Biofuels and Small Communities

Sigifredo Castro and Larry E. Erickson

Kansas State University

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United States

Carbon dioxide from fossil fuels

5.96 billion tons/year

Biomass production

6.8 billion tons / year

Using 3 tons/acre

Anaerobic Digestions in Europe

2006: 124 plants using 4 million tons solid waste/year

15 Anaerobic digestion vendors

Source separated organics

Municipal solid waste

Animal manure

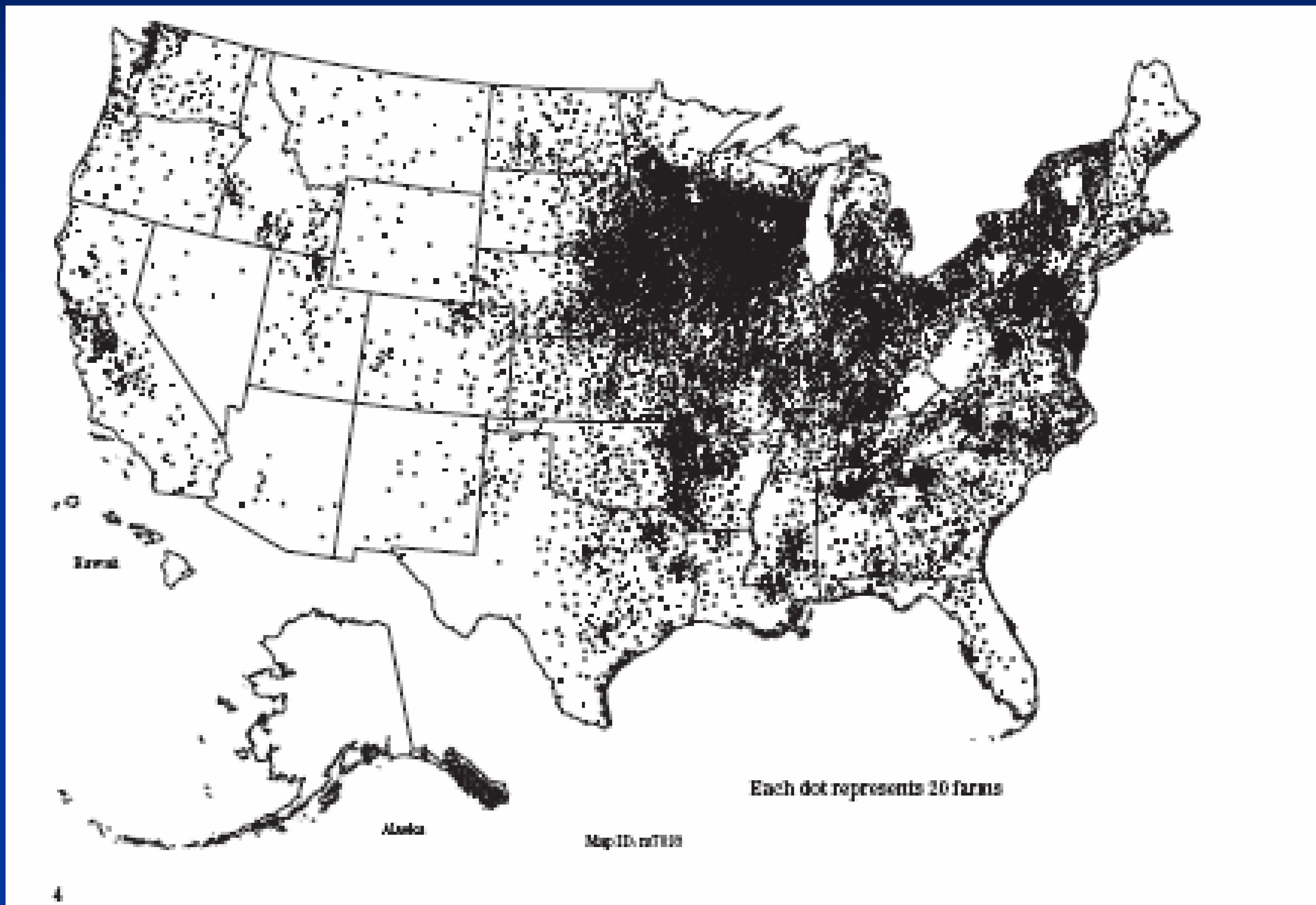
Biosolids from wastewater treatment

Food waste

Source: Biocycle, p. 51, August 2007

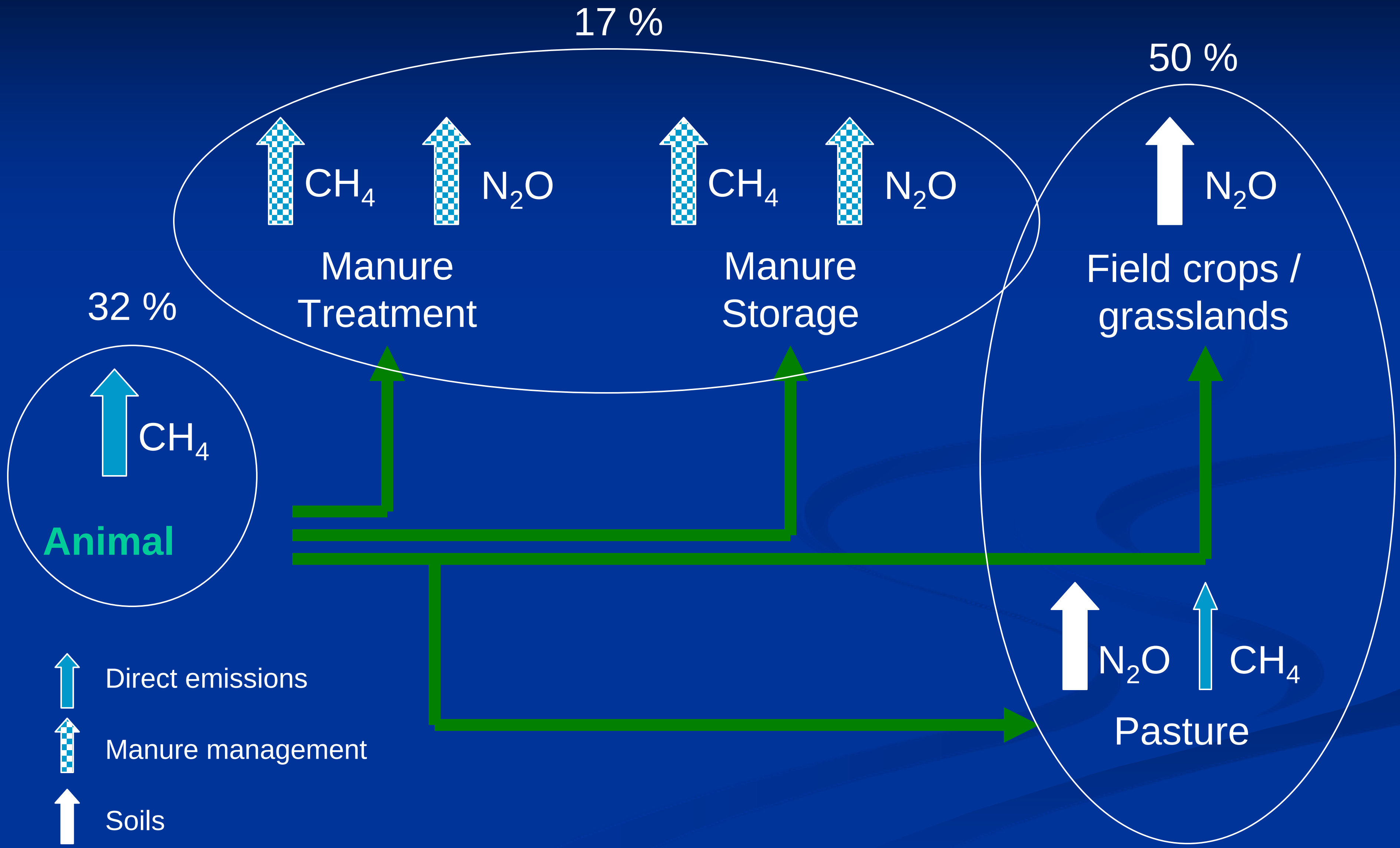
Confined Animal Feeding Operations (CAFOs)

Based on the 2003 Census of Agriculture, about 238,000 farms require implementation of CNMP(*) → > 500,000 tons of manure / year!



(*)CNMP: Comprehensive Nutrient Management Plans

Greenhouse gas generation from CAFOs:



GWP: CO_2: 1 CH_4: 21 N_2O: 310

Anaerobic Lagoons

Used by most CAFOs in the U.S.

Lagoons require careful design and management

Potential problems may arise from:

Undersized lagoons

Runoff and seepage to surface and ground waters

Instability from poor border management

Spread of disease from poor pest control

Vulnerability to severe weather conditions

Odor problems, GHG emissions

Saturation of soil

Pictures from USEPA

A better alternative: Anaerobic Digesters

Anaerobic digestion (AD):

→ Multistep process in which complex organic material is converted to simpler compounds without an external electron acceptor such as oxygen or nitrate

→ Present in many natural ecosystems; important in the biochemical cycle of organic matter

→ Old technology!

→ Applied since the end of 19th century for treatment of household waste –septic tanks, of sewage sludge in municipal wastewater treatment plants, and of industrial slurries

→ Major biological process involved in the stabilization of landfill waste

An anaerobic digester is a vessel designed to retain decomposing manure for sufficient time at the designed operating temperature to allow the growth of methanogenic bacteria in a “steady-state”.

Steps in anaerobic (oxygen-free) digestion:

Particulate and complex organics $\xrightarrow{\text{Hydrolysis}}$ Soluble simple organics

Soluble simple organics $\xrightarrow{\text{Acidogenesis}}$ Short organic acids

Short organic acids $\xrightarrow{\text{Methanogenesis}}$ CH_4 & CO_2

Biogas: 55 – 65% (CH_4) + 35 – 45% CO_2 + (N_2, NH_3, H_2S, H_2)

- 100% CH_4 = 994 BTU / ft^3

On-farm digesters could present several advantages over lagoons; sustainable operation of ADs could potentially provide:

1. Health protection:
   → Elimination of pathogenic and parasitic organisms
2. Environmental protection:
   → Reduction of GHGs and ammonia emissions to the atmosphere
   → Highest removal of COD –chemical oxygen demand
   → Better odor and fly control
   → Most weed seeds are destroyed

Energy Content of Biogas from Various Animals		
	Swine (per head)	Dairy (per head)
Animal weight (lbs)	135	1,400
Gas yield (ft^3 / head / day)	4.1	22.7
Gross Energy Content (BTU / head / day)	2,300	27,800
Net Energy Content (BTU / head / day)	1,500	18,000
Source: Barker, James C. 2001. Methane Fuel Gas from Livestock Wastes: A Summary. North Carolina State University Cooperative Extension Service, Publication #EBAE 071-80		

Challenges:

→ Stability

- Slow growth of microorganisms – start up could take 3-4 months
- High sensitivity of Methanogenic bacteria (pH, VFAs, temperature)
- Competing microorganisms – sulfate reduction vs. methanogenesis
- Toxicity – high concentration of ammonia

→ Economics

- Optimal size of digester will be specific for each CAFO
- Energy balance – temperature control
- Complexity of operation may increase capital and operational costs

→ Minimum supervision

- Instrumentation, control and automation

High performance anaerobic digesters are being developed to:

- Maximize production of biogas
- Increase CH_4 utilization efficiency → GHG mitigation
- Achieve higher quality biosolids (from Class B to Class A biosolids)
- Reduce amount of biosolids produced to conserve energy during dewatering and final trucking
- Reduce reactor size or increase its loading capacity
- Improve nutrient recovery
- Faster return of investment

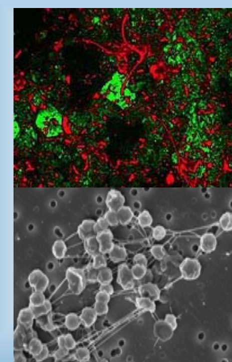
Streams

Gaseous Output

CH_4, CO_2, H_2S
H_2 , N_2O

Input

Organic Carbon (OC)
Organic Nitrogen (ON)
Organic Phosphorous (OP)
Organic Sulfur (OS)
Ammonia nitrogen (NH_4^+)
Sulfate (SO_4^{2-})
Phosphate (PO_4^{3-})

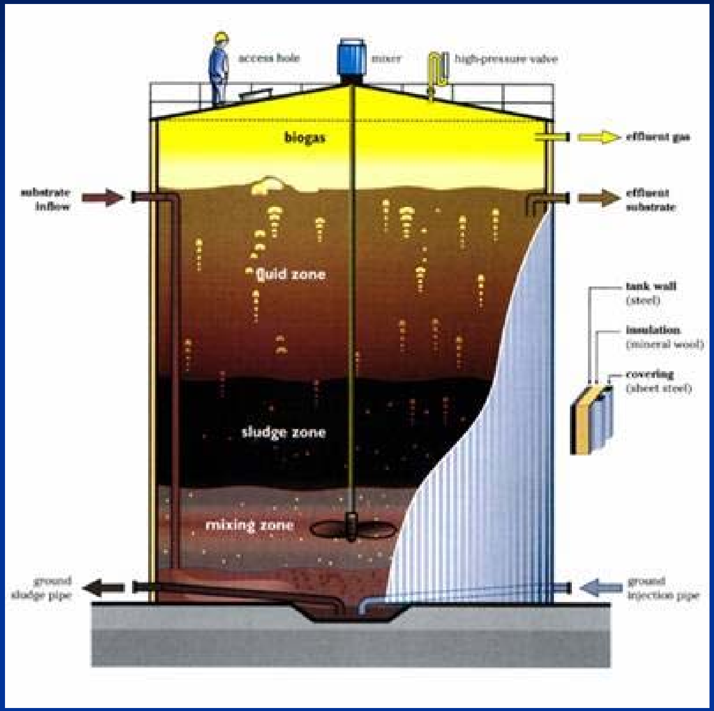


Liquid output

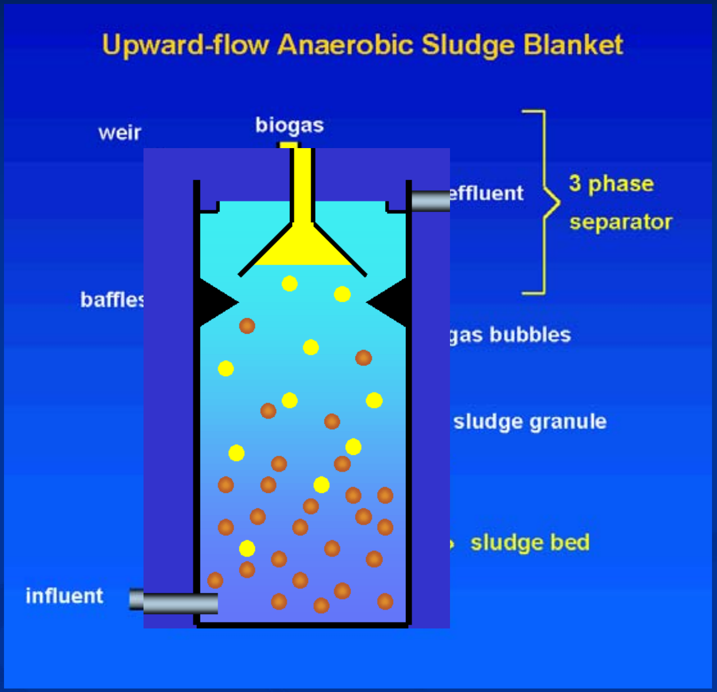
NH_4^+
PO_4^{3-}
OC_e
HS^- / H_2S_{diss}

Solids Output

Reactor configurations



CSTR



UASB

Covered lagoon

Basic Components