

BIOGAS AND ANAEROBIC DIGESTION: Fundamentals and Applications

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Global Climate Energy Program (GCEP)

Biomass Energy Workshop

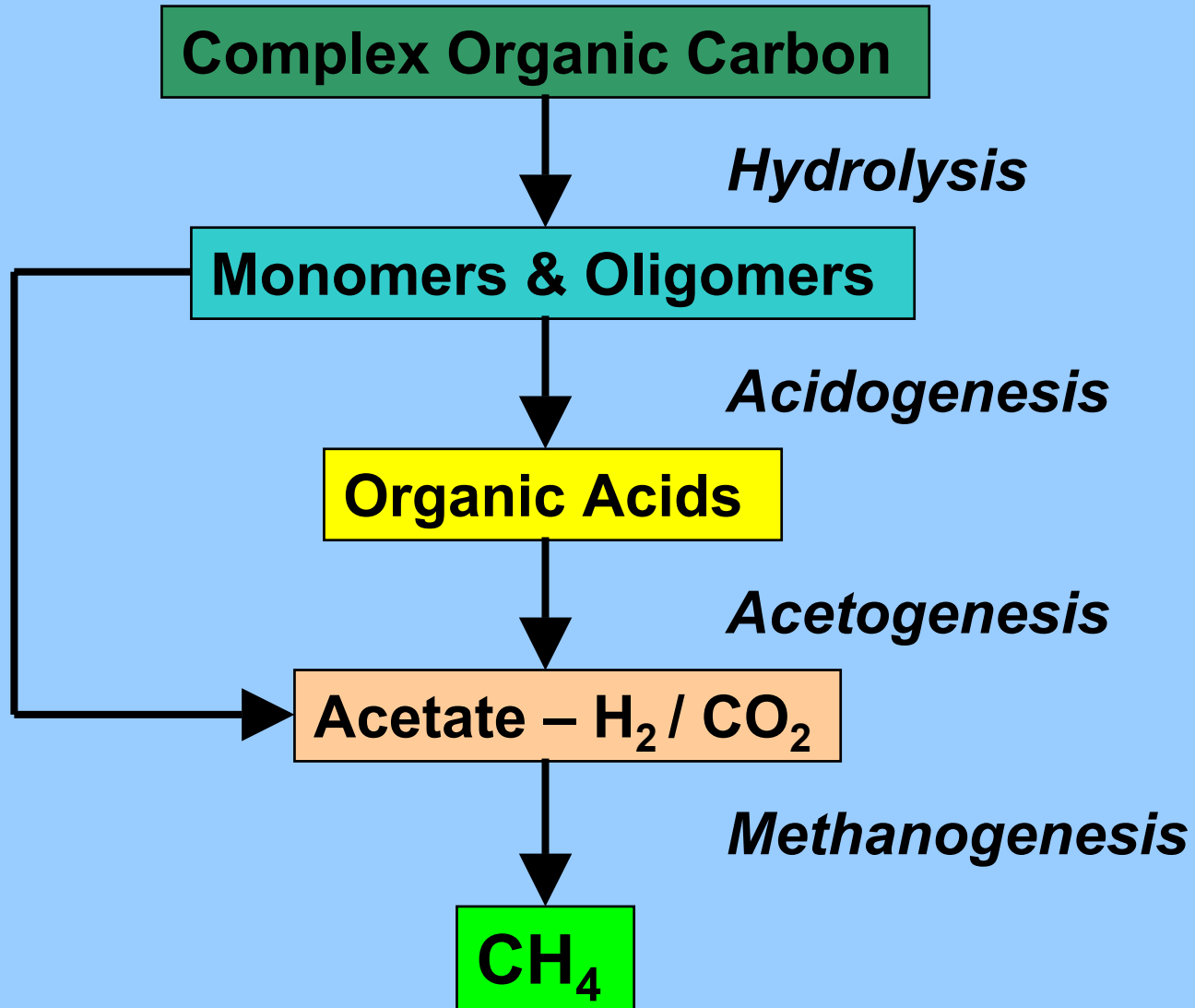
Stanford University

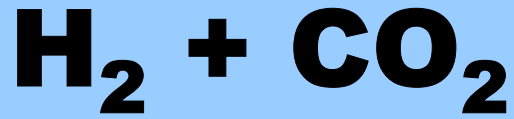
April 27, 2004



ANAEROBIC DIGESTION

- The microbial degradation of organic compounds, in the absence of oxygen, to biogas – a mixture of methane (50 to 70%), CO₂ (30 to 50%), and trace amounts of H₂, NH₃, and H₂S.





ACETATE

**Hydrogenotrophic
Methanogens
(30%)**

**Aceticlastic
Methanogens
(70%)**



ACETICLASTIC METHANOGENS

Two Mesophilic Genera:

(i) *Methanosarcina barkeri*

Methanosarcina mazei

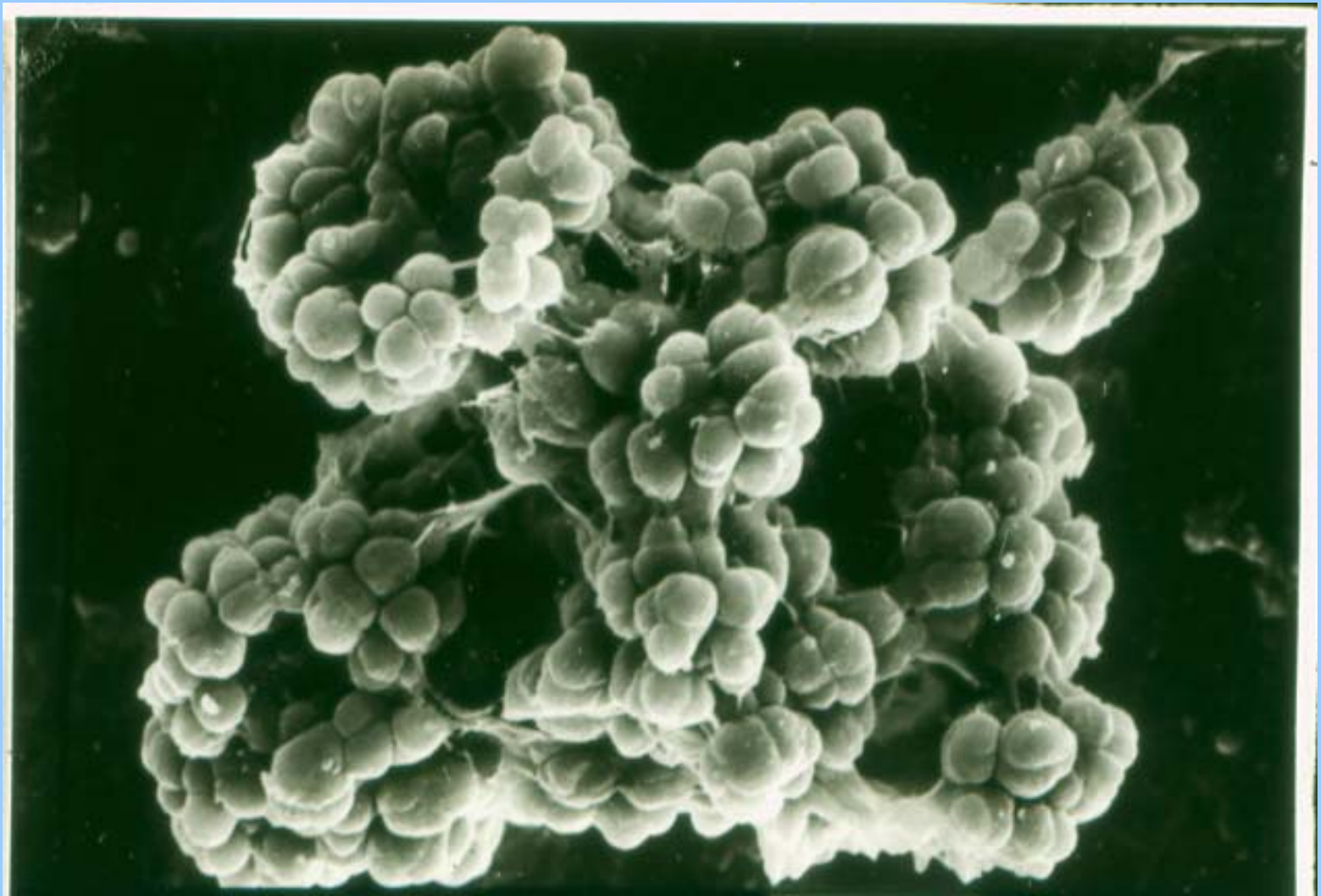
K_s : 3 – 5 mM Acetate

Doubling time: 24 hr

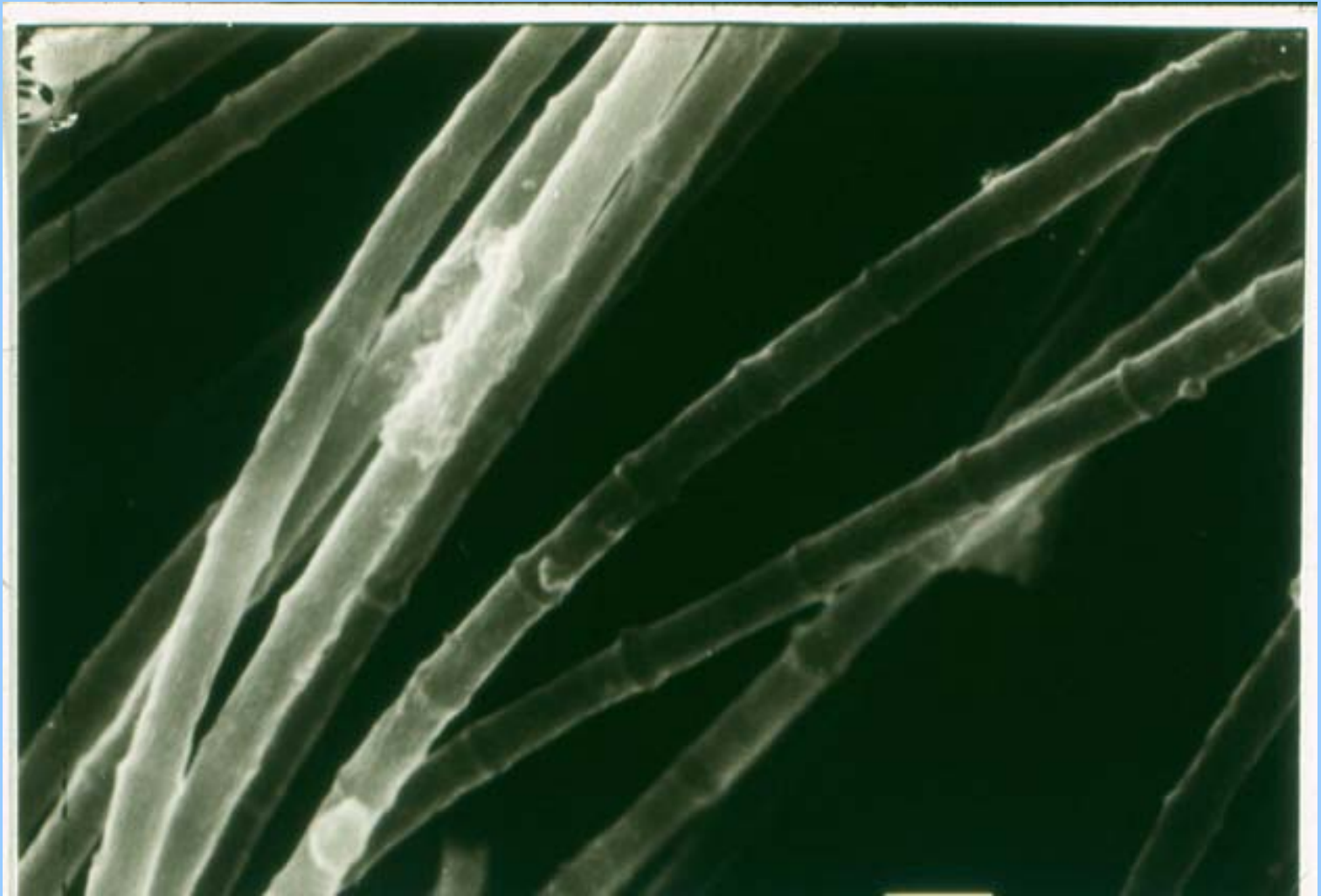
(ii) *Methanotherix soehngenii*

K_s : 0.5 mM Acetate

Doubling time: 4 to 9 days



Methanosarcina mazei



Methanotherrix soehngeni

**LIQUEFACTION
PHASE**

**GASIFICATION
PHASE**

**COMPLEX
ORGANIC
MATTER**

**SIMPLE
ORGANICS**

**ACETATE
 H_2 / CO_2**

ACIDOGENS

METHANOGENS

METHANE and CARBON DIOXIDE

LOW ODOR EFFLUENT

ADVANTAGES OF ANAEROBIC PROCESSES

- **Loadings not restricted by rate of oxygen transfer**
- **Not restricted by high cost of oxygen transfer**
- **Usable end product in the form of methane gas**
- **Less biological solids production per pound of BOD_R**
- **Less land area required due to smaller footprint**

POTENTIAL OF ANAEROBIC DIGESTION

- **Reduction of odor**
- **Production of biogas fuel**
- **Reduction of pollution**
- **Conserved fertilizer value**
- **Improved waste management and hygiene**



FEEDSTOCKS

- **Municipal wastewaters**
- **Industrial wastewaters**
- **Animal manures**
- **Municipal solid wastes**
- **Energy crops / crop residues**



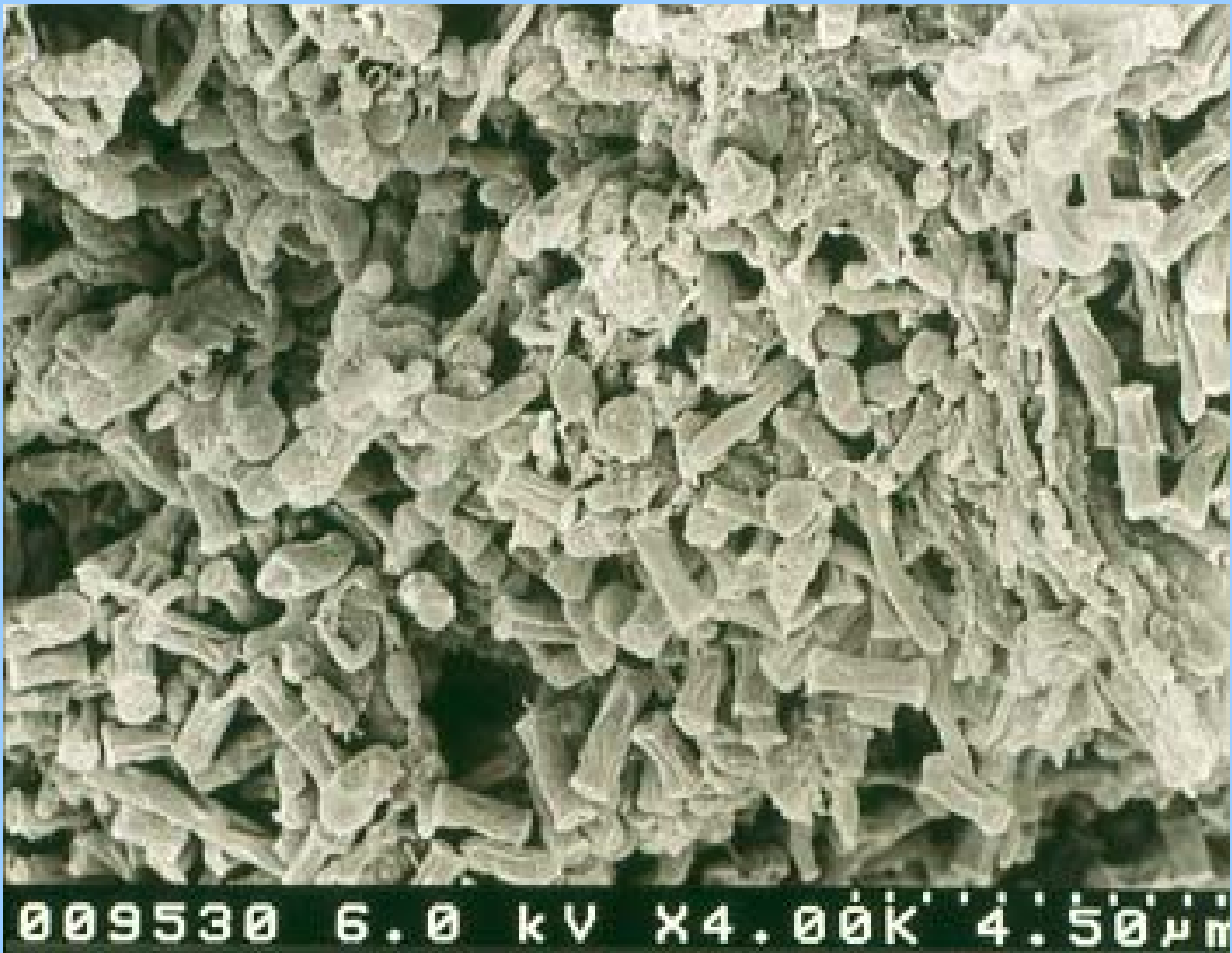






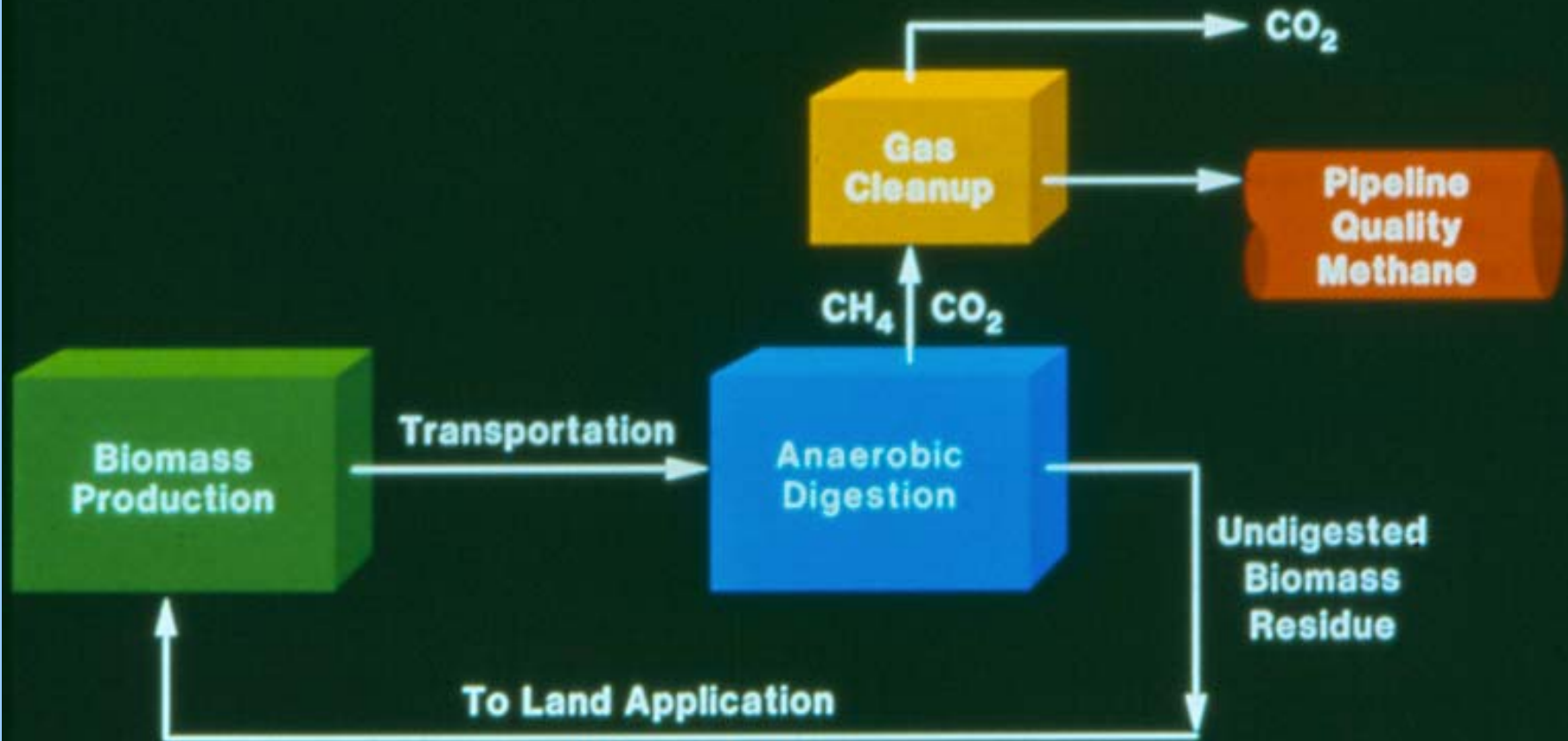
Fixed-film Anaerobic Digester

100,000 gals.

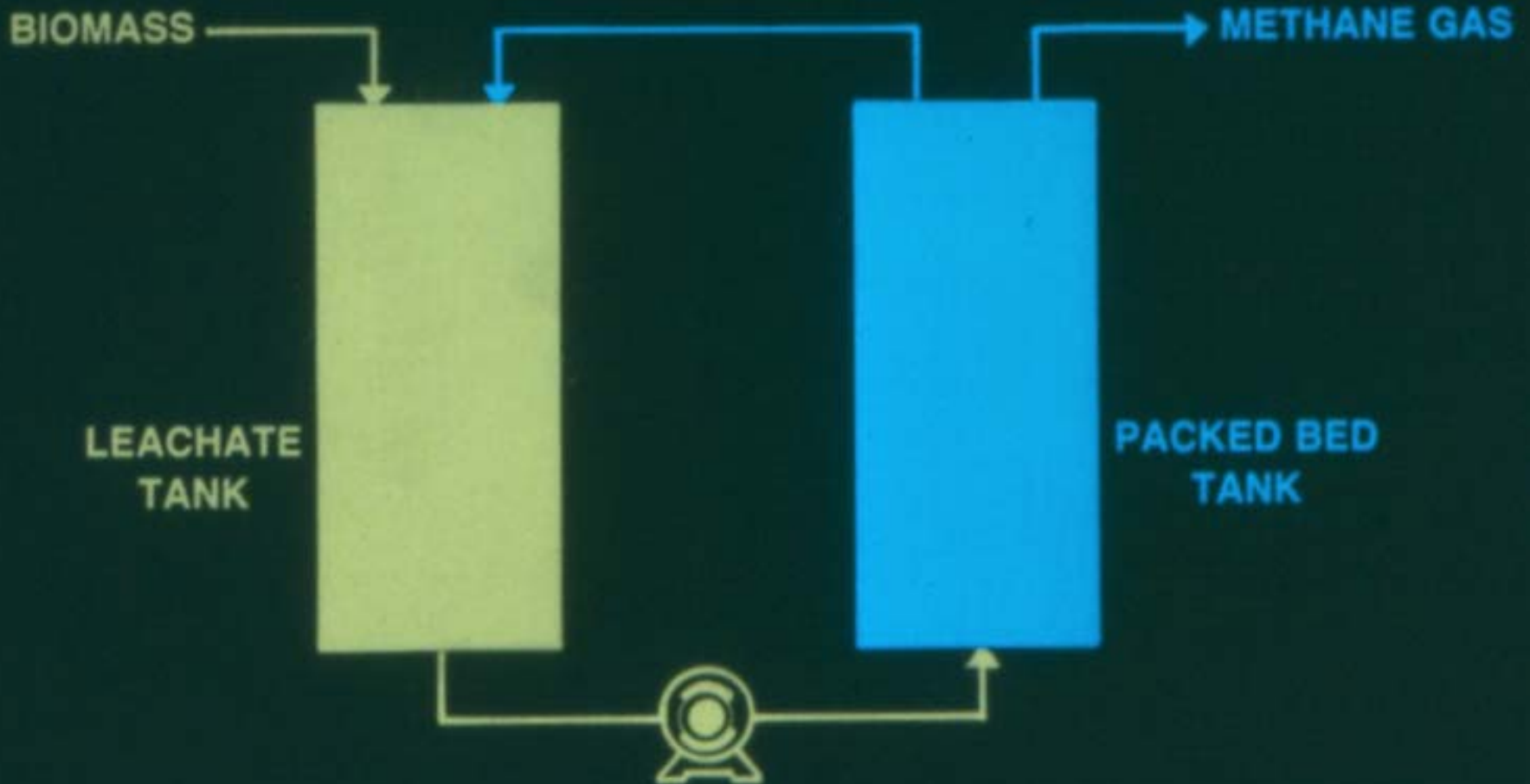




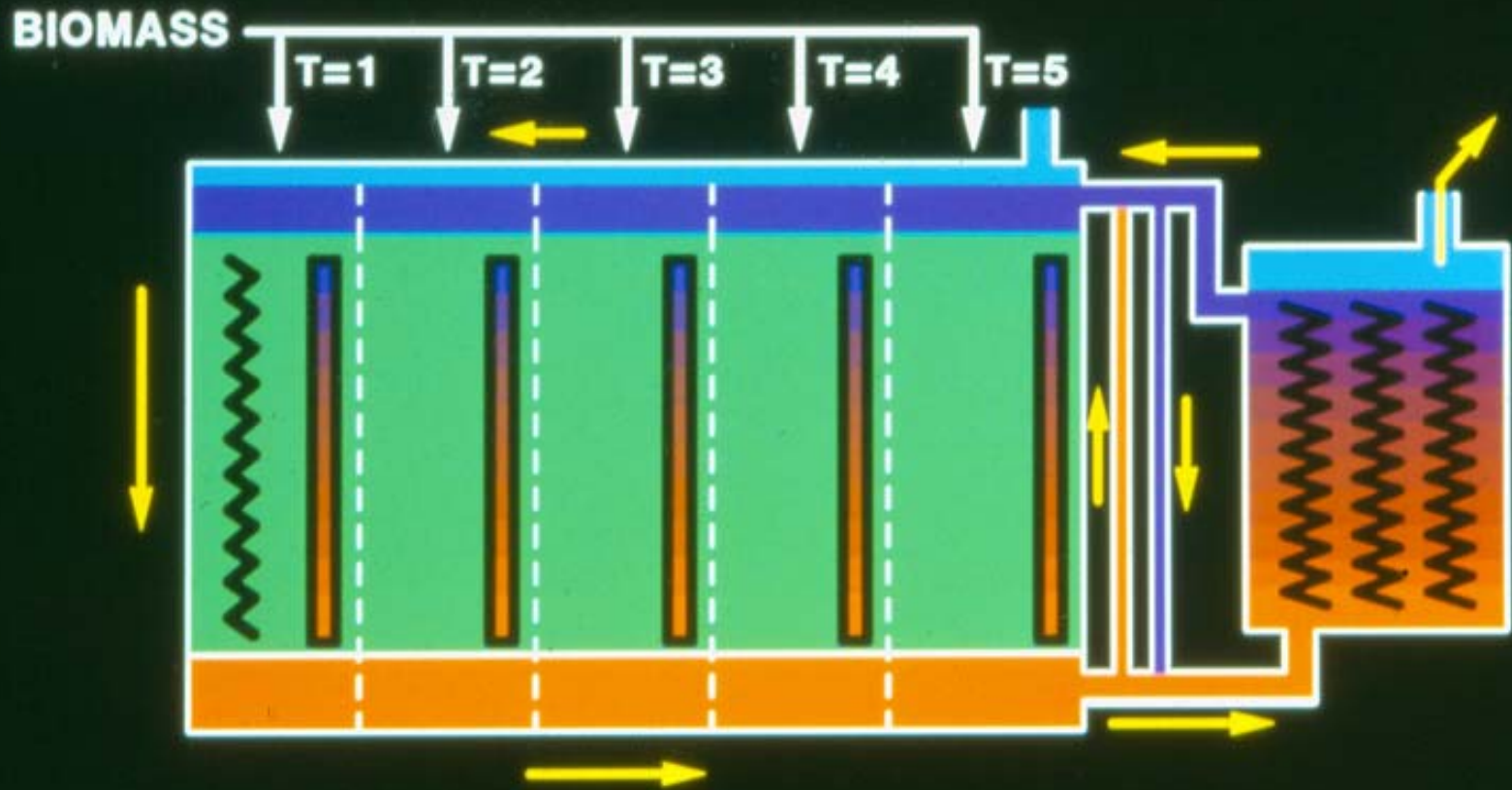
SCHEMATIC OF THE BIOMASS TO METHANE SYSTEM



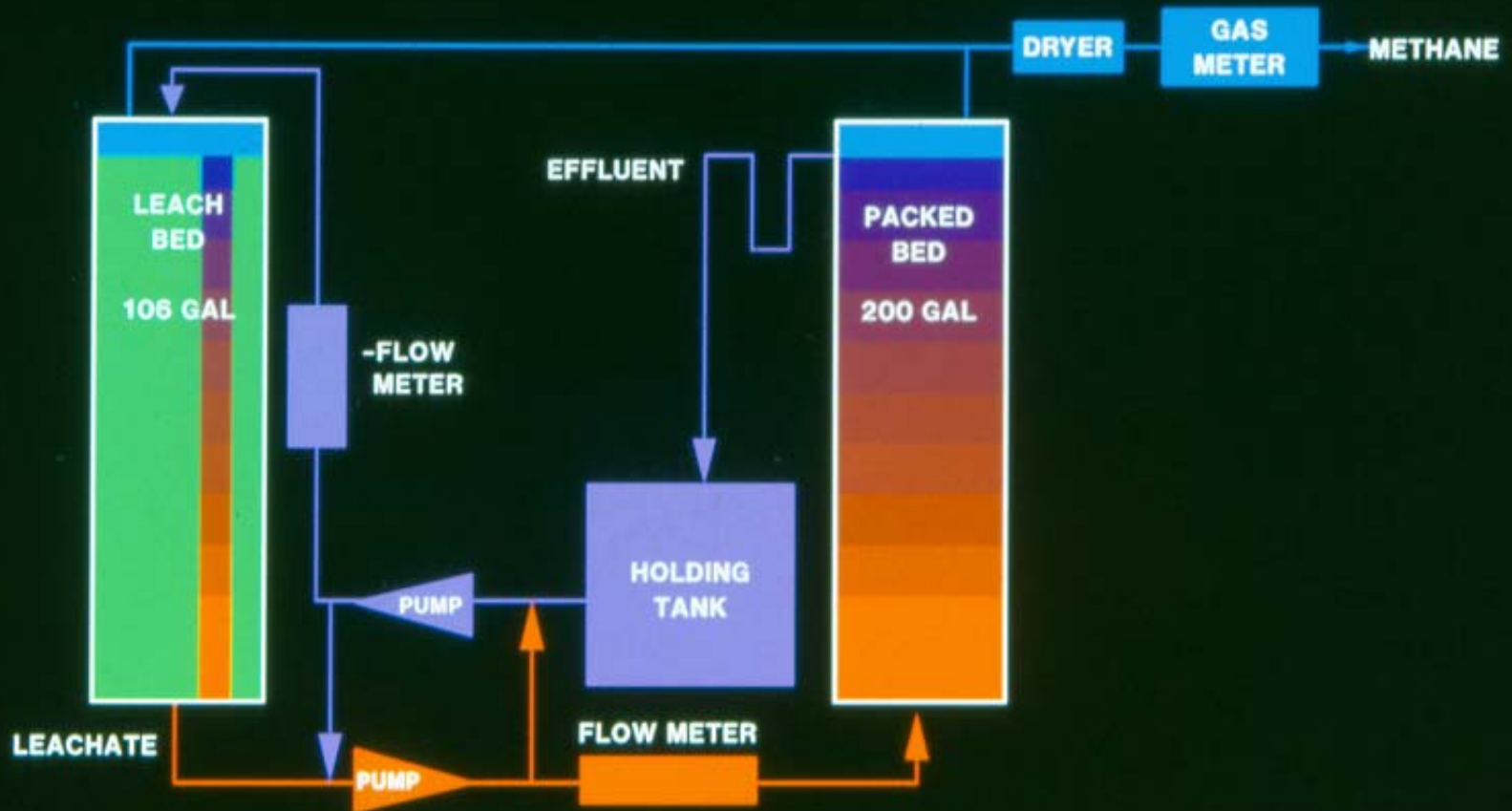
Leachate-Packed Bed Digester System



HIGH SOLIDS CONVERSION (MULTI-PHASE DIGESTION SYSTEM)



HIGH SOLIDS CONVERSION (MULTI-PHASE DIGESTION SYSTEM - SINGLE CELL)



FUTURE DIRECTION

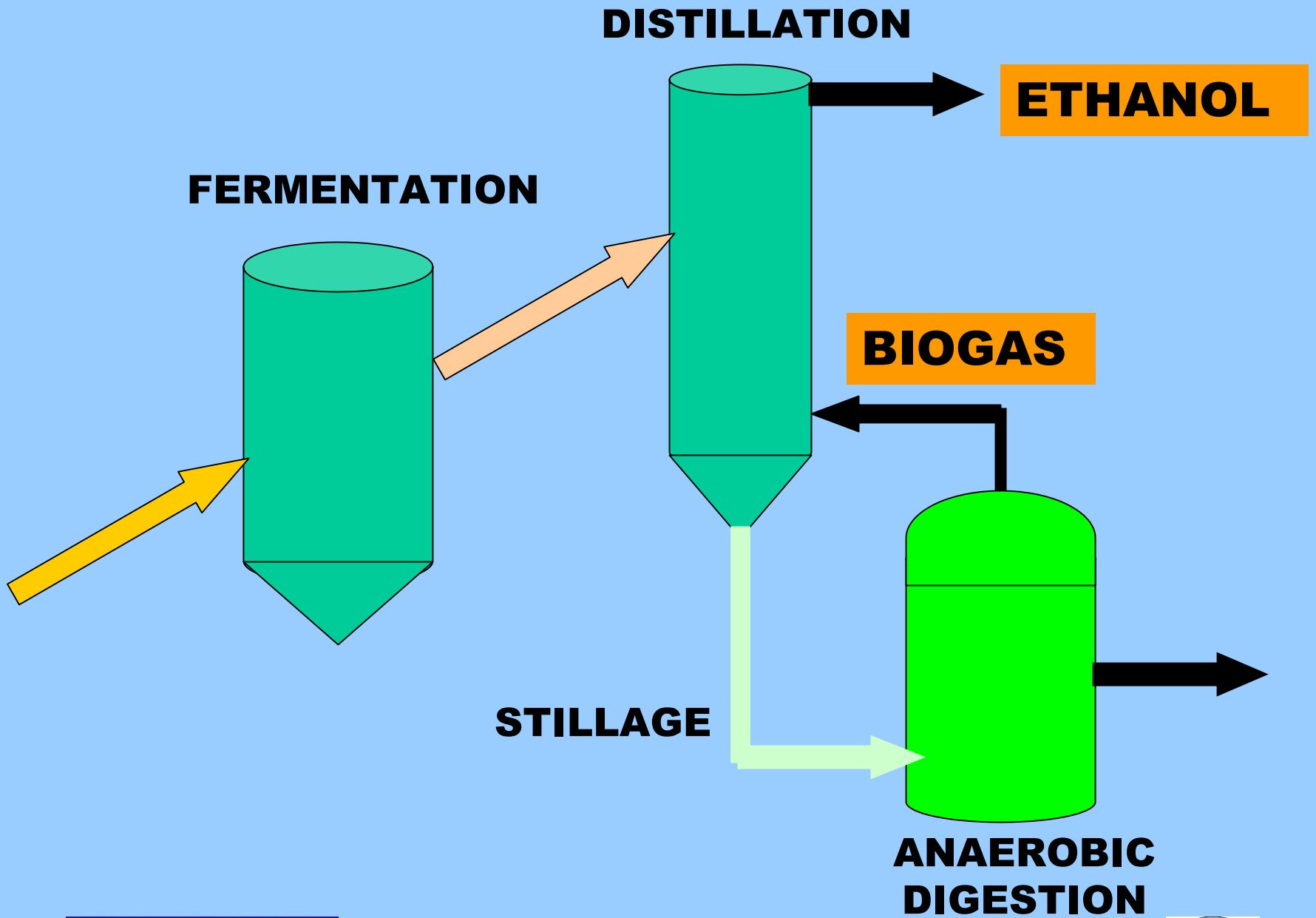
- **Increase solids loading**
- **Decrease solids retention time**
- **Improve conversion efficiency**

BIOLOGICAL & ENGINEERING

- ***Enhance Bioconversion***
 - Rate and Extent
 - Biochemistry / Microbiology
 - Pretreatment
- ***Advance Process Regulation***
 - Experimental Test Unit
 - Flexible
 - Validate bioconversion kinetics
 - Temperature, salinity

ETHANOL – How “Green”?

- **Up to 20 liters stillage per liter ethanol**
- **Increased ethanol production requires effective stillage treatment**
- **Anaerobic digestion provides a sustainable solution, producing biogas for use as an in-plant fuel**



GLOBAL TECHNOLOGY

- **Tolerant** – varied feedstock capability
- **Scalable** – custom sizing
- **Flexible** – rapid restart after seasonal idling
- **Universal** – worldwide application

CLIMATE CHANGE IMPACTS

- **GHG Reduction**
- **Renewable Energy**
- **Fossil Fuel Conservation**

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