

Residuals Management Alternatives



MICHIGAN STATE
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BIOSYSTEMS
ENGINEERING

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Residuals From: Farms and Food Processors



Evolution of Residual Management

Some things are tough to throw away

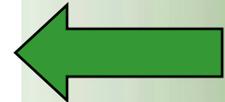


From: *Pollution Prevention: Fundamentals and Practice*, Bishop, 2000

Some things are tough to throw away



Some things are tough to throw away



Manure

Manure

Lactating Cow

150 lb/day

2.4 ft³/day

87% Water

- BOD₅: 2.9 lb/day
- BOD₅: 19,400 mg/L
- N: 0.99 lb/day
- P: 0.17 lb/day
- K: 0.23 lb/day
- Odor

(does not include bedding and dilution water)

ASAE D384.2 MAR2005, Manure Production Characteristics



Food Processing Residuals

Vegetable and Fruit Wastewater

- 3,000 to 5,000 mg/L COD
- > 1 M gal/day



Residual Treatment

How much does it cost to treat a pound of COD/BOD ?



Residual to Energy

**How much is a pound
of COD/BOD worth?**

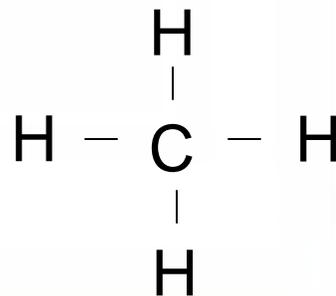


Residuals to Energy

What does carbon look like in manure and food processing residuals?

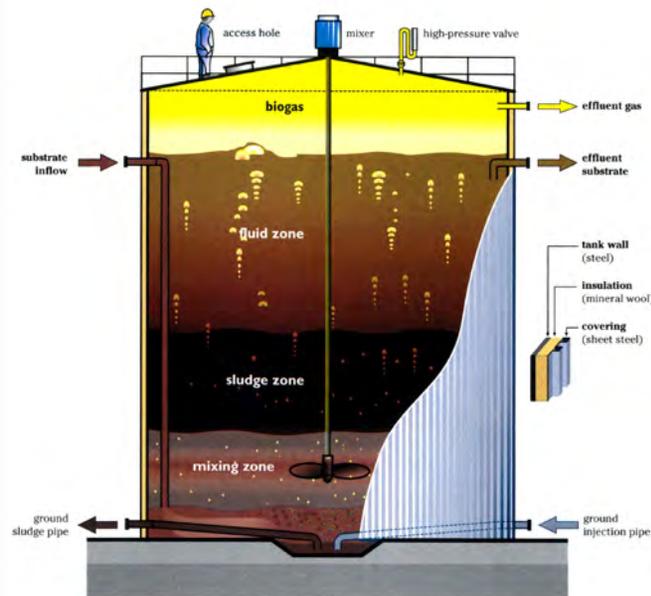


What does carbon look like in natural gas?

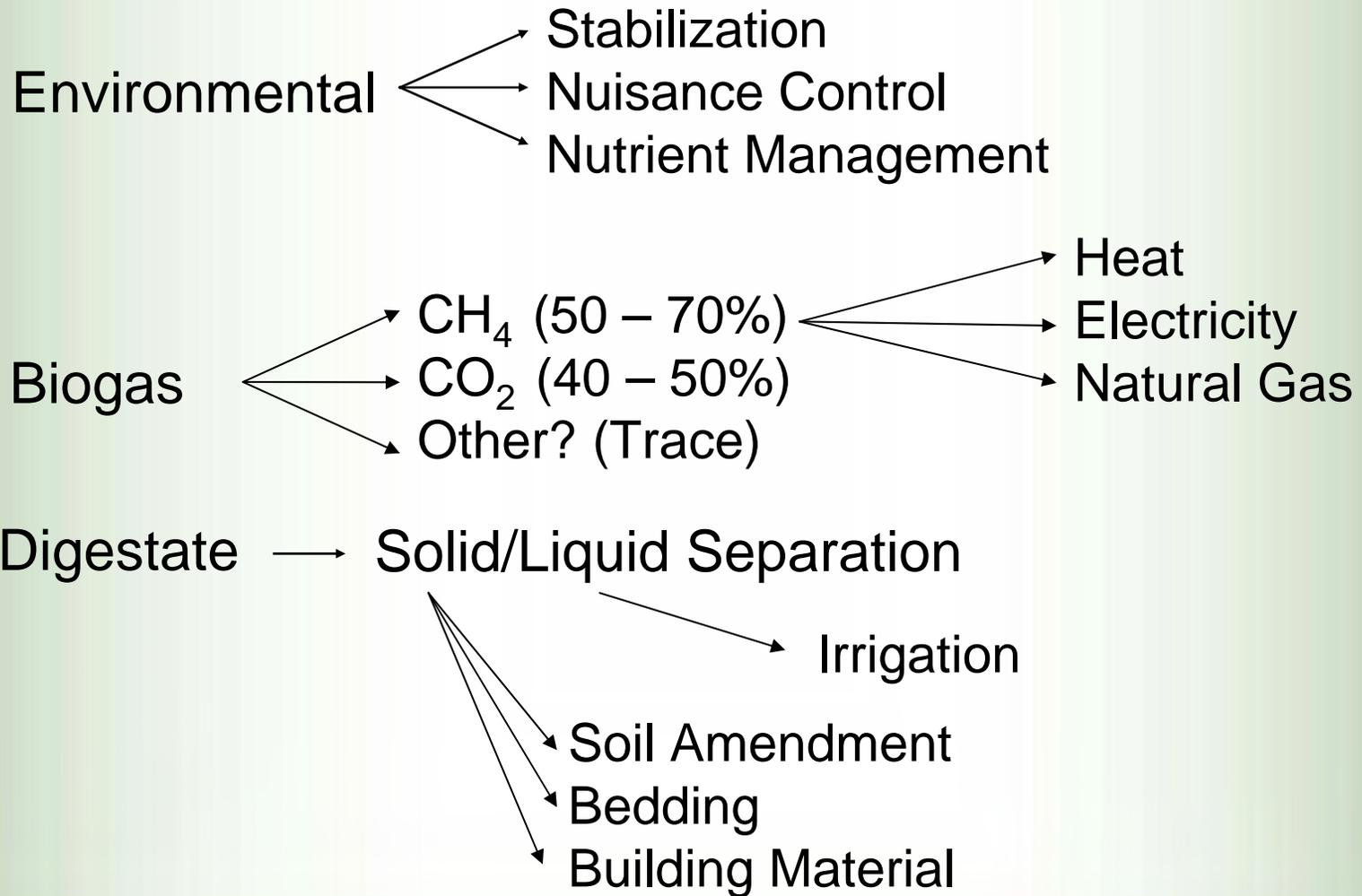


Digestion

Anaerobic Digestion: multiple microbial communities metabolize organic waste and produce biogas that is up to 70% methane



Potential Digestion Revenues



What is Biogas Worth?

For a 1400 lb dairy cow

46 ft³ total biogas/day/dairy cow

600 Net BTU/ft³ of biogas⁺

1.1 Net kW-hour/day/dairy cow⁺

18,000 Net BTU/day/dairy cow⁺



Scenic View Dairy Generator

The manure from 7 cows can power the typical house

⁺accounts for the ~35% of energy produced needs to be used to operate the digester

Alternative Fuels Project Team, MDA/MDEQ, March 2007

Anaerobic Digestion of Animal Waste: Factors to Consider, Balsam, ATTRA Pub. IP219

What is Biogas Worth?

Agricultural Methane Emission Offset

- 1 metric ton of CH₄ combusted offsets 18.25 metric tons of CO₂
- 4 - 5 metric tons /cow/year
- 1 metric ton = 1 credit

Chicago Climate
Exchange

<http://www.chicagoclimatexchange.com/market/data/summary.jsf>



How Much Does Digestion Cost?

Initial Cost: \$150 - \$500 /dairy cow*

Maintenance: \$11,000 - \$51,000*

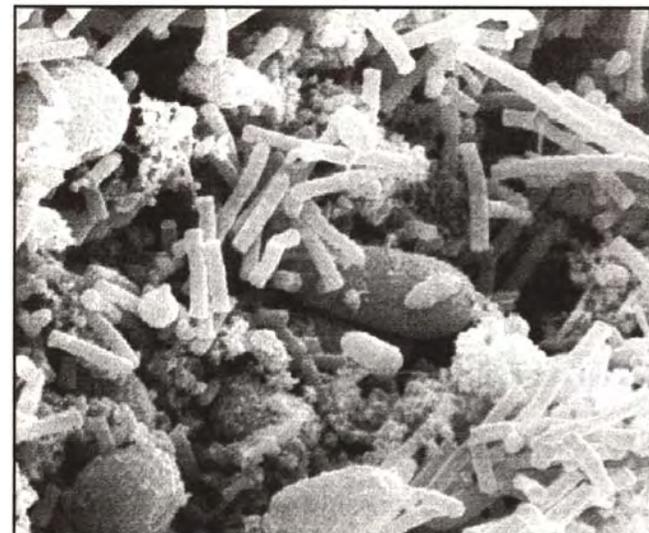
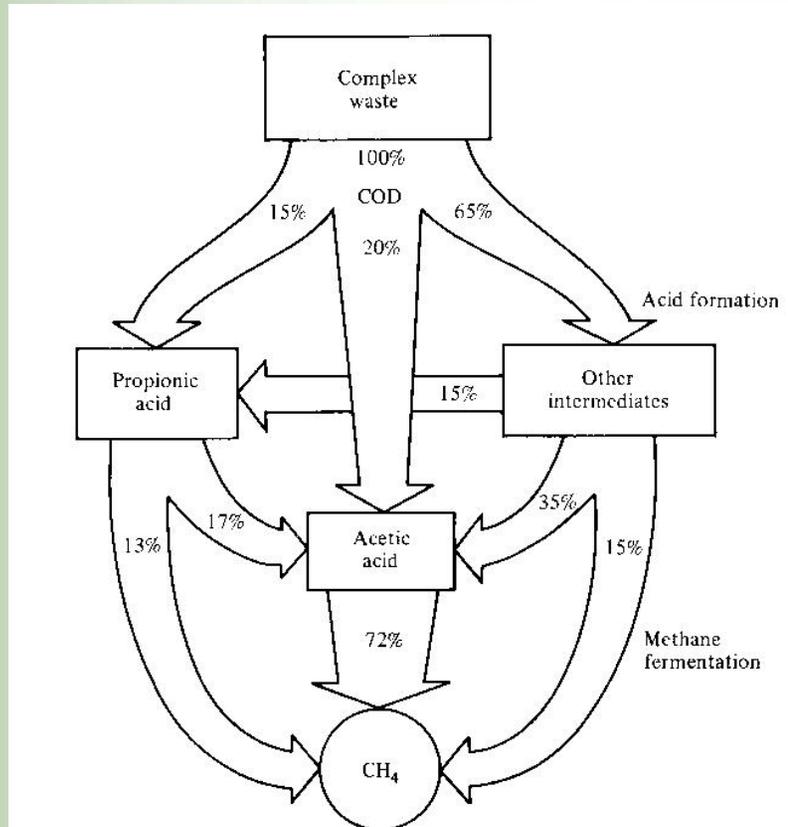
Payback: 3 – 7 years**



*USEPA AgStar Website

**Anaerobic Digestion of Animal Waste: Factors to Consider, Balsam,
ATTRRA Pub. IP219

Digestion is Complex



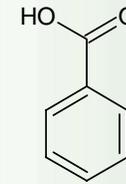
Magnified view of bacteria in the anaerobic reactor.

Biogas Energy Systems A Great Lakes Casebook, Great Lakes Regional Energy Program. Cliburn & Associates, 1994

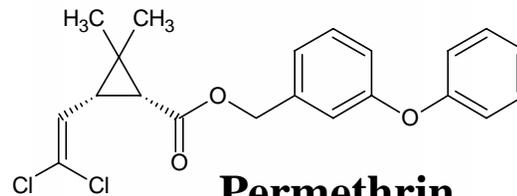
Environmental Engineering,
Peavy/Rowe/Tchobanoglous

Digestion is Complex

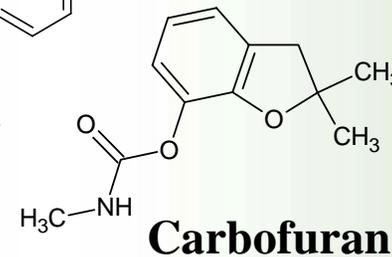
- No Oxygen
- Elevated Temperature
- Hydraulic Retention Time
- Nutrients
- C:N:P
- Buffering
- No Toxicity



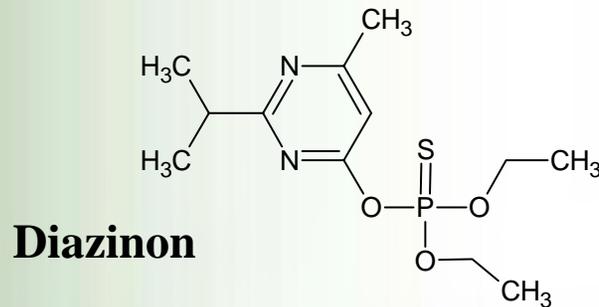
Benzoic Acid



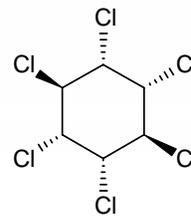
Permethrin



Carbofuran



Diazinon



Lindane

Optimization

Manure

Manure

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150 lb/day

2.4 ft³/day

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— BOD₅: 2.9 lb/day

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Odor

(does not include bedding and dilution w

ASAE D384.2 MAR2005, Manure Production Cha



Food Processing Residuals

Vegetable and Fruit Wastewater

• 1,000 to 5,000 mg/L COD

• > 4% Sol/day



C:N:P
100/4.3/0.9*

*Bouallagui, H., O. Haouari, Y. Touhami, R. Ben Cheikh, L. Marouani, and M. Hamdi. 2004. Effect of Temperature on the Performance of an Anaerobic Tubular Reactor Treating Fruit and Vegetable Waste. *Process Biochemistry* 39(12): 2143-2178.

Waste to Resource



Generating Research and
Extension to
meet Economic and
Environmental Needs

Alternative for Food Processor's Wastewater

Anaerobic Digestion Feasibility for Agricultural Residuals

<http://www.egr.msu.edu/~safferma/Research/Green/green.html>

Protocol

Is anaerobic digestion worth further exploration to meet facility specific objectives?

1. Determine Processor's Objectives
2. Profile Plant
3. Screen Wastewater
4. Predict Best Theoretical Potential
5. Conduct Laboratory Experimentation
6. Interpret Results
7. Make Recommendations



Protocol- Screening

3. Screen Wastewater

- pH
- Total Solids
- Volatile Solids
- Alkalinity
- COD (soluble)
- Total Phosphorus
- Total Nitrogen
- Organic N
- Inorganic N
- Ammonia
- Sulfide
- Sulfate
- Potassium

Without Optimal Conditions

- Unstable Digestion
- Inconsistent Biogas Production
- Low Methane Production
- Dirty Biogas

Protocol Theoretical Potential

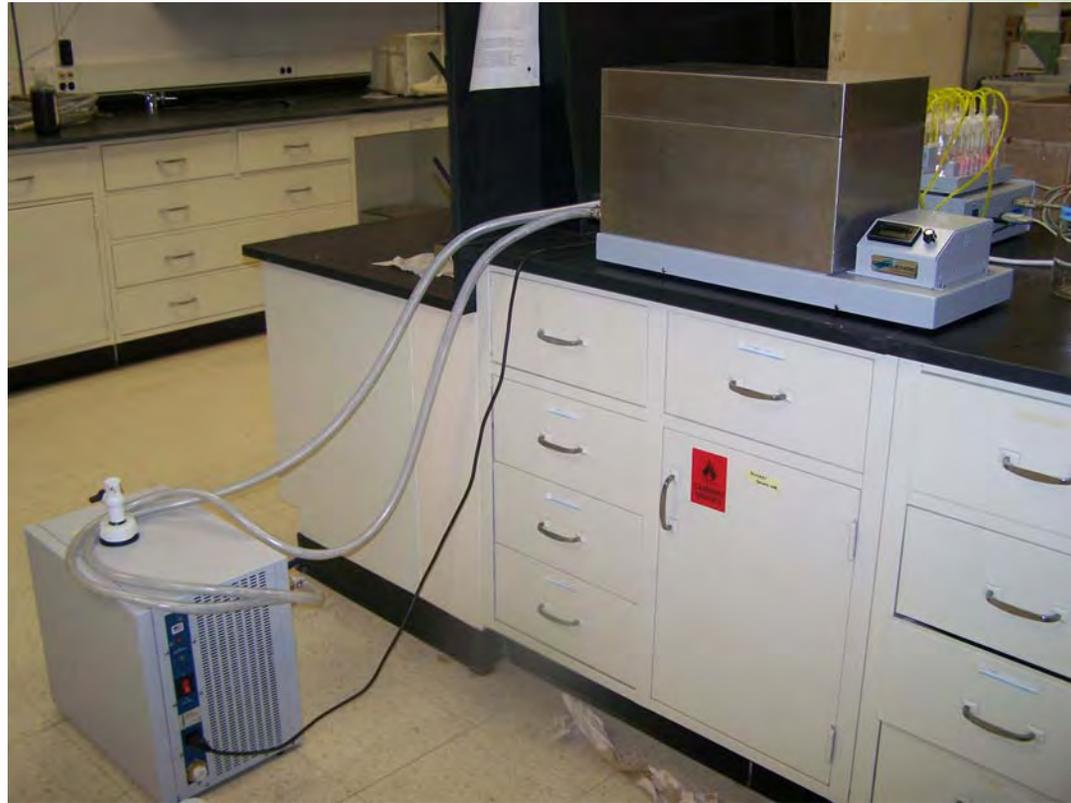
4. Predict Best Theoretical Potential

1000 mg COD = 395 mL CH₄ at 35°C

Is it worth it?

Protocol - Experimentation

Anaerobic Respirometry



Real Time, Continuous Gas Measurement

- Total volume
- Rate (ml/hr)

Protocol - Experimentation



Protocol - Experimentation

Seed - Acclimated Source

Feedstock

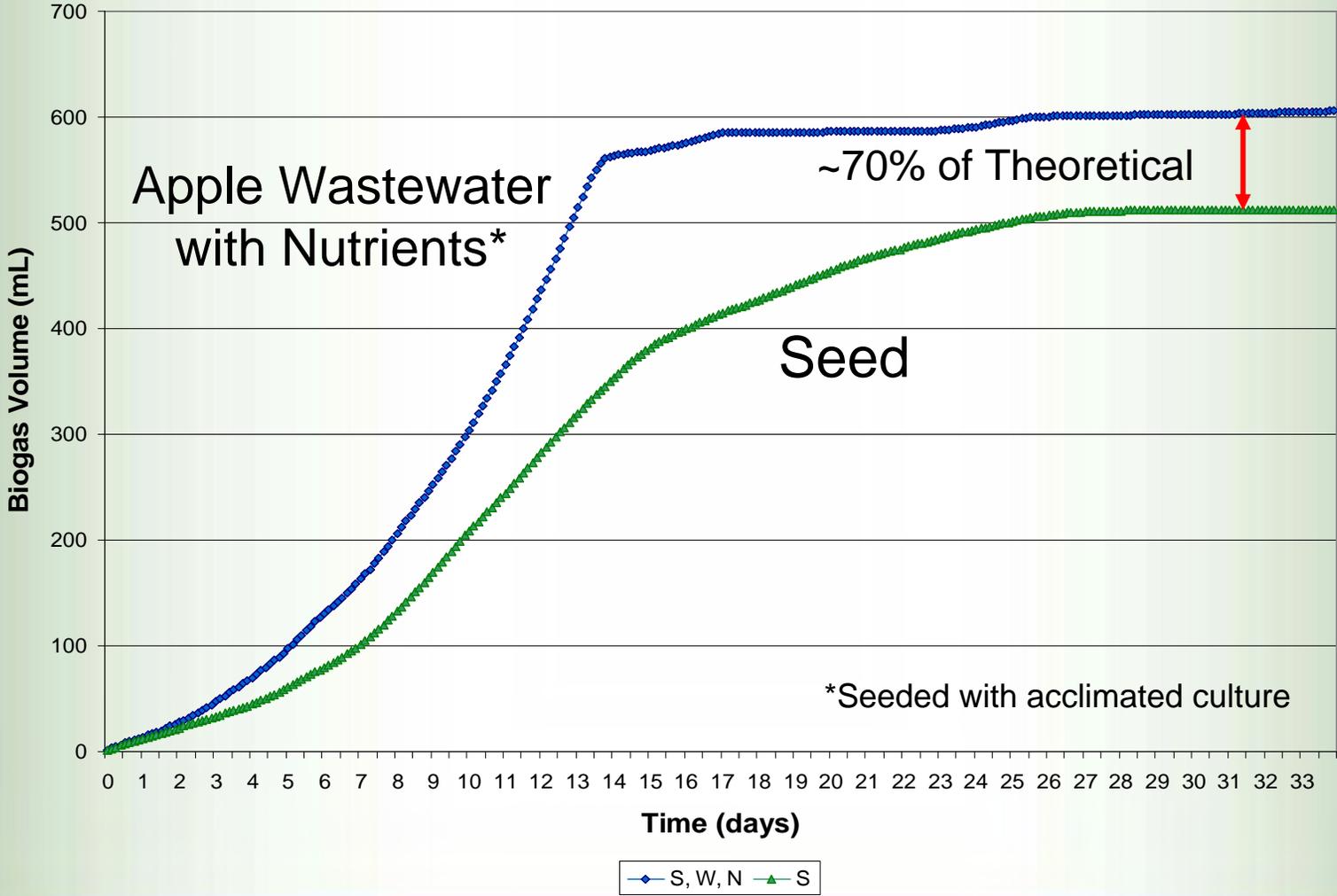
- Wastewater
- Solids
- Manure
- Municipal

Nutrient Solution

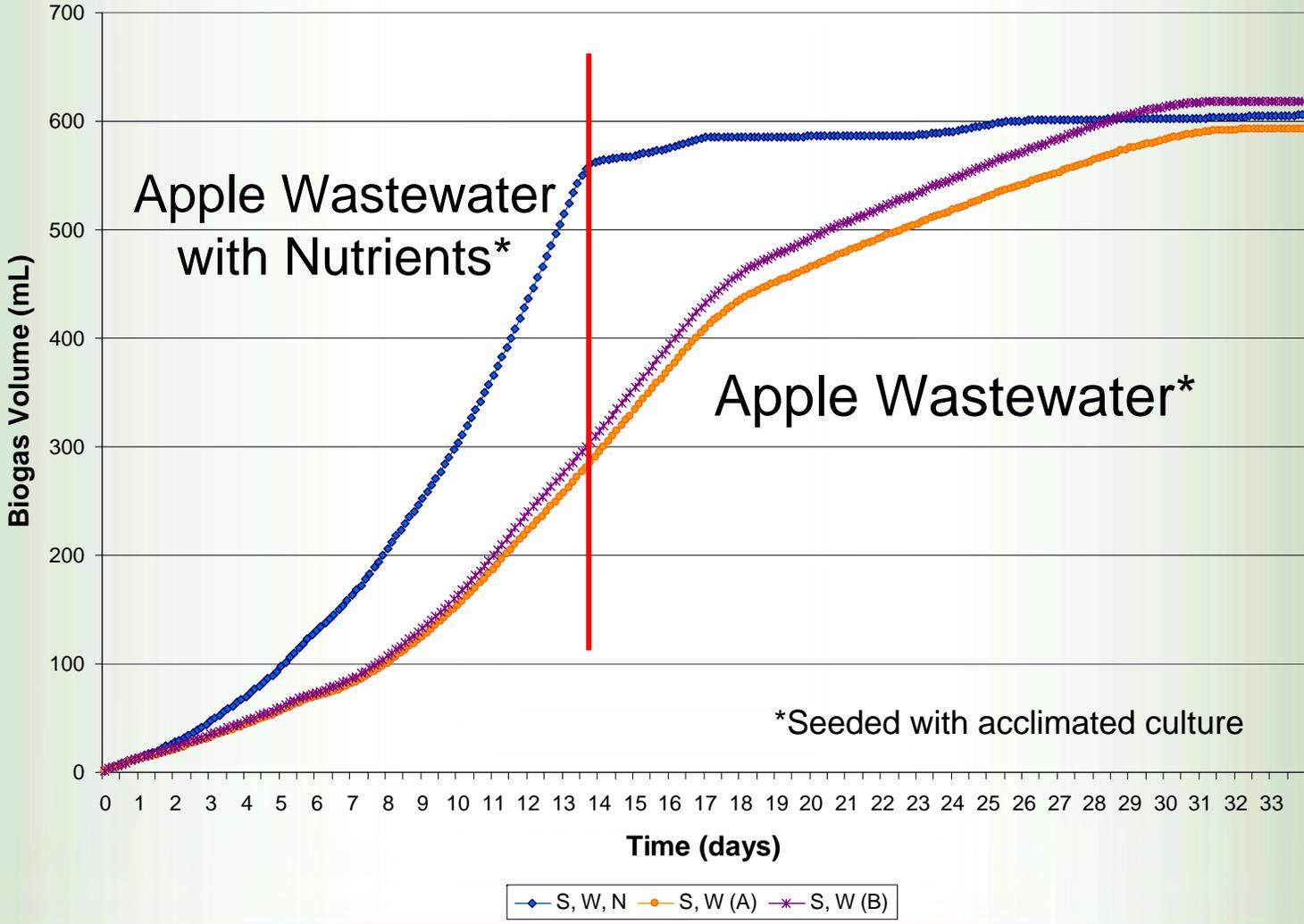
- K_2HPO_4
- NH_4Cl
- $CaCl_2 \cdot 2H_2O$
- $MgCl_2 \cdot 6H_2O$
- $FeCl_2 \cdot 4H_2O$
- $MnCl_2 \cdot 4H_2O$
- H_3BO_3
- $ZnCl_2$
- $CuCl_2$
- $Na_2MoO_4 \cdot 2H_2O$
- $CoCl_2 \cdot 6H_2O$
- $NiCl_2 \cdot 6H_2O$
- Na_2SeO
- $NaHCO_3$

Shelton, D. R. and J. M. Tiedje. 1984. General Method for Determining Anaerobic Biodegradation Potential. *Applied Environ. Microbiol.* 47(4): 850-857.

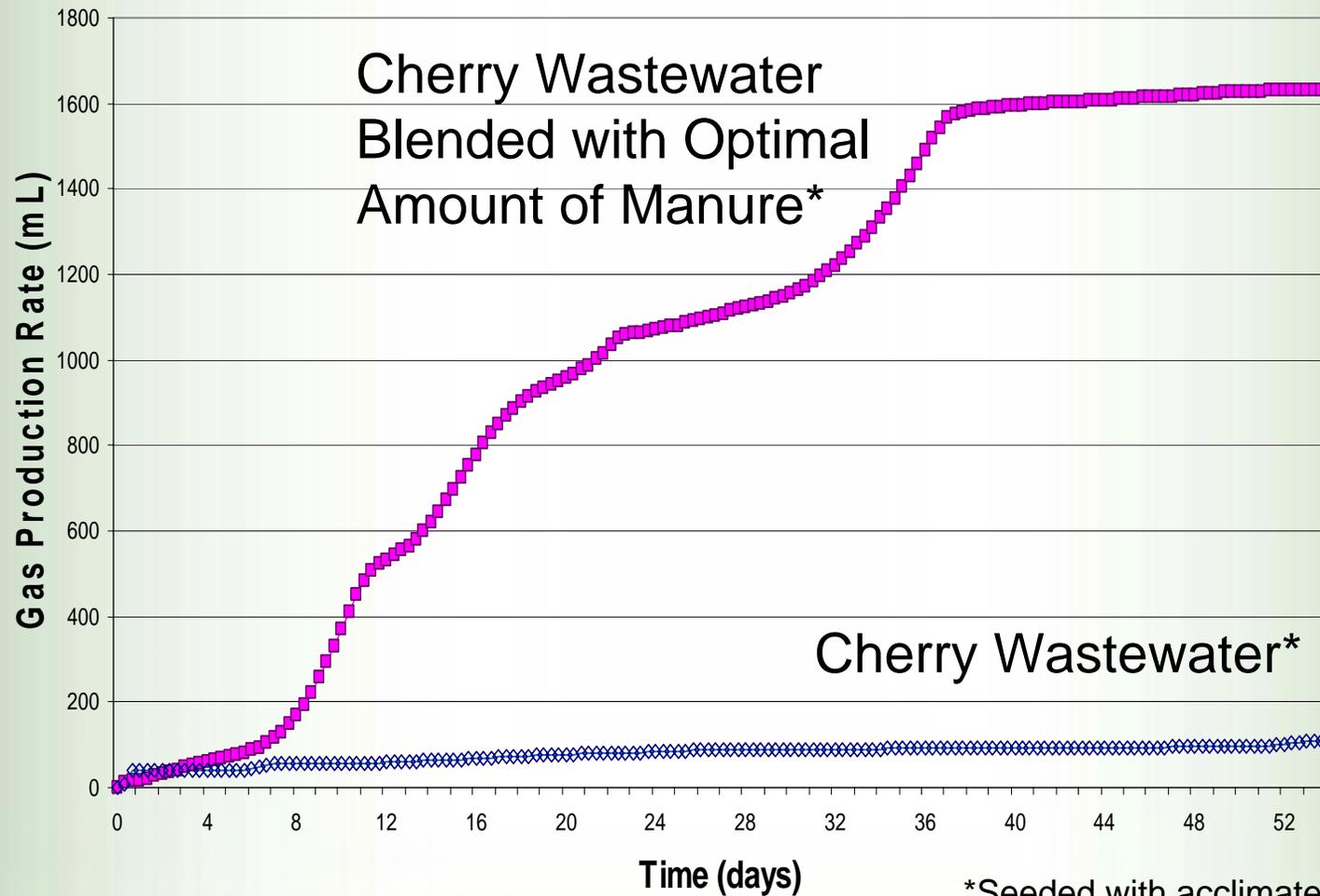
Biogas Potential



Biogas Potential



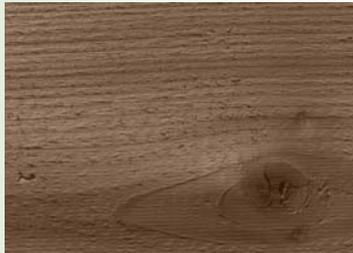
Biogas Potential



*Seeded with acclimated culture

The Future ?

Farm as a Rural Center of Production?
Centralized Digesters?



Agricultural Products – Electricity – Heat - Fiber