Van C. Kelley
South Dakota State University

Anaerobic Digester Basics

Concept is Old and Simple

Alligators have warmed nests with anaerobic digestion for millions of years

Early Science

- 1776 - direct correlation between the amount of decaying organic matter and the amount of flammable gas produced
- 1808 - methane could be produced with cattle manure
- 1895 – Biogas street lamps in England
- 1930 – anaerobic bacteria were identified

Anaerobic Digestion in USA

- Livestock manure is common feedstock

Digestion Process

$$C_6H_{12}O_6 \rightarrow 3CO_2 + 3CH_4$$

Carbohydrates → Fizz in pop + Methane

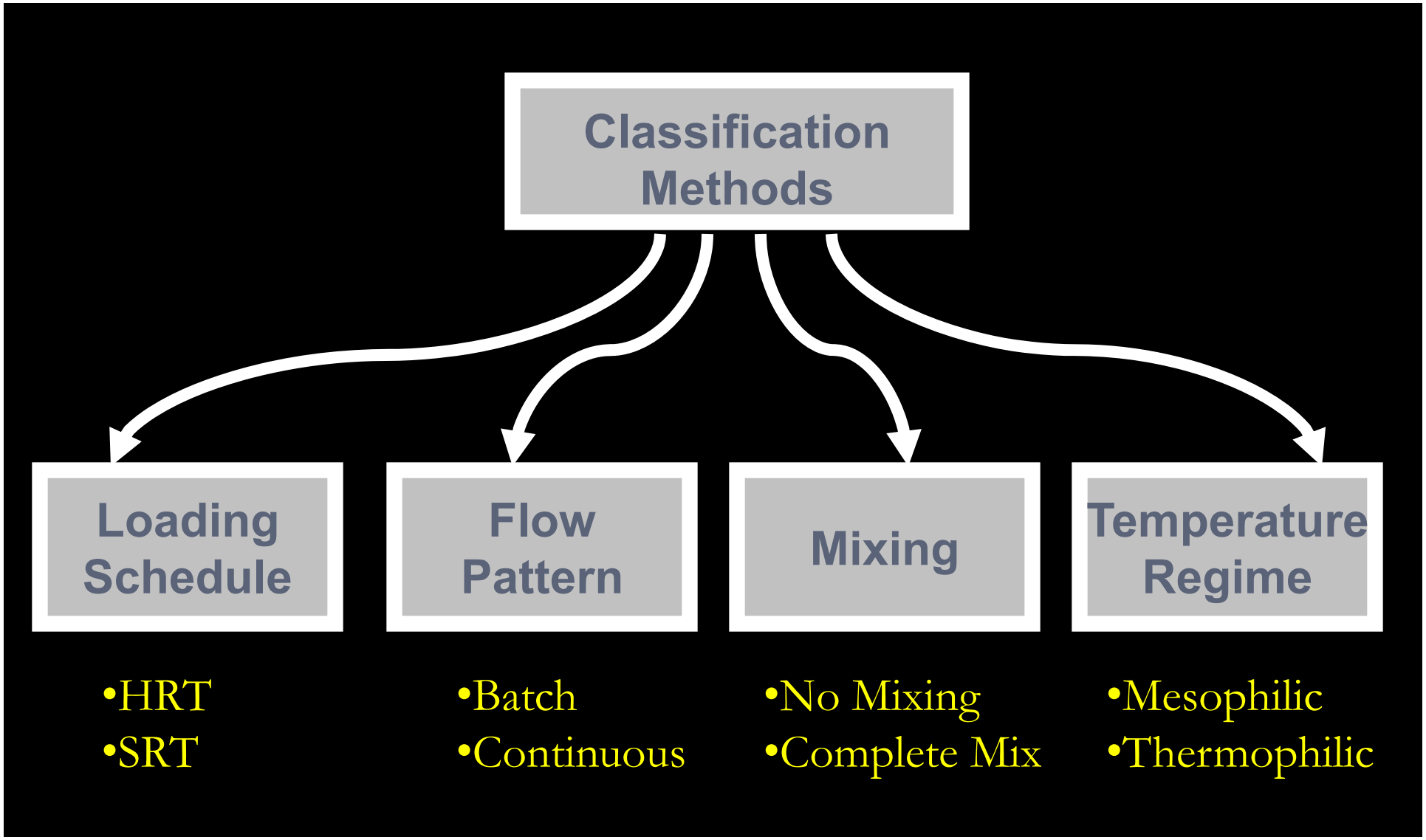
Major plant nutrients are <u>not</u> involved

- N – Nitrogen
- P – Phosphorus
- K – Potassium

Bio-gas Contents

- Methane (60-70%)
- Carbon dioxide (30-40%)
- Various toxic gases, including hydrogen sulfide, ammonia, and mercaptans
- 1-2% water vapor

Many Types of Anaerobic Digesters



Why So Many Types?

ft^3 of methane / day
for
1 Digester ft^3

18% < 0.5 ft^3 / day
7% > 1.1 ft^3 / day

Anaerobic Digester Configurations

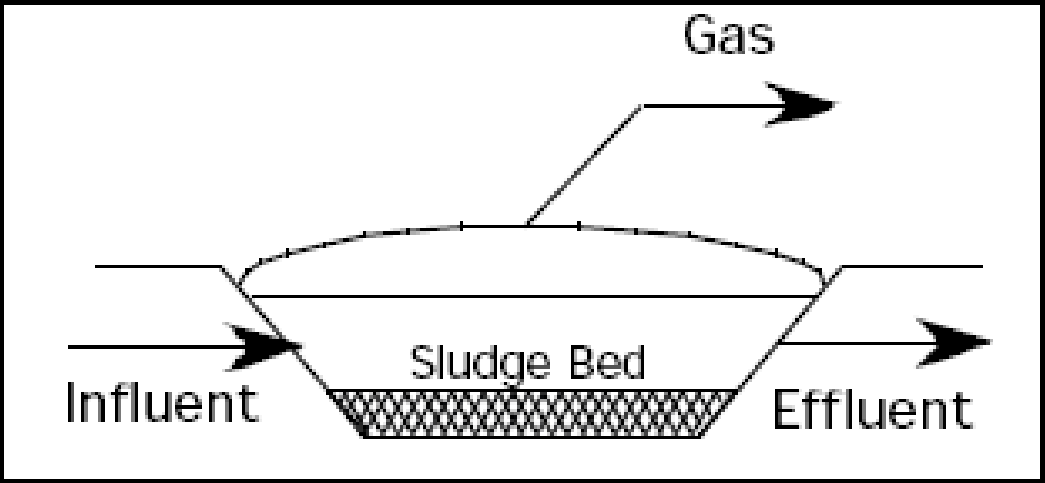
- Covered Lagoons (ambient & heated)
- Complete Mixed Digesters (CSTR)
- Plug Flow Digesters
- Anaerobic Sequencing Batch Reactors (ASBR)
- Fixed Film Digesters (anaerobic filters)

Flexible Cover on Lagoon

- Lowest gas production
- Least “controlled” system
- Longest HRT

Covered Lagoon

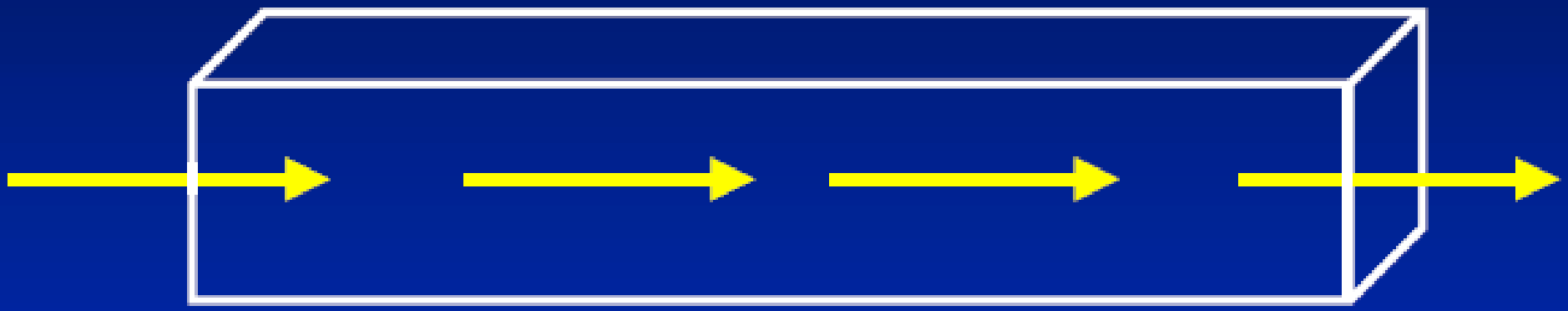
- Advantages
  - Low Cost (relatively)
  - Low Tech
  - Easy to Construct



- Disadvantages
  - Cover Maintenance – Life
  - Large Footprint
  - Solids / Nutrient Accumulation


Plug Flow Digesters
NRCS Code 366 AD Controlled Temperature

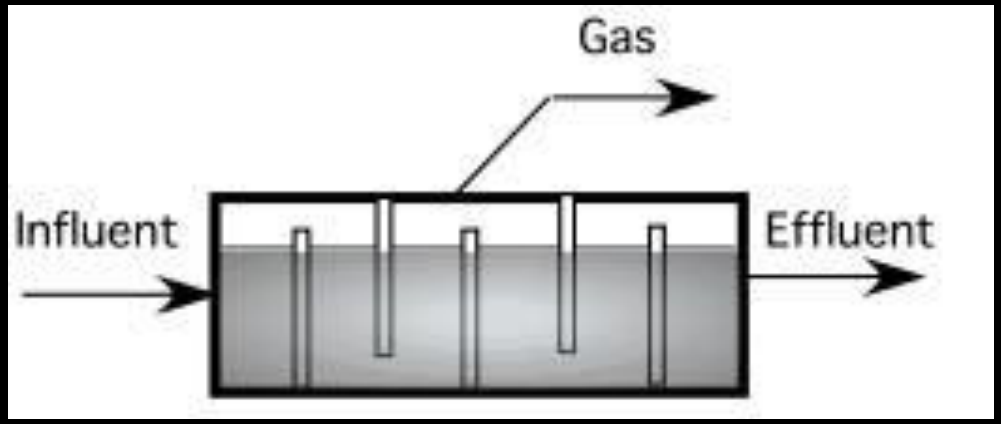
Plug-Flow Digester



No Mixing

Plug Flow Digester

- Horizontal tank
- Adding material forces tank contents to move through the tank and be digested.



Plug Flow Reactor

- Rectangular pit (typically concrete)
- Manure flows from one end to other
- Heated
- Mesophilic or thermophilic
- 15-30 day HRT
- Requires high solids (>11%)

Plug Flow Reactor

- Advantages
  - Good track record with dairy manure
  - Works well with scrape systems
- Disadvantages
  - Requires high solids manure (11 - 14 %)
  - Not compatible with sand bedding

Midwest Dairy Institute
Milbank SD

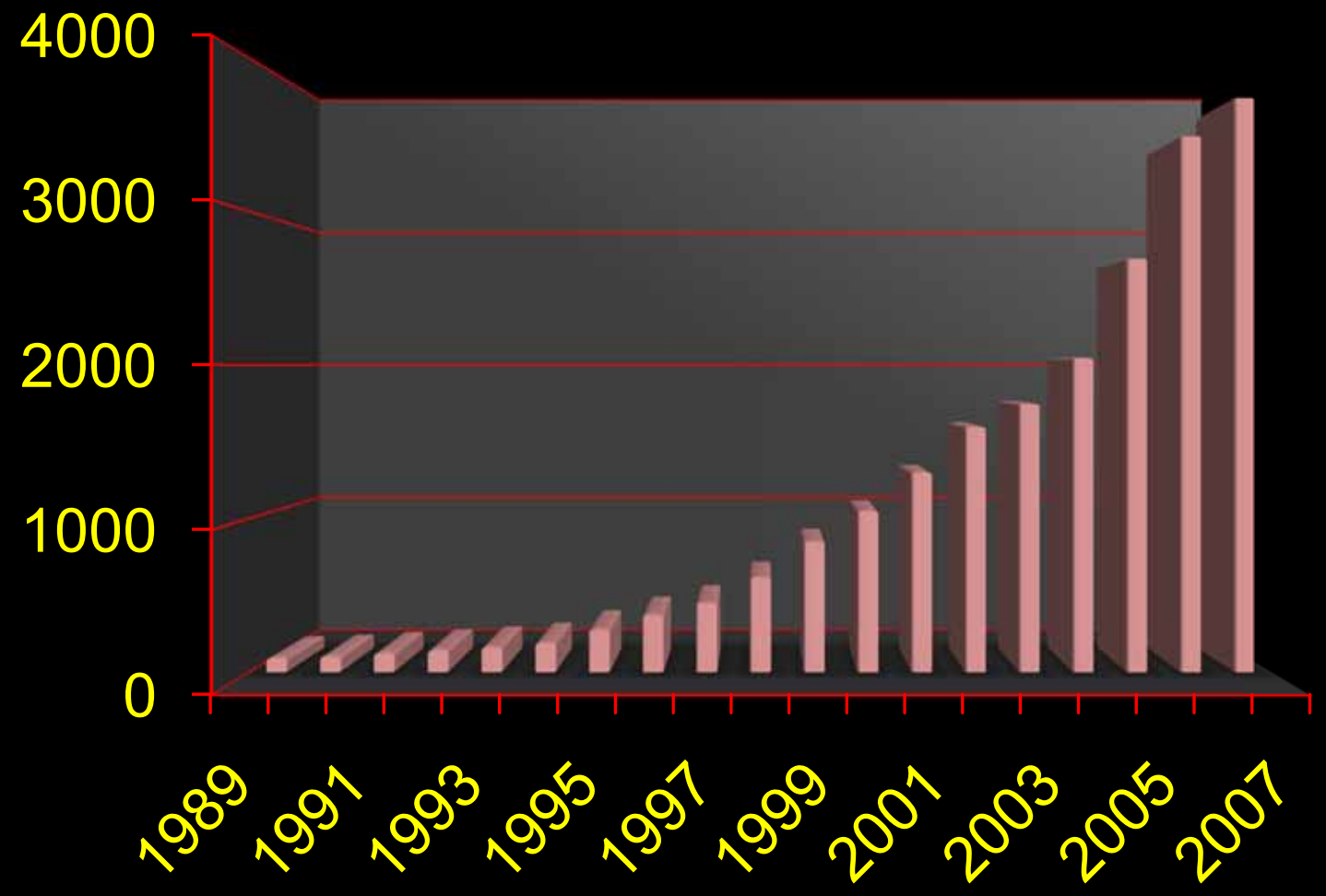
- 1.2 Million gallon digester
  - 20 feet deep
  - 85 feet wide
  - 163 feet long
- Cost: $5,800,000

Midwest Dairy Institute
Milbank SD

- 1,400 Cows
- 375 kW from Caterpillar engine
- Hot water for in-floor heat
- Bedding worth $45,000/yr

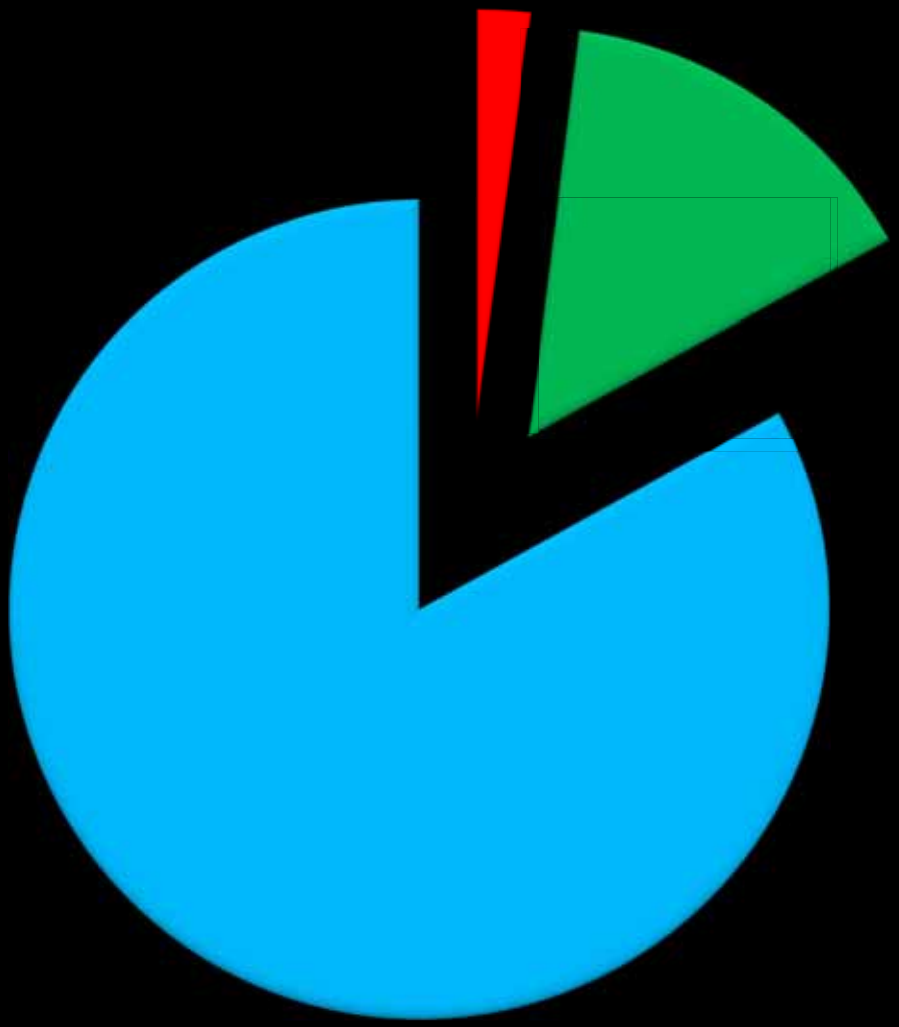
Anaerobic Digestion in Europe

Number of Anaerobic Digesters in Germany *



* von Thünen - Institut

Feedstock Used in German Digesters *



- Manure
- Energy Crops
- Energy Crops and Manure

* von Thünen - Institut

Anaerobic Digestion in Germany

- Most digesters also add corn silage

Anaerobic Digestion in Germany

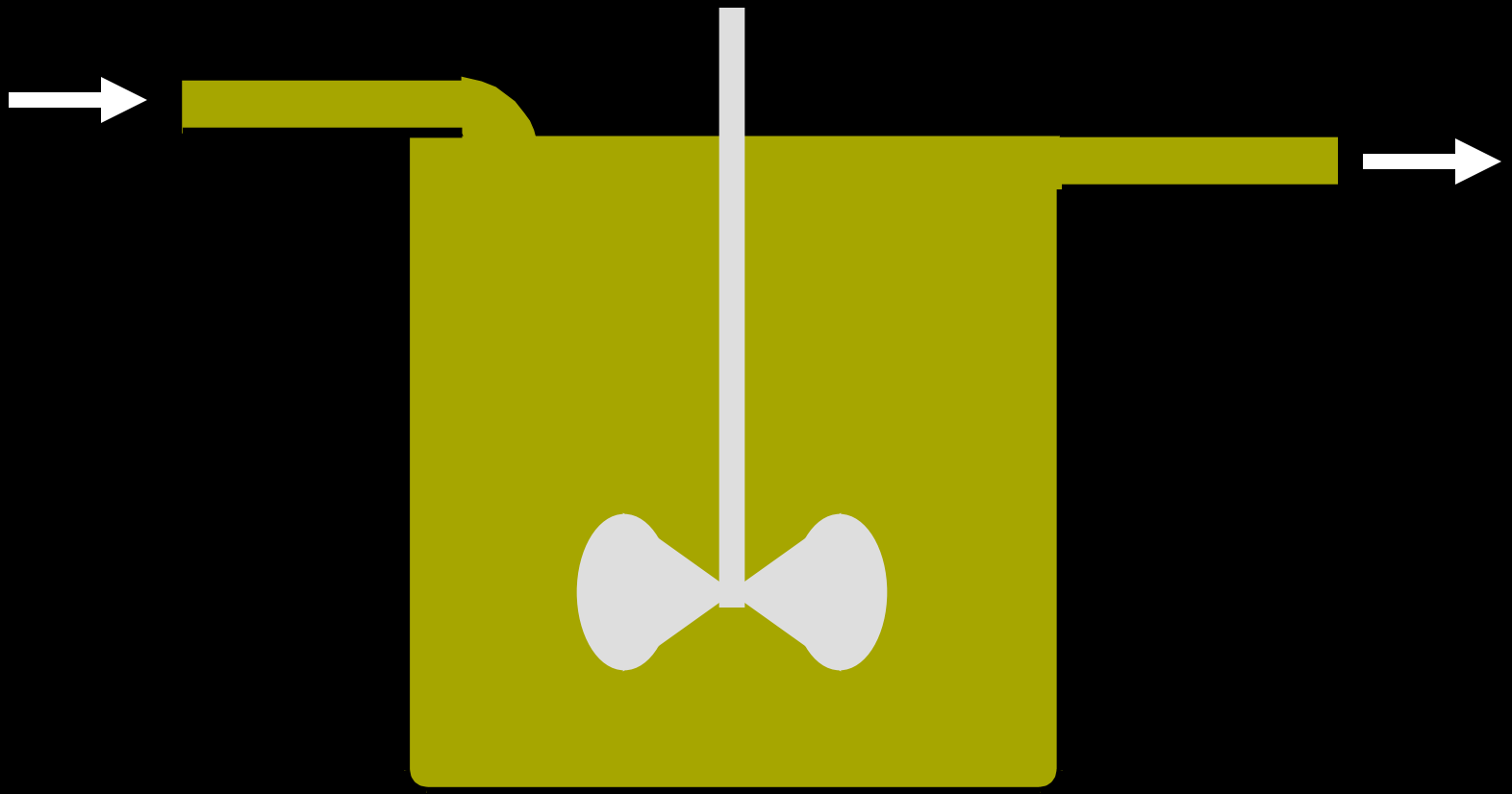
- Corn silage ready to enter the digester

Anaerobic Digestion in Germany

- Manure to be added to silage

Complete Mixed Digesters

- Complete Stirred Tank Reactors (CSTR)
- Completely Mixed Flow Reactors (CMF)
- Continuous Flow Stirred Tank (CFST)



Complete Mixed Digesters

Complete Mixed Digesters

Complete Mixed Digesters

Complete Mixed Digesters

Complete Mixed Digesters

- Covered Tank with Mixing
- Heated
- Mesophilic or Thermophilic Range
- 15-20 Day HRT
- 2-10% Solids Input

Complete Mixed Digesters

- Advantages
  - High level of experience
  - Works over wide range of influent Total Solids (TS)
    - Can be used with scrape or flush systems
    - Can be used with swine or dairy systems
- Disadvantages
  - Poor biomass immobilization (HRT=SRT)
  - Mechanical mixing requirement

Collection

Delivery to Digester Facility

Delivery to Digester Facility

Spent Digester Material (only silage)

Spent Digester Material

Spent Digester Material

Spent Digester Material

Gas Storage

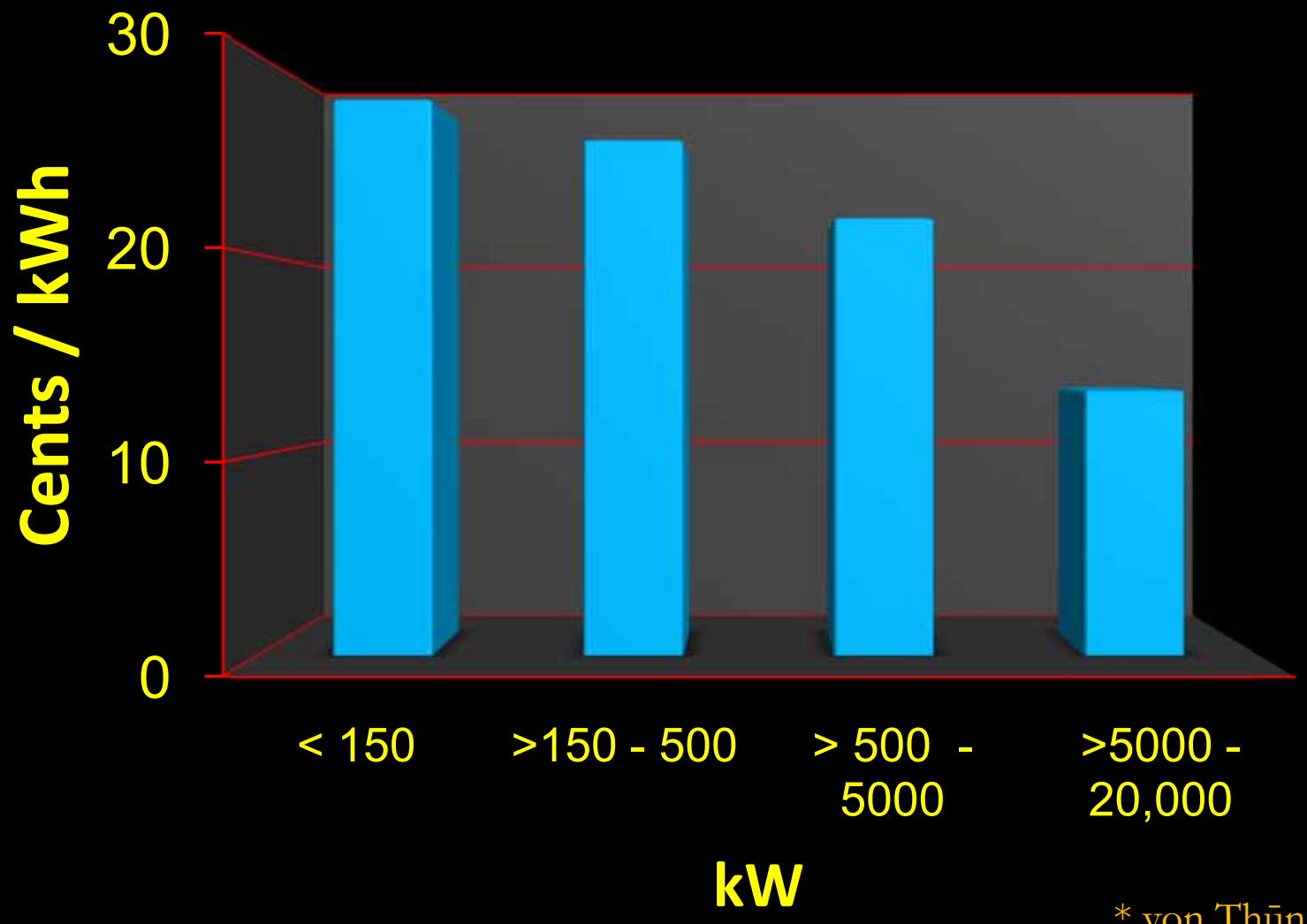
Gas Usage

Energy Conversion Note

- 20-40% efficiency in converting BTU's of methane to electricity with engine generator set.

Gas Usage

Compensation for Electricity Produced by Anaerobic Digesters in Germany *



* von Thünen - Institut

Rate Structure for Electricity Produced by Anaerobic Digesters in Germany *

150 to 500 kW Produced

12.5 ¢ = Basic rate
2.6 ¢ = Technology Bonus
2.6 ¢ = Combined Heat and Power Bonus
7.9 ¢ = Biomass Bonus

Rates vary for other size digesters
The bonus declines as size increases

* von Thünen - Institut

Potential Challenges to Success

- Lack of Well Develop Support Industry

Take-Home Message

- Proven technology
- Provides excellent odor control
- Might fit well into a total manure management system
- Can require significant system management