# Distributed Low-Energy Wastewater Treatment (D-LEWT) for Fuel Generation and Water Reuse

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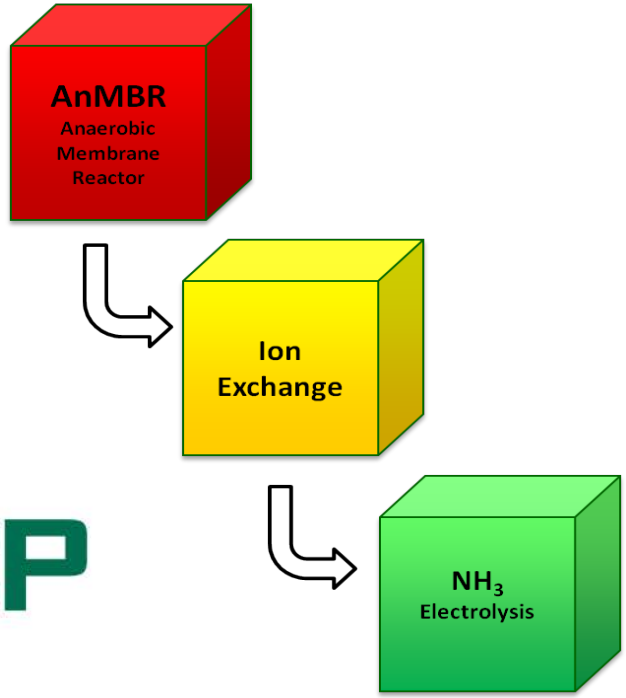


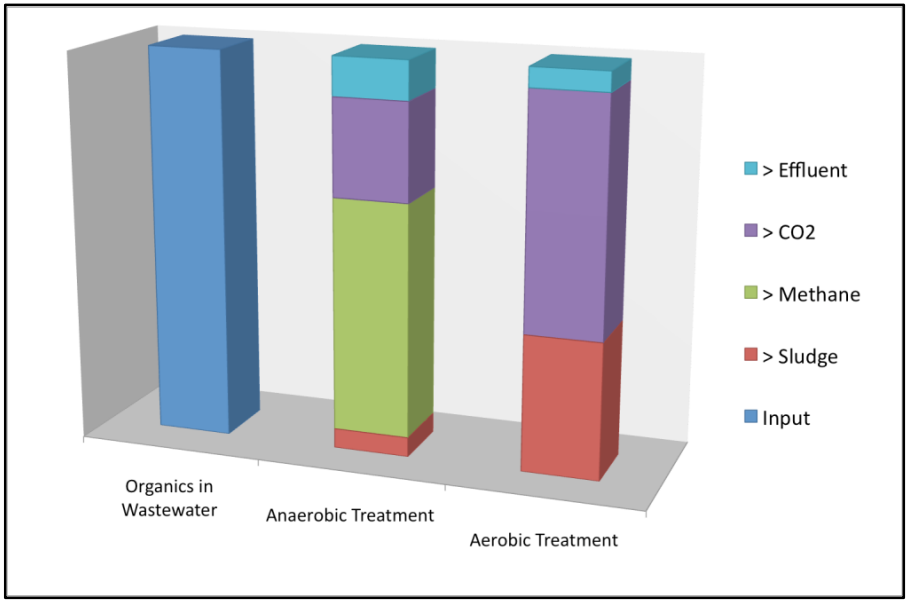

ESTCP

# Project Team

| Member | Role | Organization |
|---|---|---|
| Dr. Kathryn Guy | Principal Investigator | ERDC-CERL |
| Shane Hirschi | Project Manager | ERDC-CERL |
| Nicholas Josefik | Industrial Engineer | ERDC-CERL |
| Tapan Patel | Mechanical Engineer | ERDC-CERL |
| Nathan Peterson | Electrical Engineer | ERDC-CERL |
| Dr. Dawn Morrison | Information Specialist | ERDC-CERL |
| Dr. Lance Schideman | Environmental Engineer | U of Illinois-UC |
| Dr. Ana Martin | Environmental Engineer | U of Illinois-UC |
| Danicza Lopez | Environmental Engineer | Mountain Home AFB |

# Problem Statement

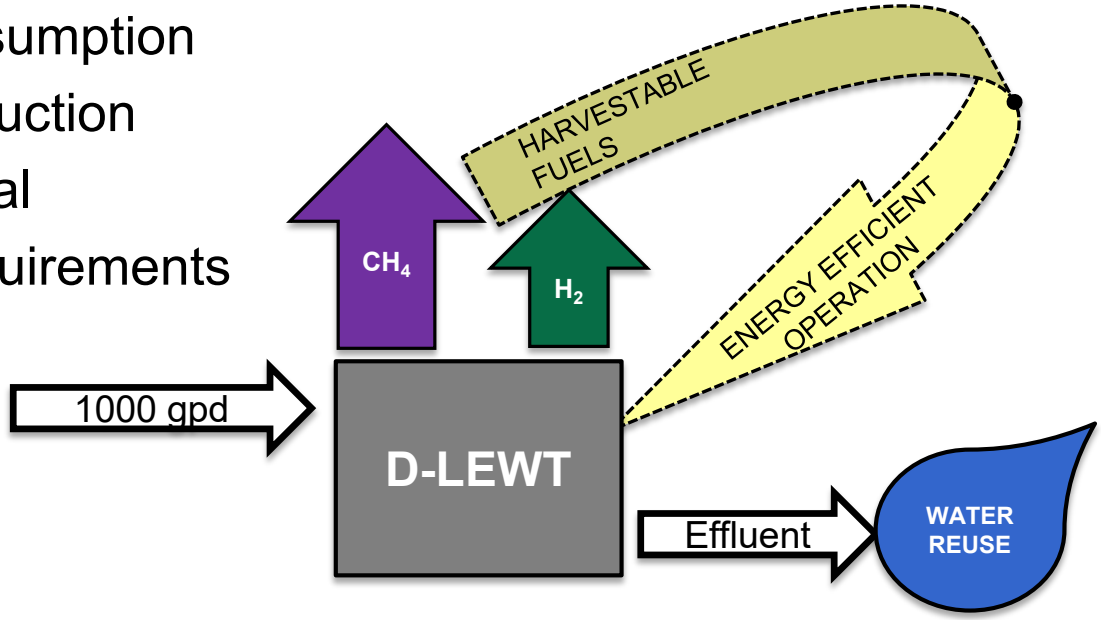
- Current wastewater treatment options:
  - Energy intensive to operate
    - DoD $250M/yr treatment (>50% aeration)
  - Miss energy generation opportunities
  - Discharge permit focused
  - Expansive infrastructure
- Over 100 installations with onsite water treatment
- Mandates and regulations
  - EO 13514
  - EPACT 2005
  - EISA 2007




http://ebsbiowizard.com/wp-content/uploads/2011/08/aerobic_v_anaerobic.png

# Technical Objectives

- Demonstrate
  - Decentralized waste water treatment (1000 gpd)
  - Harvestable fuel generation ($H_2$ & $CH_4$)
- Validate
  - Reduced energy consumption
  - Reduced sludge production
  - Effluent reuse potential
  - Low maintenance requirements

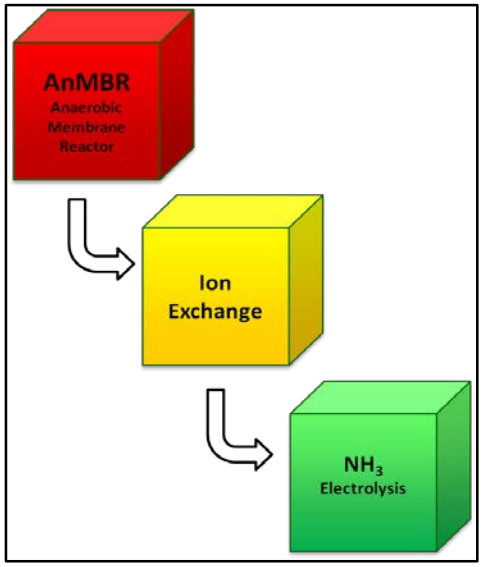


# Expected Benefits

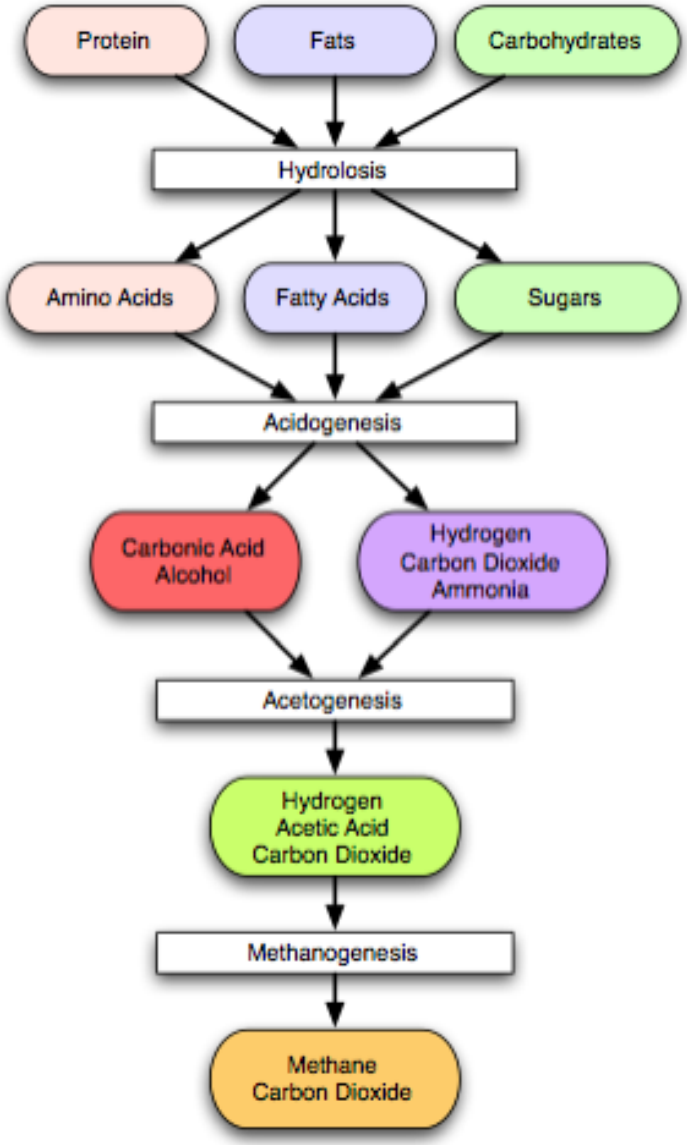
- D-LEWT system
  - Energy efficient operation while generating harvestable fuels (*potential 80% energy reduction*)
  - Treated water available for reuse applications (*>85% reuse*)
  - Segregated waste streams based on building function (simplified/consistent)
- Supports Army Net-Zero water, energy, and waste goals
- Opportunities for D-LEWT implementation
  - >100 existing on-site treatment facilities across DoD
  - New decentralized construction
  - Contingency basing applications
  - Disaster relief efforts

# Technology/Methodology Description

- AnMBR
  - Degrades organics and generates $CH_4$
  - $CH_4$ can be harvested for electrical and thermal energy
- Clinoptilolite ion exchange
  - Captures $NH_3$
  - Generates feedstock for $NH_3$ electrolysis
- $NH_3$ electrolysis
  - Converts the $NH_3$ into $N_2$ and $H_2$ gases
  - $H_2$ can be harvested for electrical and thermal energy generation

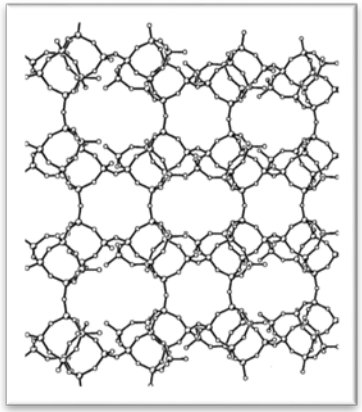


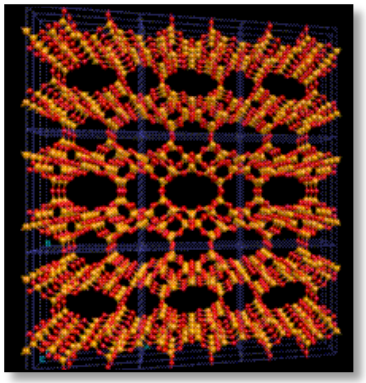
# Technical Background - AnMBR



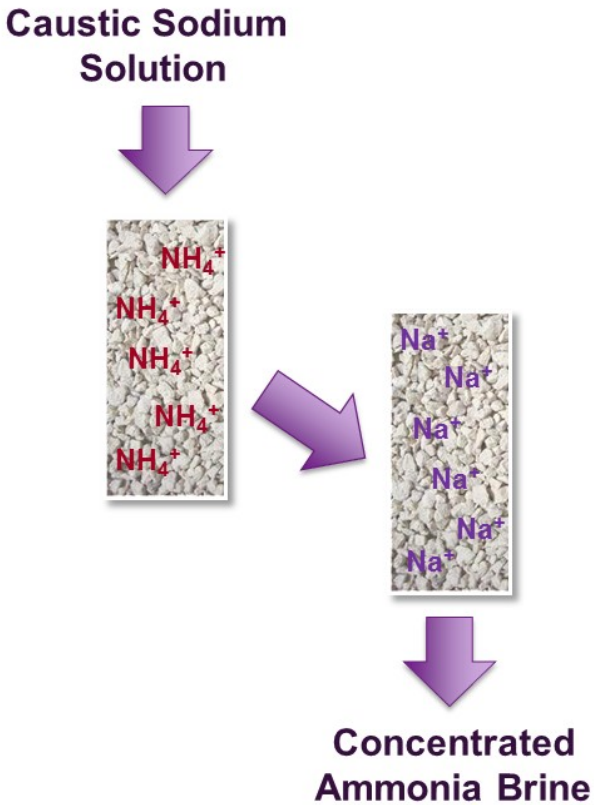

- Anaerobic biological processes remove organics from wastewater
- Organics are converted into harvestable methane gas with low sludge production
  - Approximately 90% less sludge produced compared to aerobic treatment
- Anaerobic bioreactors work well for high organic loadings (i.e., wastewater plus food wastes)
- High rate anaerobic membrane bioreactors (AnMBRs) allow for retention of particulates with shorter hydraulic retention times

# Technical Background - Clinoptilolite





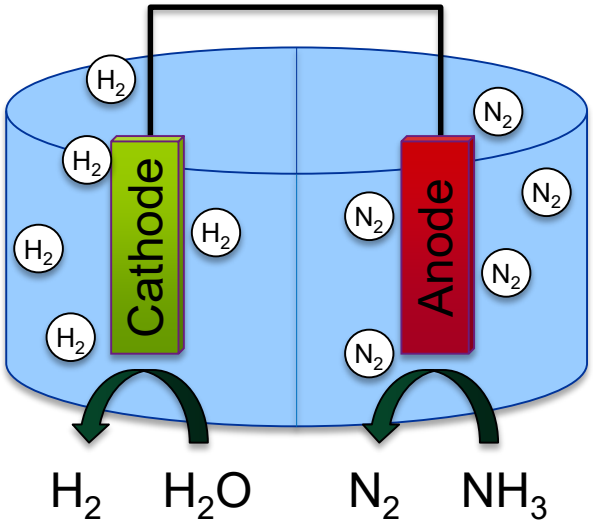
- Clinoptilolite is a naturally occurring high-siliceous, ion exchanging zeolite (Si:Al ~5.7)




- Open channel framework with high surface area carrying a distributed negative charge
- Cations such as $Na^+$ are loosely held in extraframework positions
- Integration of clinoptilolite ion exchange into integrated wastewater systems has been limited due to additional brine disposal or treatment requirements

# Technical Background – $NH_3$ Electrolysis

- Ammonia electrolysis breaks down ammonia into nitrogen and hydrogen gases
- Clean hydrogen can be captured for use in fuel cells
- Requires significantly less energy input than water electrolysis
  - ~95% less based on theoretical calculations
- Operates most efficiently at high pH with high $NH_3$ concentrations




Anode: $2NH_3(aq) + 6OH^- \rightarrow N_2(g) + 6H_2O + 6e^-$

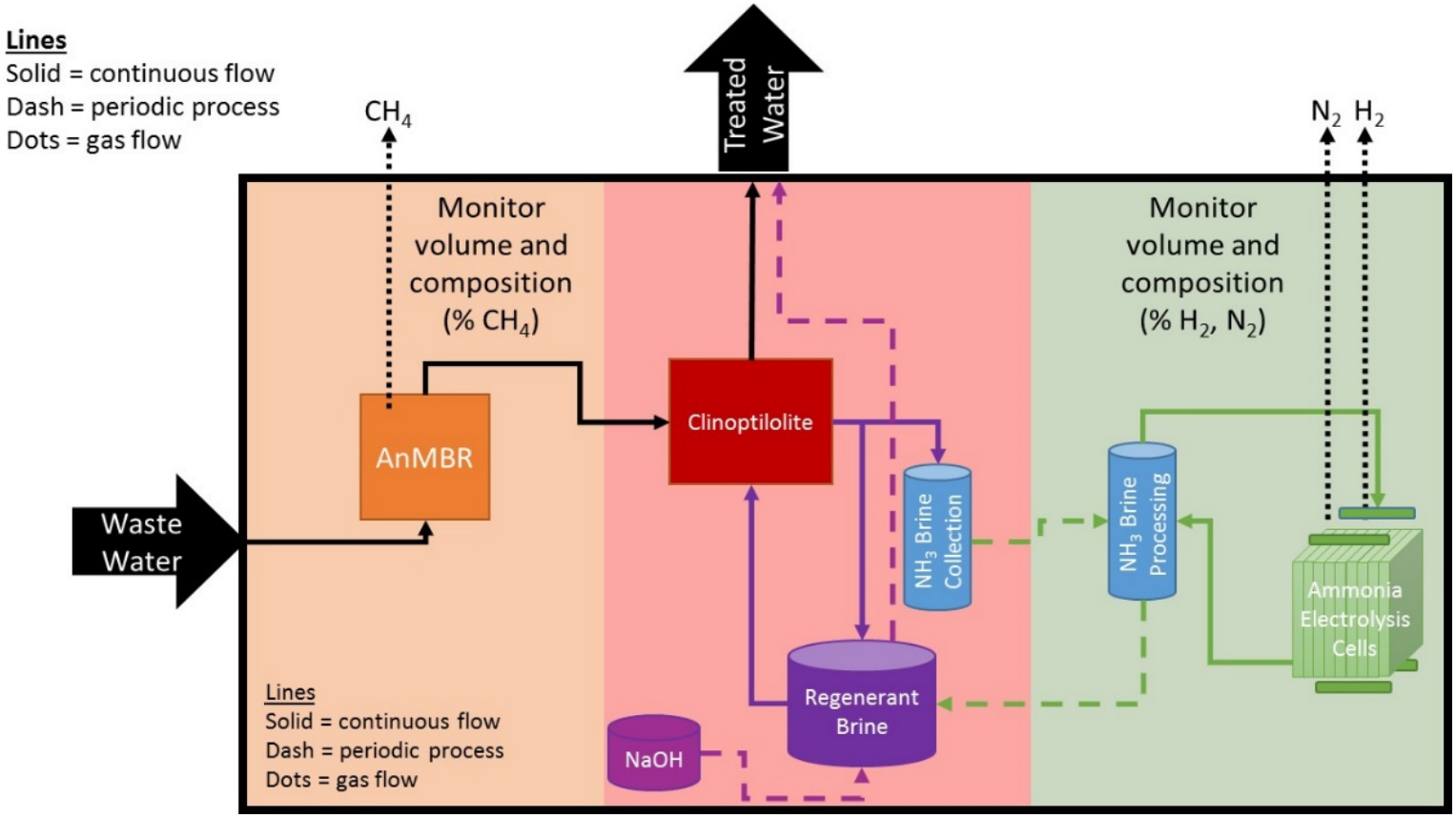
Cathode: $6H_2O + 6e^- \rightarrow 3H_2(g) + 6OH^-$

Total: $2NH_3(aq) \rightarrow N_2(g) + 3H_2(g)$

# Technology/Methodology Maturity

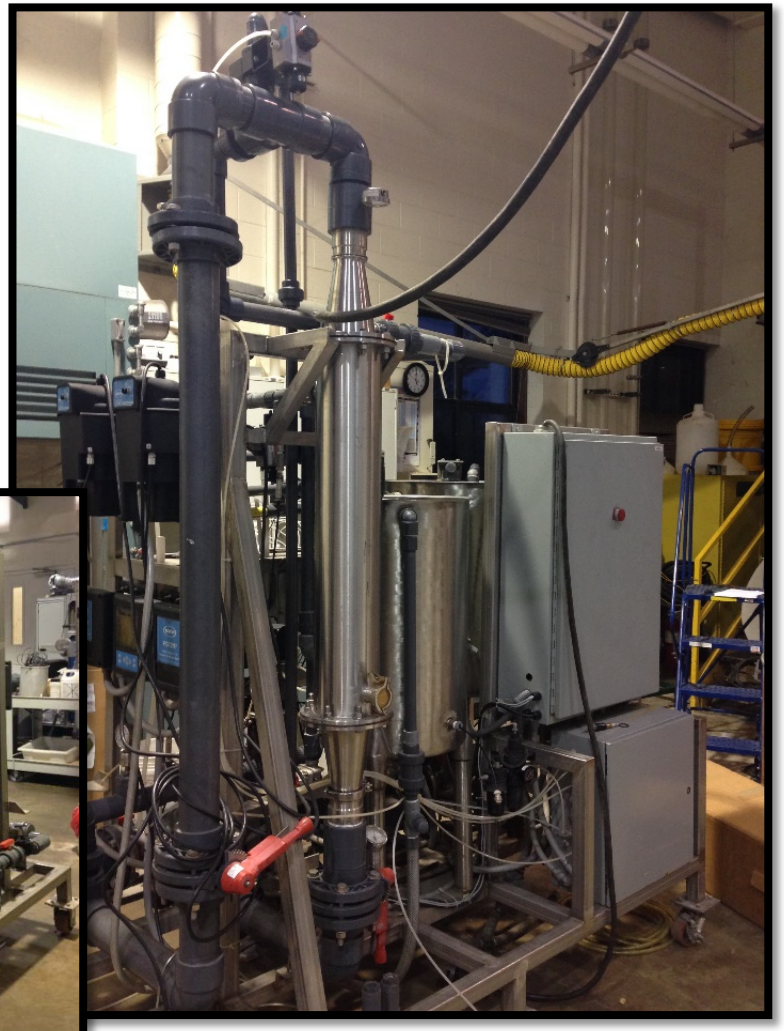
- Successful demonstration of D-LEWT technology at bench scale under SERDP ER-2218
  - Individual component technologies of the wastewater treatment system have been optimized for batch processes
  - All subsystems are COTS available technologies or assemblies of COTS materials
  - SERDP results indicate technology is mature enough to pursue demonstration and validation
- D-LEWT project focuses on automation, subsystem linkages, and balance of plant to achieve operational autonomy

# Test Design – Integrated System



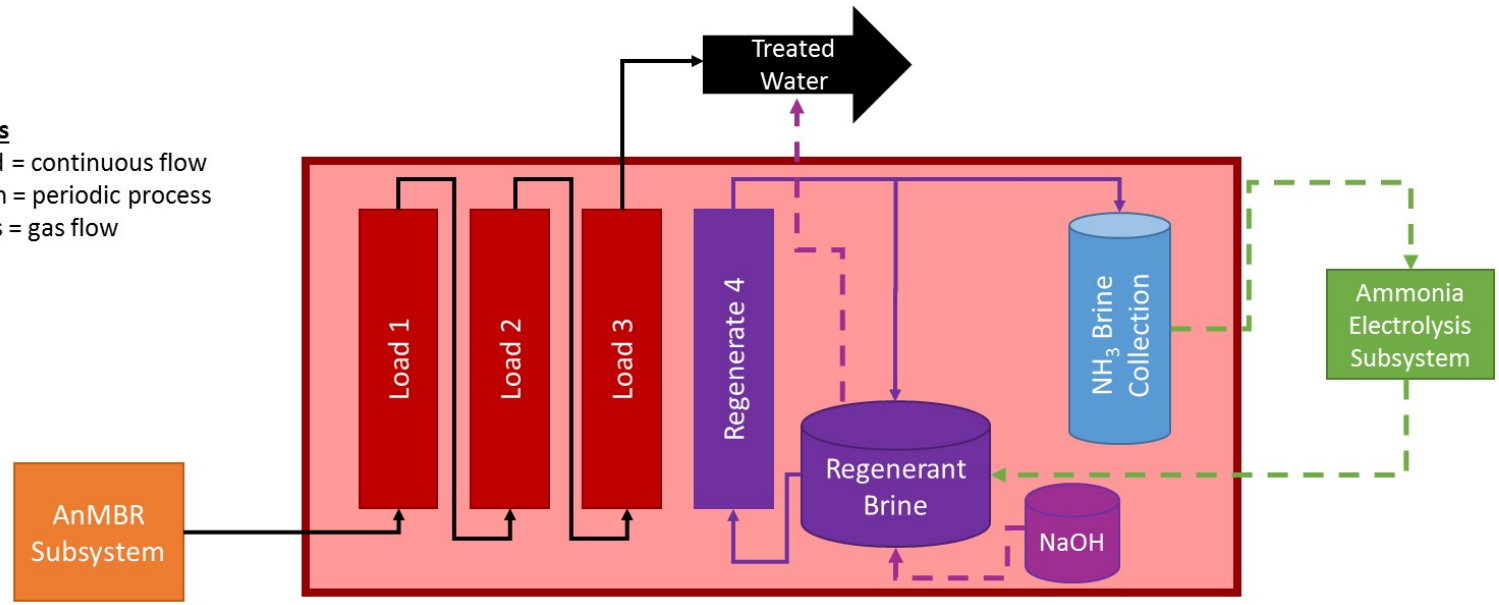
# Test Design - AnMBR

- Partnership with AnMBR experts
- AnMBR provided as cost share with University of Illinois at Urbana-Champaign
- Treats 750-1000 gpd



# Test Design – Ion Exchange

**Lines**
Solid = continuous flow
Dash = periodic process
Dots = gas flow

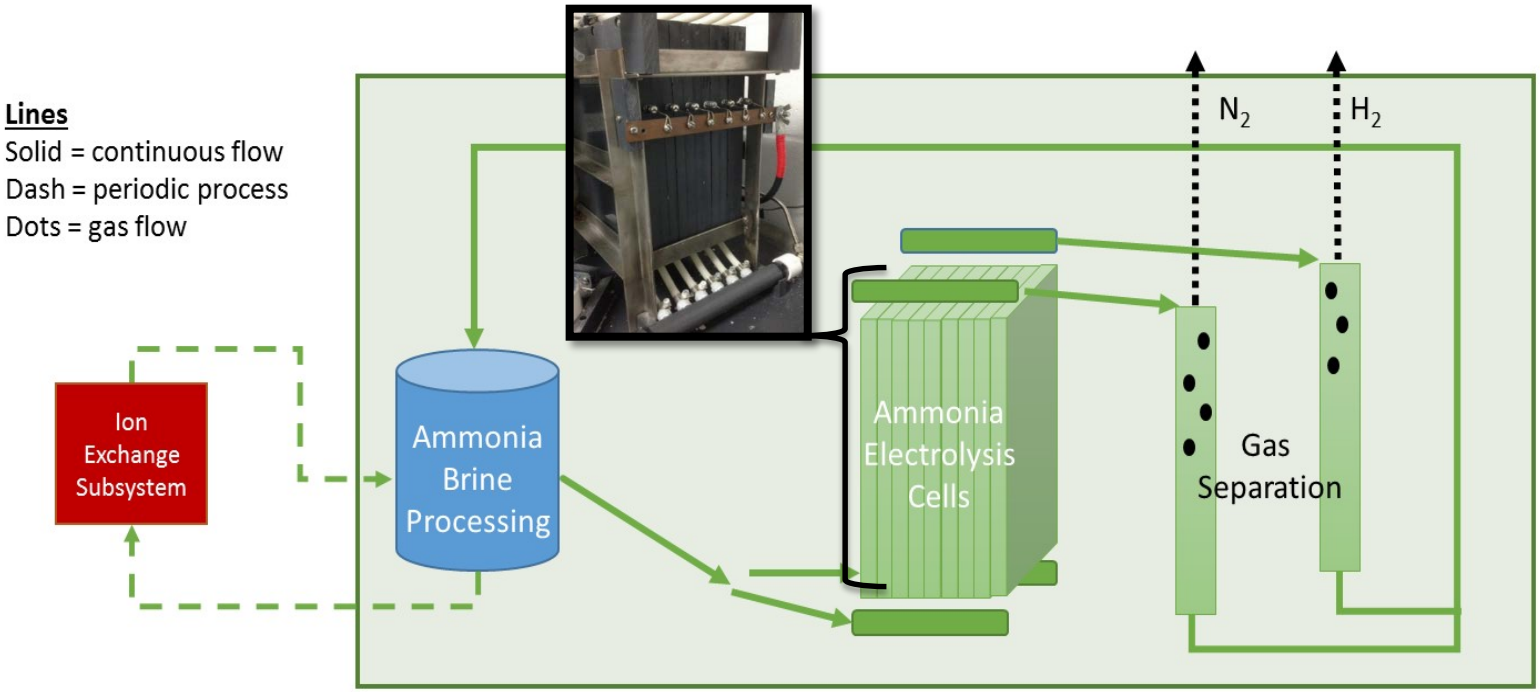



**Loading**
- Columns in positions 1-3
- Influent flows serially through all three columns
- Flow for all columns is bottom up

**Switching**
- After a user defined period of time, all columns switch functional positions
- Column 1 → Column 4
- Column 2 → Column 1
- Column 3 → Column 2
- Column 4 → Column 3

**Regeneration**
- Simultaneous with loading
- Column in position 4
- Regenerant brine introduced in a flow-hold-flow pattern with user defined time periods
- Two effluent options (Regenerant Brine, $NH_3$ Brine Collection) switched at user defined times

# Test Design – Ammonia Electrolysis




- Ammonia brine generated from multiple clinoptilolite regeneration cycles treated in batches
- Solution must be heated to 40-70°C based on user input
- Solution recycled back to ammonia brine processing tank following electrolysis until user defined time to discharge to regenerant brine tank

- User defined adjustable flow (100-500 mL/min) to both sides of electrolysis cells
- Maximum 0.925 Volts applied across each cell
- Flow enters and exits cells through manifolds
- Cells provided as GFE

- Hydrogen and nitrogen gasses are separated from the brine solution
- Composition, purity, and volume of gas generated is measured
- Vented outside of the container unit
- Degassed brine returned to ammonia brine processing tank

# Technical Approach

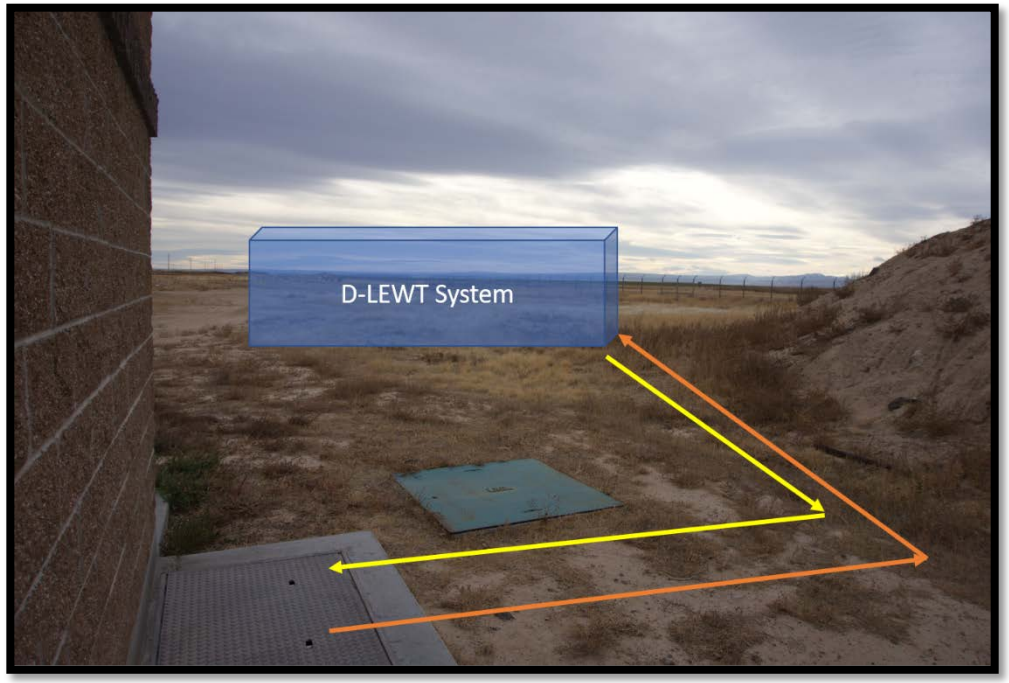
## Pre-validation Testing

- Performed at ERDC-CERL
- Based upon the performance objectives:
  - Energy consumption
  - Energy production potential
  - Effluent water quality and water reuse potential
  - Sludge mass
  - Maintenance requirements
- Performance metrics verified to minimize risks associated with onsite demonstration and validation

# Technical Approach

## Field Demonstration

- Mountain Home Air Force Base (MHAFB)
- Parallel integration with the existing wastewater treatment infrastructure at headworks
- Bypass valve to minimize risk in the event of system shutdown
- Minimal ancillary onsite infrastructure improvements required



# Site Description (MHAFB)

MHAFB headworks buildings—inlet & grate (A), grinder & pumping station (B)

Open channel post grinder, pre-pump station

# Technical Approach

## Performance Objectives

| Parameter | Objective |
|---|---|
| Capacity | 1000 gpd |
| Energy Consumption | $\leq$ 4.45 kWh/kgal |
| $H_2$ Yield | $\geq$ 0.017 kg/kgal |
| $CH_4$ Yield | $\geq$ 0.026 kg/kgal |
| Net Energy Consumption Reduction | $\geq$ 6.0 kWh/kgal |
| Sludge Reduction | > 60% |
| Water Re-Use Potential | > 85% |
| BOD | < 30 mg/l |
| COD | < 30 mg/l |
| $NH_3$ | < 5 mg/l |

# Current Status

- AnMBR
  - University of Illinois updating AnMBR with new piping and a second membrane module
  - Upgrading controls to enable integration with the parent D-LEWT system
  - Conditioning sludge for seeding the AnMBR
- Clinoptilolite
  - Subsystem designed by Highland Engineering
  - Assembly is underway with a completion date of March 2018
- Ammonia Electrolysis
  - Electrolysis cells assembled with improved catalyst
  - Received 2/5/2018

Ceramic membrane module for AnMBR

Assembled clinoptilolite column

# Next Steps

- Integrated system complete – July 2018
- Pre-validation testing complete – January 2019
- Install at MHAFB – February 2019
- Field demonstration complete – March 2020
- Final report – April 2020

# Key Points

- Decentralized waste water treatment system that generates useful methane and hydrogen fuels
- Reduced energy consumption and sludge production compared to aerated systems
- Effluent water available for reuse
- Containerized system suitable for decentralized use and deployed applications
- Supports water, energy, and waste Net-Zero goals

# Questions?