BIA Workshop on
Biomass Opportunities and Challenges in Indian Country

"Organic Recycling for Renewable Energy Generation"

(aka Anaerobic Digestion)

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Organic Recycling for Renewable Energy Generation

Outline

- History of Organic Recycling; definition
- Organic Recycling: the Emerging Opportunity
- The Basics of the Anaerobic Digestion Process
- Benefits of Organic Recycling
- Working Examples of Organic Recycling
- Conclusion and Questions

The History of Organic Recycling
(Anaerobic Digestion)

- Anecdotal references as far back as 900 AD
- First plant built in 1859 at leper colony in India
- Used in 1895 to power streetlights in Britain
- First used for MSW in US in 1939
- China: 6,000,000 backyard digesters
- AD has become the state of the art for municipal WWTPs worldwide
- Emerging as a preferred method of disposal for manure and MSW in Europe

What is "Organic Recycling"

- Organic Recycling is the practice of recycling organic materials, not just glass, aluminum, plastic & newspaper
- Any practice that seeks to find additional value from waste organics is a form of Organic Recycling: paper recycling, aerobic composting, particleboard from wood waste
- Organic Recycling seeks to re-use the material or the energy invested in it
- Organic materials are anything originally derived from an animal, plant or microorganism: a.k.a. *biomass*
- Common "organics": wood waste, ag-residues, manure
- Less common (more problematic) organics: slaughterhouse waste, restaurant grease, industrial sludges, biosolids

Traditional Organic Disposal Practices

- Landfilling
- Burning, Incineration, Combustion
- Aerobic composting
- Land Application

Why Practice Organic Recycling

- Current practices have negative social, environmental, cost impacts
- Municipalities and corporate waste generators must contend with rising energy and disposal costs
- Economic and legislative drivers are forcing industrial and municipal waste generators to see waste products as valuable resources
- Organic recycling can provide distributed renewable energy generation for communities, farms, process plants
- Organic Recycling promotes self-sufficiency and energy independence

Where is Organic Recycling Being Implemented?

Europe	Asia/Australia	North America
Germany	South Korea	Cuba
Denmark	China	United States
Austria	Japan	Canada
Sweden	Thailand	Mexico
Belgium	India	South America
Poland	Pakistan	Brazil
Hungary	Bangladesh	Argentina
Norway	Indonesia	Columbia
Finland	Australia	Bolivia
Ireland	New Zealand	Africa
Spain		Nigeria
Italy		Kenya

Drivers of Organic Recycling in the EU

- Cost of disposal and energy
- Land Use Issues: Landfill diversion and nutrient management
- Proximity Principal: Waste should be dealt with as near to the source as possible
- Hierarchy of Waste Management - Prevention, Re-use, Recycling, Energy Recovery
- Countries should seek self-sufficiency for waste and energy
- Generators of waste should be involved in its management
- Organic Recycling is good stewardship of natural resources

Indicators of Heightened Interest in Organic Recycling

- Growing number of states and countries with landfill bans
- Rising numbers of municipal composting programs
- Rising numbers of farm scale anaerobic digesters
- Increase in used of Anaerobic Digestion by corporate waste generators: Cargill, Tyson, Excel, Seneca, Mapleleaf
- Renewed interest in cellulose to ethanol technologies
- Increase in number of supermarket-based recycling programs
- Rise in the number of pellet boilers in Europe

What methods are currently used to Recycle Organics?

- Pellet Boilers for MSW and wood waste: Austria, Scandinavia
- Aerobic Composting: San Francisco, CA, Portland, OR
- Landfill Gas to Energy (LFGTE) Projects: throughout USA
- Biofuels production: ethanol from ag-residues and MSW, biodiesel from grease
- Gasification of C&D debris, poultry
- Particleboard from ag-residues and wood waste
- Anaerobic digestion of animal manure and food residuals
- Not all recycling methods for organics generate energy

Focus on Organic Recycling with Anaerobic Digestion for Renewable Energy Generation:

Municipal and Corporate Organic Waste Feedstocks

Low-Solids or Liquid Wastes	Medium-Solids and Wet Wastes	High Solids Organic Feedstocks
Spent beverages	Food residuals	Slaughterhouse waste
Spent stillage from breweries	Fats, oils, grease (FOG)	Organic fraction of MSW
Whey and cheese wastes	Biosolids	Green Waste & Yard Waste
Municipal wastewater	Dairy manure	Animal mortalities
Commercial wastewater	Paunch manure	Paper, cardboard, packaging
Industrial sludges	Food processing wastes	Feedlot & racetrack manure
CAFO flush water	Drip trap grease	Food processing wastes
Port-a-let pumpings	Used restaurant cooking oil	Agricultural residues

So, what does Organic Recycling have to do with Tribal Oppotrtunities?

- Take advantage of the emerging opportunity:
  - Generate capital investment and economic development
  - Create new revenue centers
  - Capitalize on feedstock resources
  - Diversify industrial base
- Expand Tribal involvement in the community
- Lead sustainability by example

Organic Recycling for Renewable Energy: The Emerging Opportunity

- Disposing of organic wastes is becoming more difficult and more costly
- Current practices have negative social and environmental impacts
- Economic and legislative drivers are forcing industrial and municipal waste generators to see waste products as valuable resources
- New AD process technologies expanding feedstock applications
- Result: Anaerobic Digestion is emerging as a cost-competitive Renewable Energy technology

The Emerging Opportunity: U.S. Solid Waste Market

- 6.75+ billion tons of domestic solid waste
- 250 million tons of MSW per year
- 5+ tons animal waste per person per year
- Growing at 3-5% per year
- Oil is >$60/bbl and rising, making renewable energy applications solid commercial opportunities

Potential Feedstocks for Organic Recycling and Renewable Energy Production via Anaerobic Digestion

- Wastewater
- Spent Beverages
- Food Processing Wastes
- Food Residuals
- Agricultural Residues
- Municipal Solid Waste
- Animal Manure
- Industrial Sludges
- Biosolids
- Slaughterhouse Waste
- Animal Mortalities
- Industrial Wastes
  - Pharmaceutical
  - Rendering
  - Textile
  - Tannery

The Basics of Anaerobic Digestion I

- AD is a microbial bioconversion process
- Occurs naturally in lakes, bogs, wetlands, landfills, animals
- Recycles complex organic molecules (carbon biomass) into single carbon compounds CO_2 and CH_4 called “Biogas”

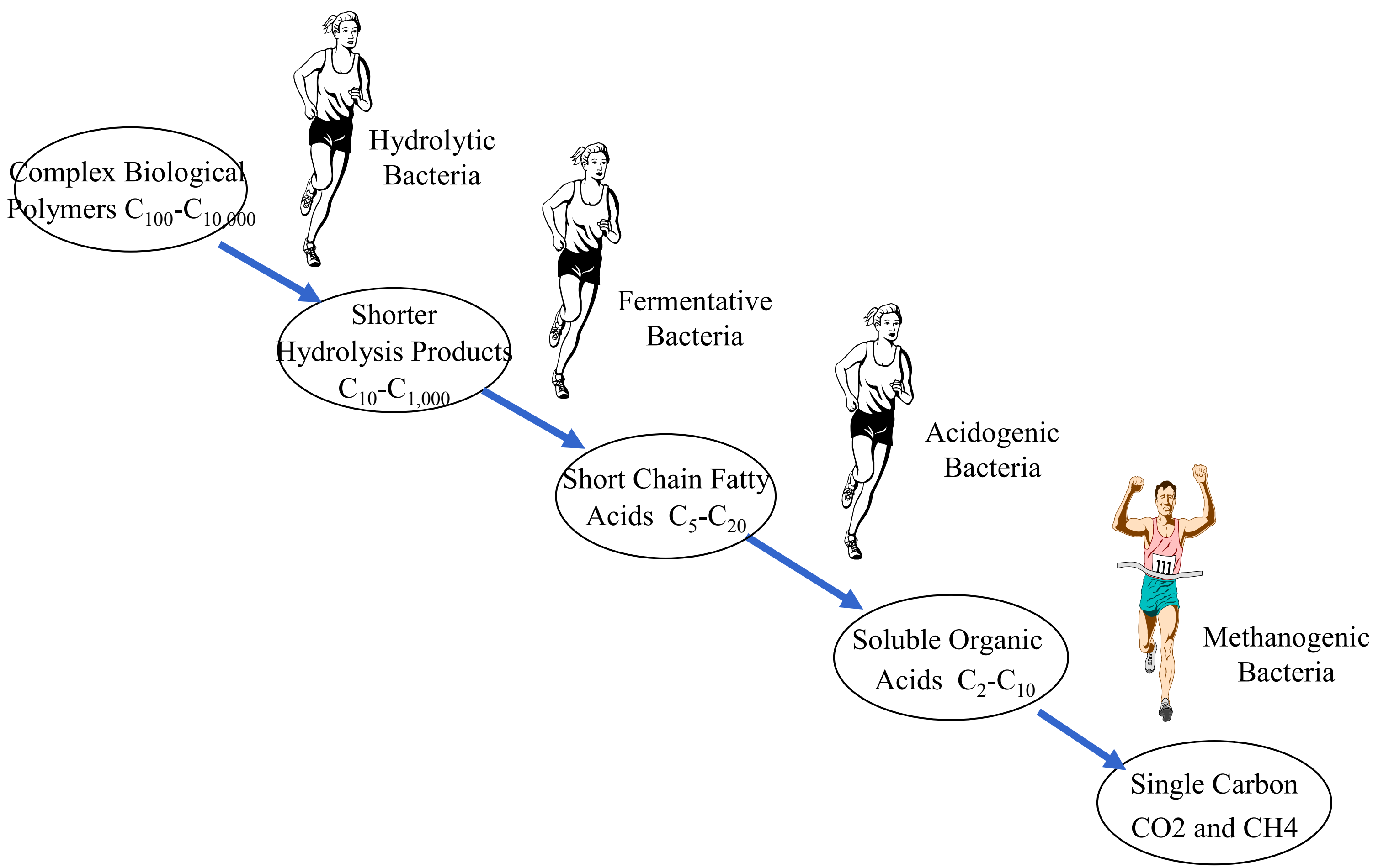
The Basics of Anaerobic Digestion II

- Bacterial Process - Mixed Symbiotic Consortium
- Occurs in absence of air
- Occurs over wide range of temperature (20-100°C)
- Occurs over a wide range of solids loading
- Applicable to most biological materials

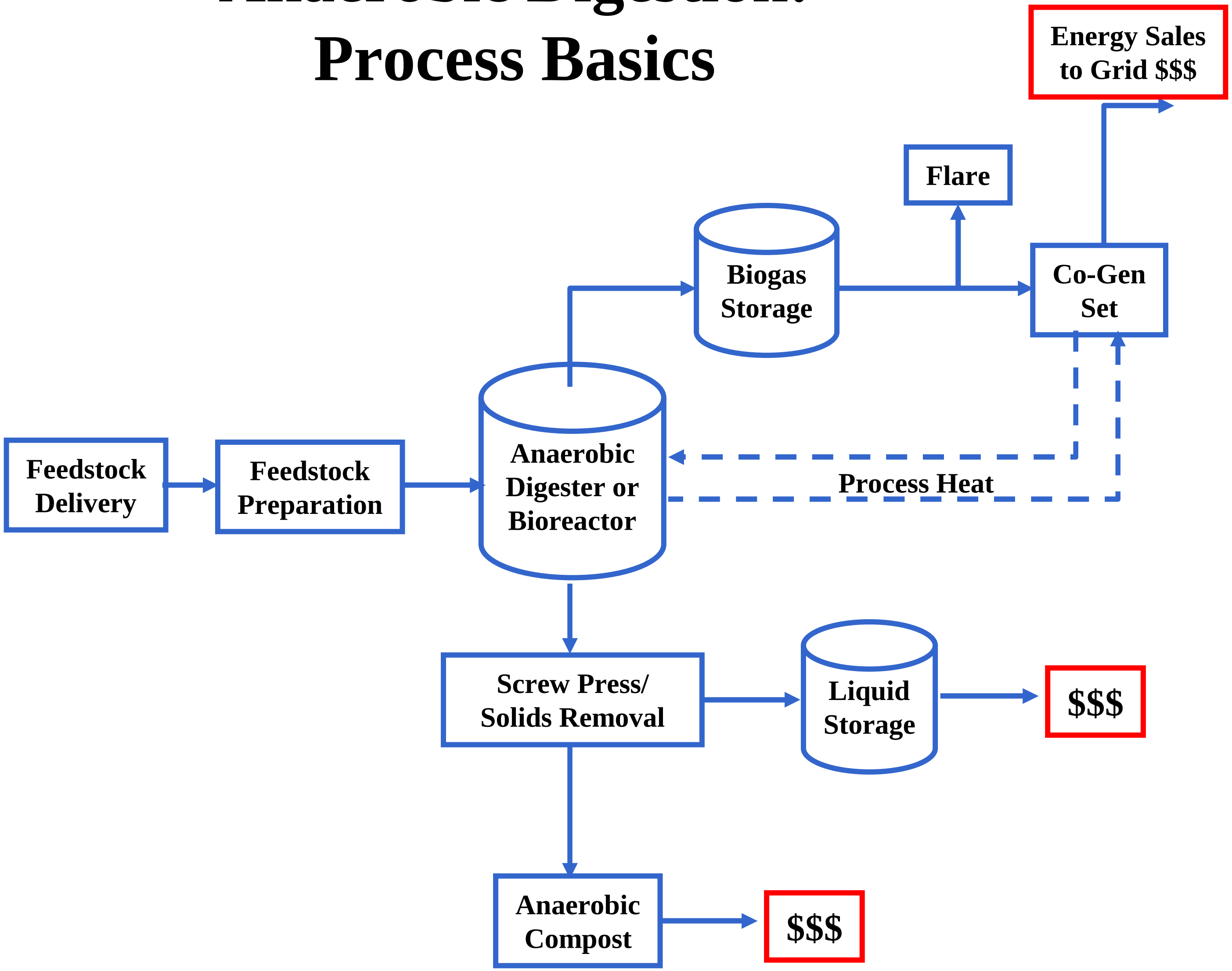
The Basics of Anaerobic Digestion III

- Three Basic Temperature Regimes for AD
  - Psychrophilic: <20°C (68°F)
    - Lagoons, swamps
    - Slow process
  - Mesophilic: 35°C to 40°C (95°F to 105°F)
    - Rumens of Animals
    - Industrial and farm digesters
    - Faster Process
  - Thermophilic: 50°C to 60°C (125°F to 140°F)
    - Sanitizes pathogen-bearing feedstocks
    - Fastest reaction kinetics
    - Shortest residence time

"The Anaerobic Digestion Relay Race: Passing the Carbon Baton"



Anaerobic Digestion: Process Basics



Anaerobic Digestion:
Key Process Control Parameters

- Feedstock Composition
- Feedstock Concentration
- Temperature
- pH and Alkalinity
- Presence of toxic compounds
- Residence Time
- Organic Loading Rate
- Ratio of feedstock to microbial populations

Anaerobic Digestion: Feedstock Resource Drives Process Design

- Low Solids Feedstocks
  - <3% total solids by weight
  - little or no suspended solids
  - single phase liquid system, readily mixed
- Medium Solids Feedstocks
  - 3% to 12% total solids by weight
  - contains suspended solids
  - slurry system, can still be mixed
- High Solids Feedstocks
  - up to 25% total solids by weight
  - "solids-processing" system
  - requires non-traditional mixing

Anaerobic Digestion: Low Solids Applications

- Low Solids Feedstocks
  - Secondary wastewater treatment
  - Spent beverages & out of spec/expired products
  - Hydraulic flush manure systems (swine)
- Low Solids Processes
  - Anaerobic Lagoons - Fixed, Floating, or Submerged Covers
  - Completely Mixed Reactors
  - Anaerobic Filter Reactors
  - Upflow Anaerobic Sludge Blanket Reactors
  - Fixed-film Packed Bed Reactors

Anaerobic Digestion: Low Solids Covered Lagoon

(Photo of Courtesy of RCM Digesters)

Anaerobic Digestion: Medium Solids Applications

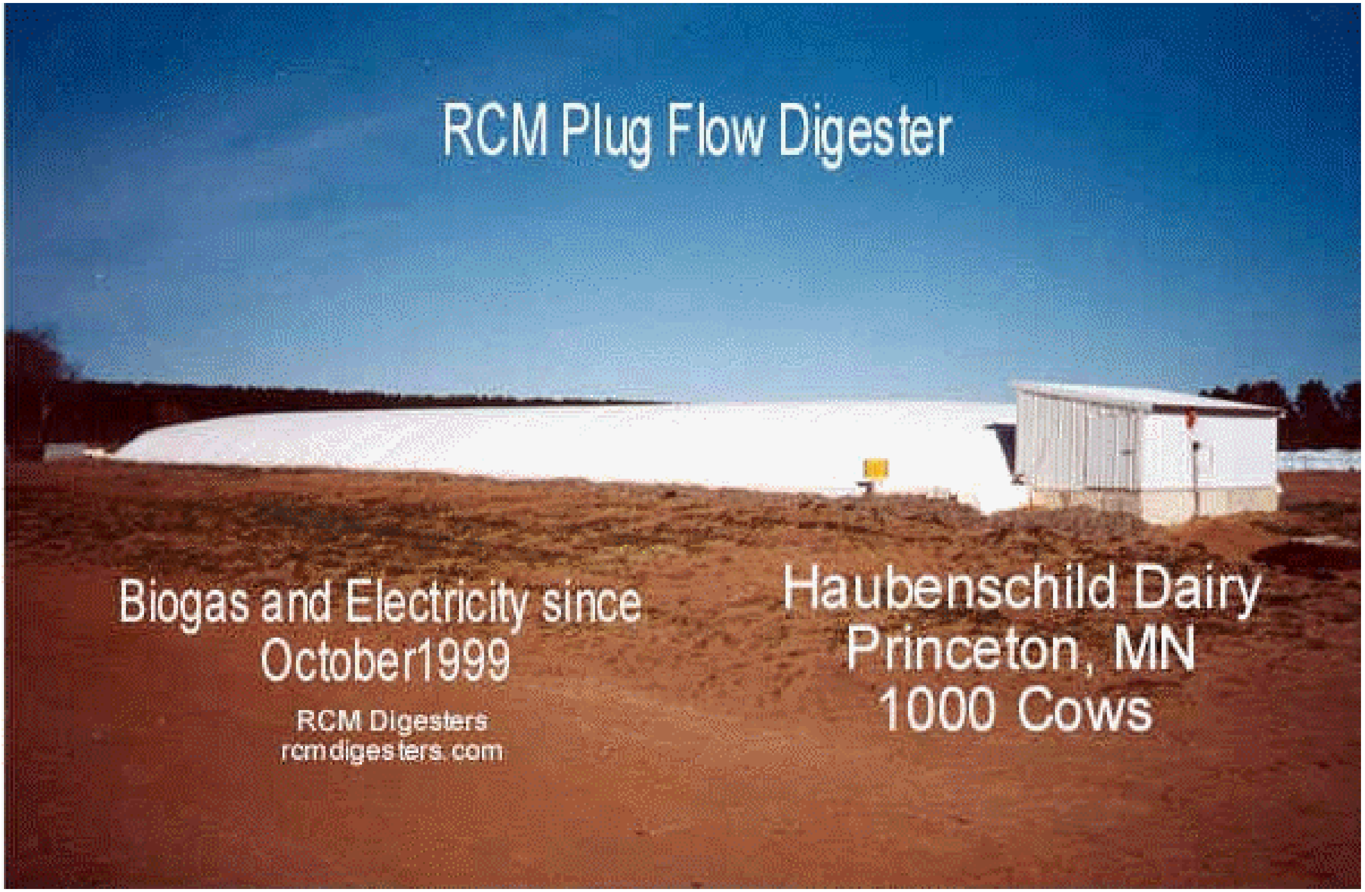
- Medium Solids Feedstocks
  - Dairy manure
  - “Scraped” swine manure
  - Industrial DAF sludges

- Medium Solids Processes
  - Plug Flow Reactors
  - Complete Mix Slurry Reactors
  - Slurry-Loop Reactors
  - Acid-Phased or Temperature Phased
  - Contact Reactors

Anaerobic Digestion:
Medium Solids Applications:
Complete Mix Slurry Digesters

(Photo Courtesy of the Danish Biogas Program)

Anaerobic Digestion: Medium Solids Applications: Plug Flow Digester



(Photo of Courtesy of RCM Digesters)

Anaerobic Digestion: High Solids Applications

- High Solids Feedstocks
  - Organic Fraction of MSW
  - Ag-residues
  - Food Processing Waste; Food Residuals
  - Clarifier sludges (pulp/paper)
- High Solids Processes
  - Dry Continuous
    - Plug Flow
    - Complete Mix
  - Dry Batch with Permeate Recycle
  - Sequencing Batch Reactors

Anaerobic Digestion: High Solids Applications: Plug Flow Digester

(Photo of Plug Flow MSW Digester Courtesy of Pinnacle Biotechnologies)

Anaerobic Digestion:
High Solids Applications: Plug Flow Digester

(Photo Courtesy of www.kompogas.ch)

The Benefits of Anaerobic Digestion: Environmental

- Closed Systems Eliminate Odors
- Residence time reduces Pathogens, Weed Seeds; Produces Sanitized Compost
- Reduces CH4 and CO2 GHG Emissions; Ammonia Emissions
- Captures Nutrients for Reuse & Reduces Use of Inorganic Fertilizers
- Promotes Carbon Sequestration
- Increases Beneficial Reuse of Recycled Water
- Protects Groundwater and Surface Water Resources

The Benefits of Anaerobic Digestion: Energy

- Net Energy-Producing Process
- Generates High-Quality Renewable Fuel
- Produces Surplus Energy as Electricity and Heat
- Reduces Reliance on Energy Imports
- Contributes to Decentralized, Distributed Power Systems
- Proven Source of Electricity, Heat, and Transportation Fuel

The Benefits of Anaerobic Digestion: Economic

- Turns Waste Liabilities Into New Profit Centers
- Adds Value to Negative Value Feedstocks
- Reduces Operating / Energy Costs
- Reduces Water Consumption
- Reduces Reliance on Energy Imports
- Increases Self-Sufficiency

Summary of Anaerobic Digester Systems Operating in the US and Europe

Country	Biosolids	Biowaste/Solid Industrial	Agricultural	Industrial Wastewater
Austria	100	3	100	25
Canada	50			13
Czech Republic			10	4
Denmark	64		21	5
Finland		1		3
Germany		49	1500	91
Greece	2		1	2
Italy		4	50	38
Netherlands		2	0	84
Norway	17		2	5
Portugal			94	3
Spain		1	6	27
Sweden	134	4	3	8
Switzerland	70	11	69	20
UK	200	1	25	26
USA	1600		28	92

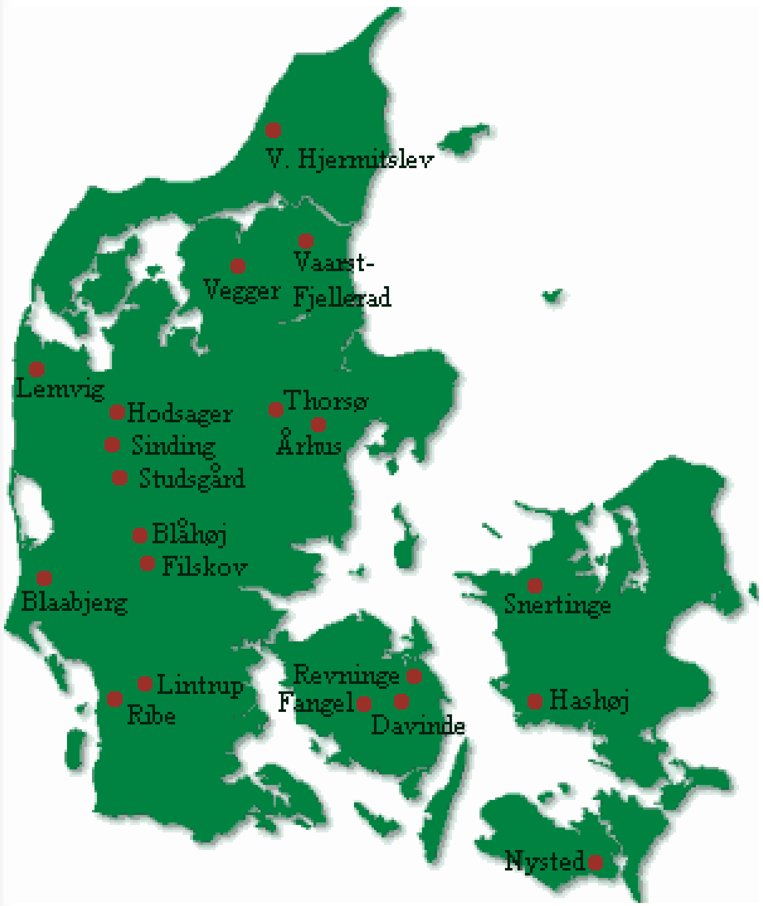
(Table from www.iea.org/)

Summary of Anaerobic Digester Systems Operating at Commercial Scale

Country	Commercial Scale Systems (over 2500 tpy or 7 tpd)	Smallest (tpy / tpd)	Largest (tpy / tpd)
Austria	17	5,000 / 15	160,000 / 460
Belgium	3	20,000 / 57	182,000 / 520
Canada	1		150,000 / 430
Czech Republic			
Denmark	21	10,000 / 30	190,000 / 540
Finland	1		15,000 / 45
France	1		85,000 / 240
Germany	47	2,500 / 7	120,000 / 340
Greece			
Indonesia	1		unavailable
Italy	4	4,000 / 11	300,000 / 860
Japan	1		unavailable
Netherlands	5		10,000 / 30
Norway			
Portugal			
Spain	1		34,000 / 100
Sweden	9	3,000 / 9	105,000 / 300
Switzerland	14	5,000 / 15	15,000 / 45
Ukraine	1		12,000 / 35
UK			
USA	3	3,000 / 9	30,000 / 90

(Table from www.iea.org

Summary of Biogas Program in Denmark: Why it works



- Nationwide program started in 1988
- 21 centralized plants
- Laws prohibit landfilling or land application
- Laws mandate 7 month winter hold
- Government provides 20-40% financing subsidy
- Law mandates electricity purchase
- Law mandates minimum price
- Cities use centralized heat

Summary of Biogas Program in Germany: Why it works

- Laws prohibit landfilling or land application - fines
- European Union Renewable Energy Law mandates electricity purchase
- European Union Renewable Energy Law mandates minimum price of 0.102 to 0.076 Euro for 20 years
- Government provides 30% subsidy of reduced interest loans, debt reduction
- 1500 single farm systems; 250 in last year

Working Anaerobic Digester Systems on Farms in the U.S.

- 31 digester systems operating at commercial livestock farms
- 15 are at swine farms; 14 are at dairy farms; 2 are at caged layer farms
- 18 systems were installed since 1990
- 23 systems use the captured biogas for CHP; 8 flare
- In 1999, ≈ 1 million MWh of power produced (≈115 MW)
- Over 4,800 metric tons of methane captured
- GWP equal to 27,500 metric tons of CO_2 on a carbon-equivalent basis

Working Anaerobic Digester Systems in California & Oregon

Location	Year built	Animal type and population	Manure handling	Installed cost	Biogas end-use	CH4 reduction Mt CE/year*
California						
CA	1982	Swine; 1,650 sows farrow-to-finish	Flush	$220,000	Electricity and hot air	2,316
CA	1984	Swine; 900 sows farrow-to-finish	Flush	$120,000	Electricity and hot air	1,263
CA	1986	Swine; 550 sows farrow-to-finish	Flush and gravity drain	$75,000	Electricity and hot air	772
CA	1998	Dairy; 200 cows	Flush	$150,000	Flare	149
CA	1982	Dairy; 400 milkers	Scrape	$200,000	Electricity and hot water	806
Oregon						
OR	1997	Dairy; 1,000 milkers	Scrape	$287,300	Electricity	1,129

(Table from www.epa.gov/agstar/)

Working Examples of Anaerobic Digestion Technology: Haubenschild Farm, MN

Parameter	Design Value	Actual: 750 Cows
Time Frame	1998	Sep-'00 to Jul '02
Cows	1,000	750
Cost per Cow ($)	307	355
Total Installation Cost ($)	307,700	355,000
Manure Slurry: Waste & Bedding		
Gallons (per cow-day)	17.5	27
Total Slurry (gal/day)	17,500	20,000
Digester Size		
Volume (gal)	352,000	352,000
Residence Time (days)	20	15
Gas Production		
Per cow (ft^3/day)	65	93
Total (ft^3/day)	65,000	70,000+ (excess flared)
Electrical Output		
Per cow (kwh/day)	2.3	4.0
Total (kwh/day)	2,340	2,970
Avail Power Capacity (kW)	97	124
Thermal Output (mmBTU/day)	18	n/a
Revenue Generation		
Offset Heating Costs ($/yr)	$4,000	$4,000
Offset On-Farm Electricity Use ($/kwh)	$0.07	$0.073
Excess Elec. Sales ($/kwh)	$0.02	$0.073
Projected Electric Revenues ($/yr)	$40,300	$80,957
Total Projected Income ($/yr)	$44,300	$84,957

(Table from www.mnproject/pdf/haubyrptupdated.pdf)

Working Examples of Anaerobic Digestion Technology: Blaabjerg, DK

Blaabjerg Plant Equipment:
1. Blending Tank
2. Industrial Sludge Holding Tank
3. Manure Hold Tank
4. Digester
5. Gas holder
6. Effluent Sludge Tank
7. CO-GEN Building
8. Office & Laboratory Bldg.

Blaabjerg Main Operating Data:
Animal manure........................... 222 tons/day
Alternative biomass.................... 87 tons/day
Biogas production...................... 3,1 mill m³/year
Digester capacity (2 x 2500 m³).. 5000 m³
Process temperature.................. 53,5°C
Utilisation of biogas................... CHP-plant
Average transport distance......... 5,0 km

Working AD System Equipment: Blaabjerg









Working Examples of Anaerobic Digestion Technology: Denmark

Davinde Main Operating Data:

Animal manure........................ 25 tons/day
Alternative biomass................. 3 tons/day
Biogas production................... 0,3 mill m^3/year
Digester capacity.................... 750 m^3
Process temperature............... 36,0°C
Utilisation of biogas................. Gas fired boiler
Average transport distance...... 5,7 km
Contractor: Kruger Ltd
Year: 1988

Snertinge Main Operating Data:

Animal manure............................ 66 tons/day
Alternative biomass..................... 42 tons/day
Biogas production....................... 1,6 mill m^3/year
Digester capacity (3 x 1000 m^3).. 3000 m^3
Process temperature................... 52,5°C
Utilisation of biogas.................... CHP-plant/gas boiler
Average transport distance......... 5 km
Contractor NIRAS Ltd
Year: 1996

Summary of Renewable Energy From Anaerobic Digestion

- Anaerobic Digestion is emerging as competitive renewable energy technology
- AD process is applicable to wide variety of organic feedstocks
- AD has a proven industrial track record
- AD has substantial environmental and economic benefits
- Legislative mandates have helped create industry in Europe
- Successful systems can be farm-based or centralized
- Widespread success in US dependent on cost-effective designs and energy incentives

The Dawn of a New Age of Renewable Energy

(or maybe the Sunset of the Fossil Fuel Age?)