Small-Scale Anaerobic Digestion: Technology and Applications

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Outline

• U.S. small-scale anaerobic digestion market
• International designs and trends
• Domestic Research
• Future of U.S. small-scale digesters
As an example: Dairy Farms in the U.S.

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<th>Herd Size (Head Cattle)</th>
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71,997 Farms - 95.8% of Total

Adapted from: USDA, NASS Farms, Land in Farms and Livestock Operations
Low-Cost, Small-Scale AD… Not traditionally an option

Avg. U.S. Digester Cost: $1.5 million
(U.S. EPA, 2006, 2009)
A Brief History of Small-Scale AD

Early Implementation

- India - reports as early as 1852
  (Voegeli & Zurbrügg, 2008)
- China - 1920
  (Nianguo, 1984)

Early Government Support

- China, 1958 - Widespread dissemination of AD begins
  (Agromisa, 1984)
- India, 1981 - National Project for Biogas Development

Source: Mi, 2007
Over 20,000 worldwide

Large-Scale Anaerobic Digesters

United States | Austria | China (2000) | Germany | China (2009)
--- | --- | --- | --- | ---
135 | 350 | 822 | 5000 | 16000

Over 40 million worldwide

Small-Scale Anaerobic Digesters

- United States: 13
- Africa: 1000
- S.E. Asia: 3000
- Latin America: 10000
- India: 4000000
- China (2000): 8000000
- China (2009): 37000000

The Growing Market

Small-Scale Digesters Operating in China - Past and Projected

Millions of Digesters


0   | 0    | 0    | 0    | 10   | 20   | 30   | 40   | 50   | 60   | 70
Small-Scale AD Globally

- China and India lead the way
- Increased economic viability
- Spreading widely throughout Asia, Southern Africa, & Latin America (Buxton & Reed, 2010)
- Cold-climate, small-scale AD lags behind
  - Most projects promoting concept
International Small-Scale AD: Numerous Designs
All attempting to minimize cost & maximize performance…
Numerous Feedstocks

• Primary wastes
  – Animal & livestock manure
  – Food waste

• Secondary wastes
  – Human manure
  – Agricultural waste

Sources: (Akinbami, 2001; Bi, 2006; Voegeli, 2008)

Photo Credits: (U.S. NRCS, Jean Ryder, www.docklandsrecycling.co.uk)
Use of Products

• Biogas
  – Primary: Cooking, Heating, Lighting
    (Munyehirwe & Kabanda, 2008; Mi, 2007; Singh & Sooch, 2004)
  – Secondary: Electricity
    (Lansing et al., 2008)

• Effluent
  – Fertilizer
  – Feed

• Solids
  – Compost
Chinese fixed-dome

Floating Drum

Taiwanese-
Floating dome/Floating bell

- “Indian” model
- Mixed Waste
- Waste movement due to hydrostatic pressure
- Internal divider designed to prevent short-circuiting
- High maintenance
  (Buxton & Reed, 2010; Lawbuary, 2006; Singh & Sooch, 2003)
Fixed Dome

- “Chinese” model designs vary
  - Janata and Deenbandhu
    (Buxton & Reed, 2010; Khoiyangbam et al., 2004; Singh & Sooch, 2003)

- Mixed waste

- Less maintenance, longer lifespan
  (Buxton & Reed, 2010; Singh & Sooch, 2003)
Plug-Flow Bag Digesters

- Widespread
- Intended for higher solids waste
- Waste moves in “plugs”
- Cheap, but history of problems w/integrity

(Lansing, 2010; Eaton - IRRI Mexico, 2009)
Taiwanese Model Digesters
Costa Rica digesters

- Tubular Polyethylene Plastic Bag
- No Mechanical Parts
- Simple to build and operate
- Low-cost ($150-1500)
Covered Lagoon

- Low maintenance
- No heating
- Lower biogas production, esp. during winter
- Wonderful for odor control

http://www.em-group.co.th/images/cover_lagoon11.JPG
Predominant problems

- Lack of skilled technicians
  - Construction
  - Maintenance/troubleshooting
- Blockages within systems
- Solids accumulation & associated maintenance
- Lack of engineering knowledge for upgrading

Sources: Munyehirwe, 2008
International Trends

• Mass production of proven designs

• Higher quality materials
  – HDPE, Fiberglass

• Household and small-community units
International Trends

- Integrated farming systems
  (Mi, 2007; Todd, 2006; Marchaim, 1992)
- Increased government subsidization
  (Mi, 2007)

Diagram credit: Mi, 2007
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Dairies Operating in the U.S.

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Digging in Cold Climates

- Gas production drops with decreasing temperature
  - Increased retention time
    - Leads to increased size/capital requirements
  - Maintenance of digester temperature
    - Leads to higher energy inputs/sophistication of equipment
    - Additional insulation
Trend: Adaptation of tropical models

Credit: Aziza Kenya

Credit: Jay Martin - OSU
University of Maryland - Small-Scale Plug Flow Setup

- Influent pre-heated
- Effluent recirculated & reheated
- Digesters insulated & buried
- Hot water circulation for additional heating
Aims of research

- Economic analysis
- Energy yield & system function: unseparated vs. separated manure
- Contribution of effluent recirculation
- Small-scale vs. Continuous Stirred-Tank Reactor (CSTR) on same substrate
- Emergy modeling
Additional Small-Scale Research in the U.S.

- Ohio State University
  - Modification of Chinese fixed-dome digester
- Designed for small family/farm use
- Also looking at effluent recirculation
Additional Small-Scale Research in the U.S.

- University of Wisconsin - Platteville
  - Compost heated plug-flow digester

Figure 6. Design of Taiwaneso digester heated by compost to be tested at the University Wisconsin-Platteville.

Figure 7. Top-view layout of small-scale digesters to be located at the UW-Platteville Pioneer Farm.
USEMCO sets up first small-farm manure digester

By Jessica Larsen

Monday marked a big step for Tomah manufacturer USEMCO.

It’s when the company’s first manure digester was shipped off to be tested at farmer Wayne Peters’ 200-cow Chaseburg dairy.

“If this works well, the market for small farms will greatly improve,” USEMCO president Pat Rezin said.

Though Wisconsin leads the nation in the agricultural use of anaerobic digesters, current technology — which requires on-site construction of concrete or steel structures — is best suited to farms with at least 1,000 animals.

USEMCO has developed a tank that makes it economical for farms with as few as 100 cows. The steel structure stands 40 feet tall and is 13 feet wide.
Opportunities & Possible Avenues of Approach

- Recognize market
  - Small-scale farms and waste generators constitute a large market
- Scale up, not down
  - Engineering based on viable small-scale designs
- Focus on biogas as end-product
  - Heating, cooking, refrigeration
- Explore digestion options
  - Co-digestion of food waste

(Humboldt Waste Management Authority, 2010; Chanakya et al., 2008)
The Bioenergy Industry with Smaller-Scale Digesters

U.S. potential: 1.8 million applications

U.S. natural gas consumption reduced by 25% (equivalent to 1 billion barrels of oil per year)

U.S. methane emissions reduced by 5% per year (reduction of 34.5 million tons of CO₂ equivalents)
Questions?

Photo courtesy of Raul Botero