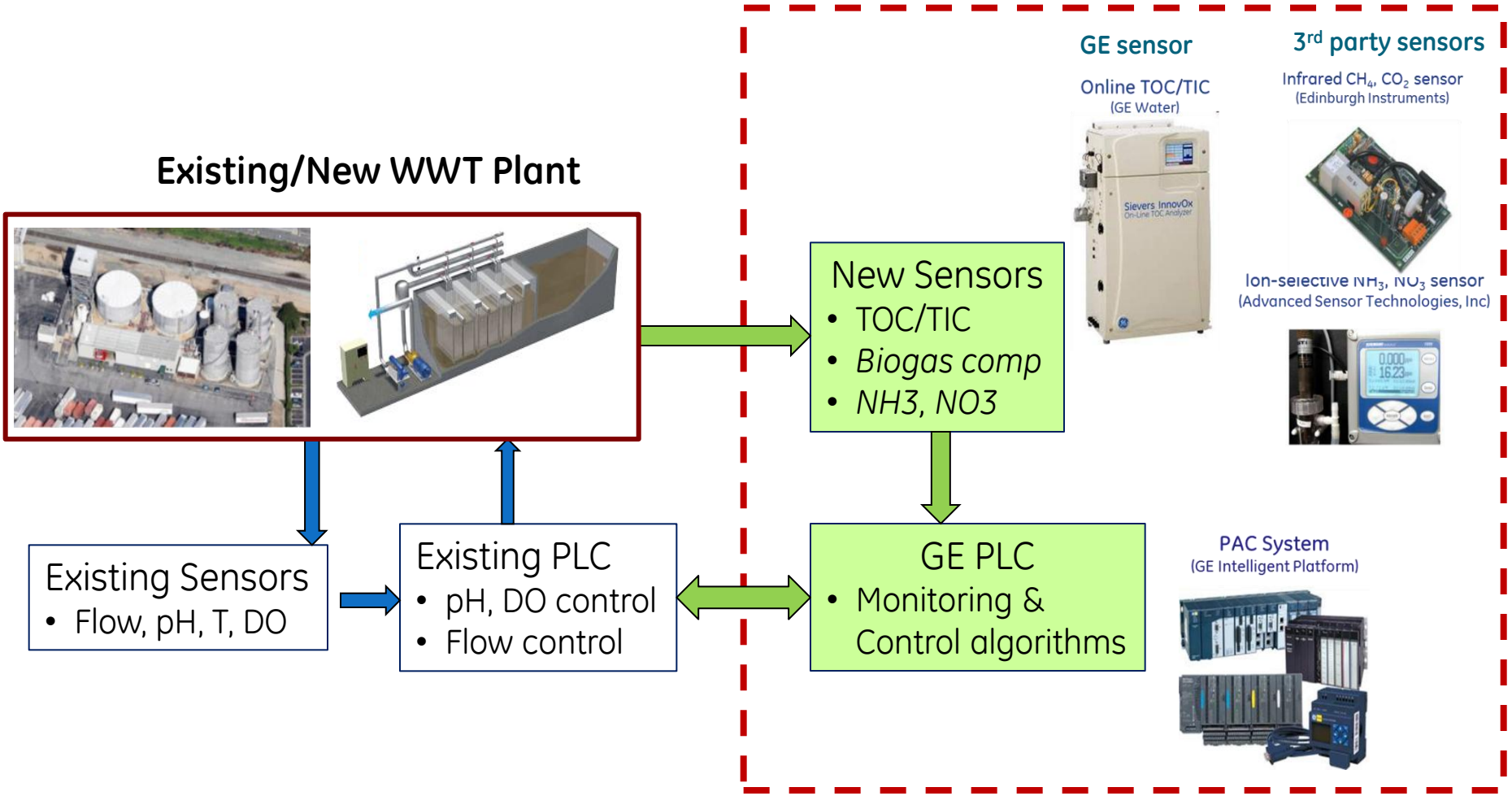
1. Improve Anaerobic system performance – reliable & efficient
2. Improve amount of biogas fuel for untapped energy use.
3. Ease demand on downstream products such as activated sludge or membrane bio-reactor.

Transition and Deployment

- **Target Customer** – Food & Beverage Industrial Waste Water Treatment plants
  - Initial focus on Breweries
  - Extension to other F&B industry segments
  - Initial discussions with AB InBev (brewery) and ADM (corn milling) for Phase 2 – significant value and high customer interest
- **Implementation & Use**
  - Monitoring & controls solution package
    - New online sensors
    - Flexible model-based solution to adapt to different process configurations, waste water compositions and operating conditions
    - GE Intelligent Platforms PLC with monitoring & controls algorithm
    - Interfaced with existing on-site PLC and plant operator
  - Enable robust & efficient operation despite variations in waste water
  - Reduce reliance on operators through automation – improved consistency in operation across sites

Transition and Deployment

WWT Monitoring & Control Solution



Commercialization Approach

Key Drivers for 2011/2012/2013

1. IP protection
2. Assign New Product Introduction (NPI) Team
3. Establish Voice of Industry (VOI)
4. Update Voice of Customer (VOC)
5. Justify funding for commercialization with ROI
6. Identify sales channels
7. Launch Product

Commercialization Approach

NTI to NPI transition and product commercialization

- **June 2011- Begin AB Pilot (L.A.)**
  - August 2011 – Begin ADM Pilot (Decatur)
- **Dec 2012 – Conclude AB pilot and begin NPI**
- **Dec 2013 – Launch product**
  - Leverage GE Water chemicals/equipment sales channels for existing plants
  - Growth for new plants – leverage non-GE sales channels

Translation for 2013 funnel

- **Breweries**
  - AB brewery - 12 plants in US (121 plants in AB InBev group globally)
  - Miller brewery - 11 plants in US
  - Heineken – more than 90 plants globally
- **Other F&B segments - corn milling, dairy processing, potato …**
  - e.g. ADM, Frito Lays, Cargill, Nestle, …

Questions?