# Biomass to Energy Conversion Processes


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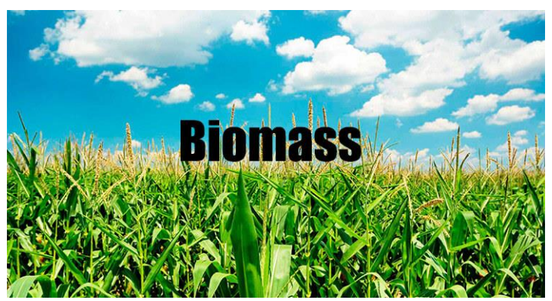
# Biomass – Composition and Characteristics

## Photosynthesis

In the process of photosynthesis, plants convert radiant energy from the sun into chemical energy in the form of glucose—or sugar.

| (water) | (carbon dioxide) | | (sunlight) | | (glucose) | | (oxygen) |
|---|---|---|---|---|---|---|---|
| $6\,H_2O$ | + $6\,CO_2$ | + | radiant energy | → | $C_6H_{12}O_6$ | + | $6\,O_2$ |




# Biomass-To-Energy Conversion Process

## [1] Thermochemical Conversion Process

## [2] Biochemical Conversion Process

# Thermochemical Conversion Process

## 1.COMBUSTION

**Biomass + Stoichiometric oxygen → Hot combustion products**

Combustion or burning is a complex sequence of exothermic chemical reactions between a fuel and an oxidant accompanied by the production of heat or both heat and light in the form of either a glow or flames, appearance of light flickering.

In a complete combustion reaction, a compound reacts with an oxidizing element, such as oxygen, and the products are compounds of each element in the fuel with the oxidizing element.

# 2. PYROLYSIS

**Biomass + Heat → Charcoal, oil, gas**

Pyrolysis is the chemical decomposition of a condensed substance by heating. It does not involve reactions with oxygen or any other reagents but can take place in their presence. Pyrolysis is a special case of thermolysis, and is most commonly used for organic materials; extreme pyrolysis, which leaves only carbon as the residue, is called carbonization and is related to the chemical process of charring.

Higher efficiency is achieved by the flash pyrolysis where finely divided feedstock is quickly heated to between $350^0$ and 500 $^0$C for less than 2 seconds.

Fuel bio-oil resembling light crude oil can also be produced by hydrous pyrolysis of many feedstocks.


# Pyrolysis of Biomass

# 3. GASIFICATION

**Biomass + Limited oxygen → Fuel gas + Pyrolysis oils + Char + Ash + Steam**

Gasification is a process that converts carbonaceous materials, such as coal, petroleum, or biomass, into carbon monoxide and hydrogen by reacting the raw material at high temperatures with a controlled amount of oxygen and/or steam. The resulting gas mixture is called synthesis gas or syngas and is itself a fuel.

- Controlled combustion
- 20-40 % oxygen supply
- Producer gas
- Cal value : 1500 kCal/$Nm^3$
- Major constituent gases CO & $H_2$ Others $CO_2$, $CH_4$, $N_2$

# Composition of Producer Gas

| Constituent | % (vol.) |
|---|---|
| *CO* | *18-22* |
| $H_2$ | *13-19* |
| $CH_4$ | 1-5 |
| Heavier Hydrocarbons | 0.2-0.4 |
| $CO_2$ | 9-12 |
| $N_2$ | 45-55 |
| Water Vapour | 4 |

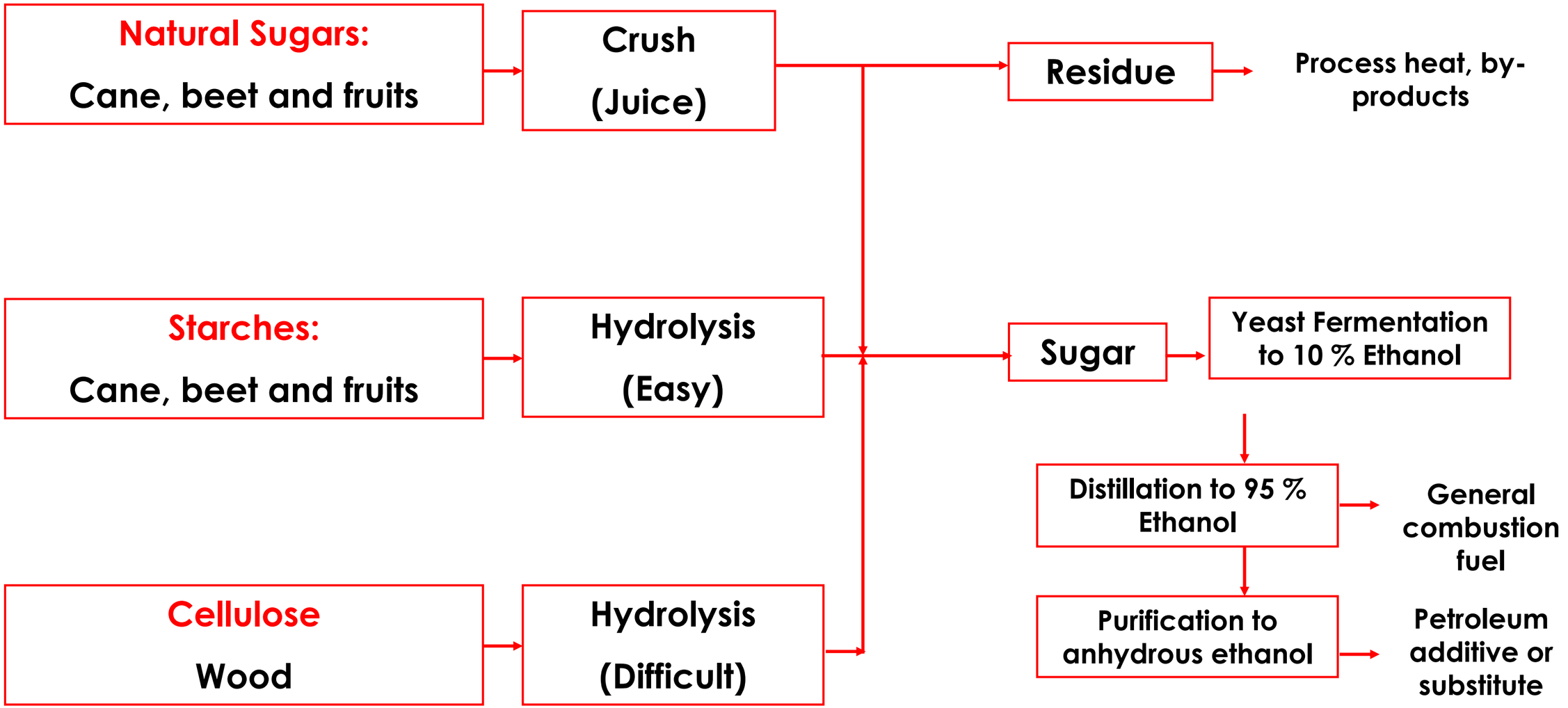
# Biochemical Conversion Process

## 1. Alcoholic Fermentation Process

- Ethanol, $C_2H_5OH$ is produced naturally by certain micro-organisms from sugars under acidic conditions, i.e. pH 4-5.

- The most common micro-organism is yeast *Saccharomyces cerevisiae*, is poisoned by ethanol concentration greater than 10 %.

- Stronger concentrations up to 95 % are produced by distilling and fractionating.

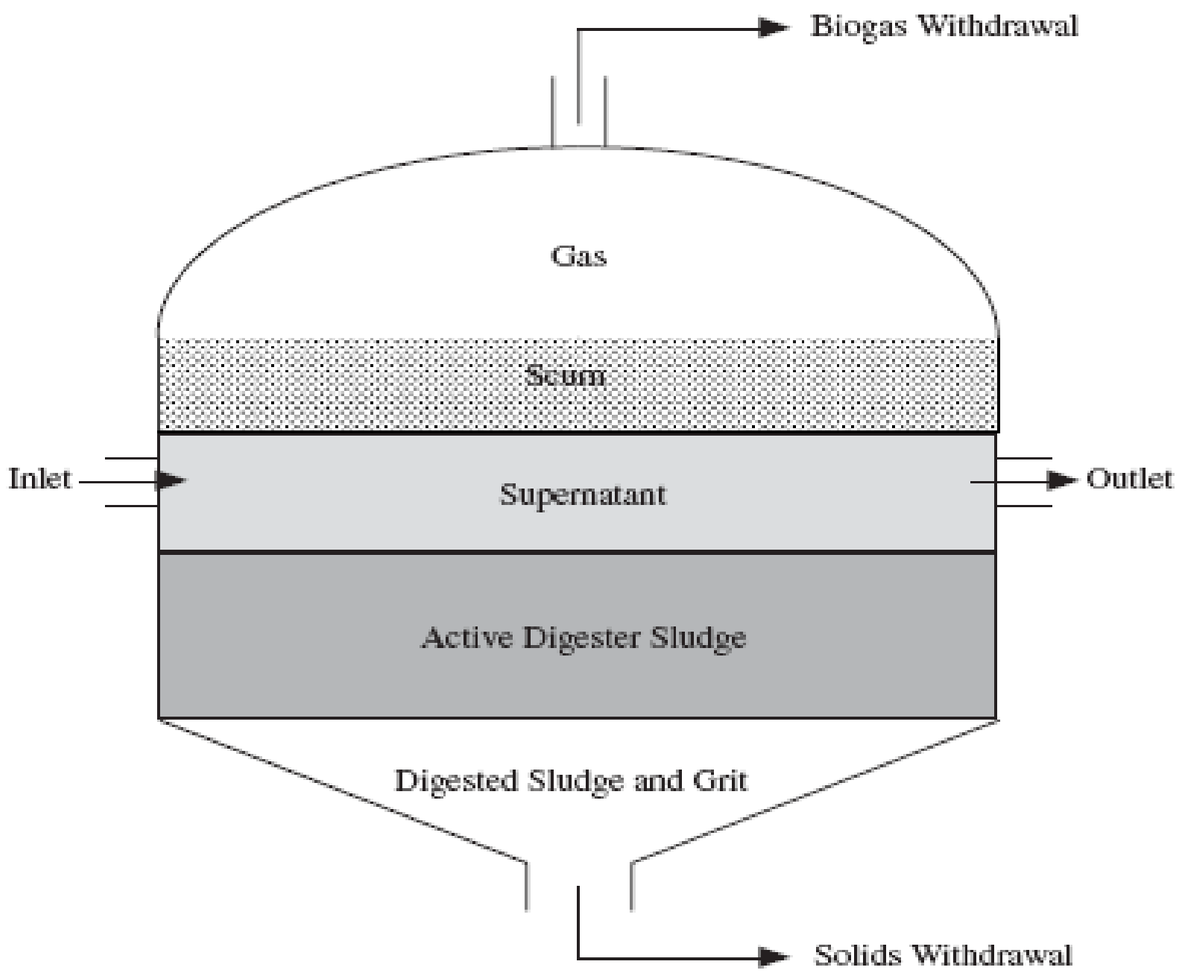



# Ethanol Production Process

# Ethanol Production Potential from Biomass Crops

| Raw Material | Ethanol Productivity L/Tonne) |
|---|---|
| Sugar beet | 90-100 |
| Sugarcane | 60-80 |
| Sweet sorghum | 80-90 |
| Potato | 100-120 |
| Maize | 360-400 |
| Cassava | 175-190 |
| Wheat | 370-420 |
| Barley | 310-350 |

# 2. Anaerobic Digestion Process



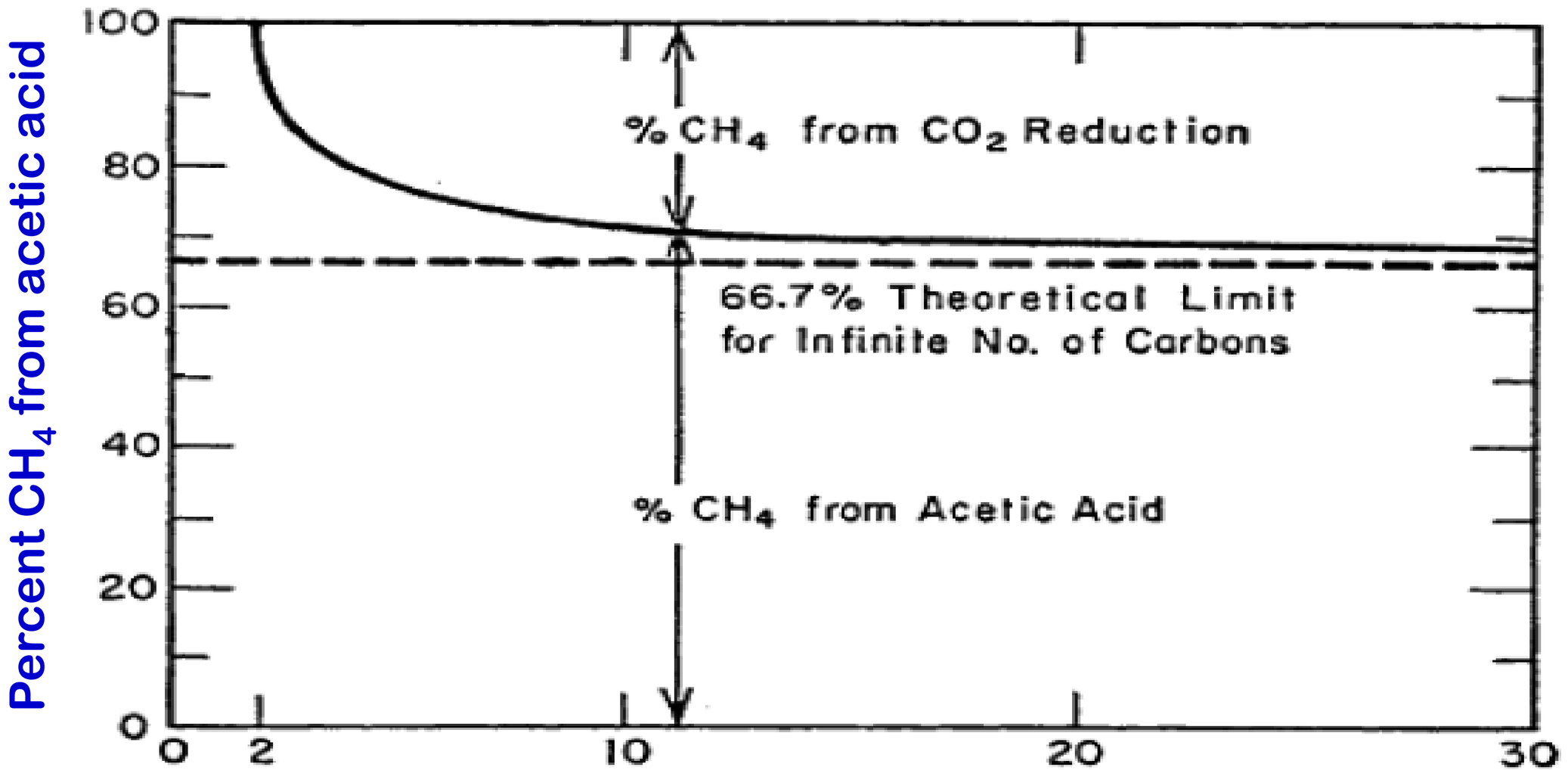
- The formation of inflammable gas in nature, especially in swamps and mines, has been known since the earliest times.
- In **1776** ***Volta*** examined this phenomenon in some detail and arrived at the conclusion that the gas, which is composed mainly of methane, originates du to the rotting of biomass materials.
- The recognition of the fact that the formation of methane is a microbial process began with the work of ***Popoff*** **(1875),** ***Hoppe-Seyler*** **(1886)** and others in the latter half of the nineteenth century.
- But it was not until **1906** that the fundamental investigations of ***Sohngen*** gave a somewhat clearer perception of the forms and characters of the ***~methane forming bacteria*** and of the types of chemical conversions which they are able to carry out.

***Thayer*** **(1931)** in particular, starting from the hypothesis that methane might arise from a decarboxylation of acetic acid.

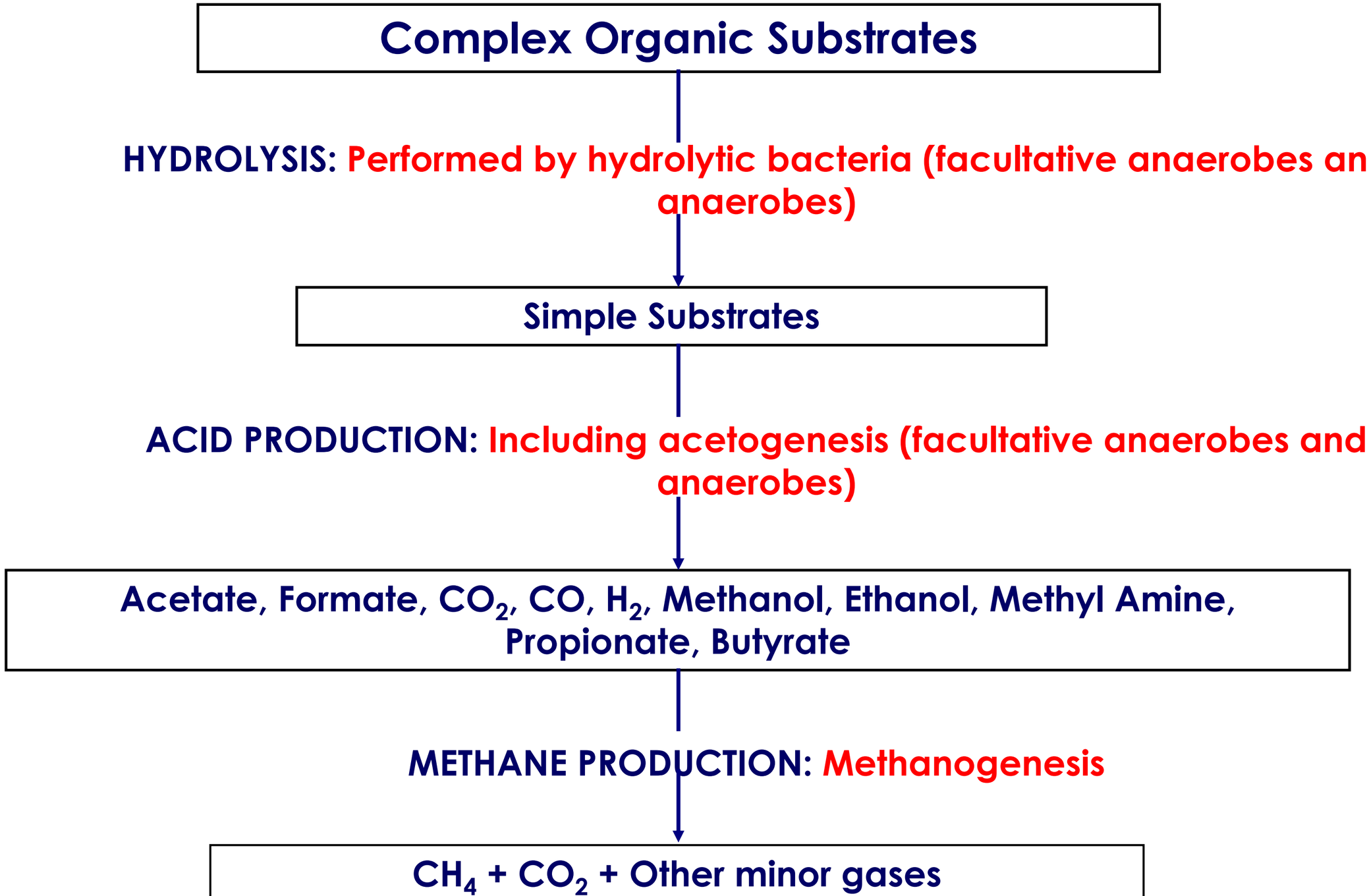
$$CH_3COOH \sim CH_4 + CO_2$$

He examined the fermentation of propionic and butyric acids to see whether the corresponding hydrocarbons, ethane and propane, would be formed. His results were, however, entirely negative, thus confirming the older work of ***Sohngen*** and others: no other hydrocarbon than methane was detectable.

# Percent methane from acetate and $CO_2$ reduction routes



# Anaerobic Digestion Process



# Stage I- Hydrolysis

Complex Carbohydrates → Simple Sugars

Complex Lipids (Fat) → Fatty Acids

Complex Proteins → Amino Acids

# Stage II- Acid Production

Simple Sugars + Fatty Acids + Amino Acids

Organic acids, including acetate + Alcohols

Acetogenesis (acetate production):

Organic acids + Alcohols  Acetate

# Stage III- Methane Production

## Acetoclastic Methanogenesis

Acetate $\longrightarrow$ $CH_4 + CO_2$

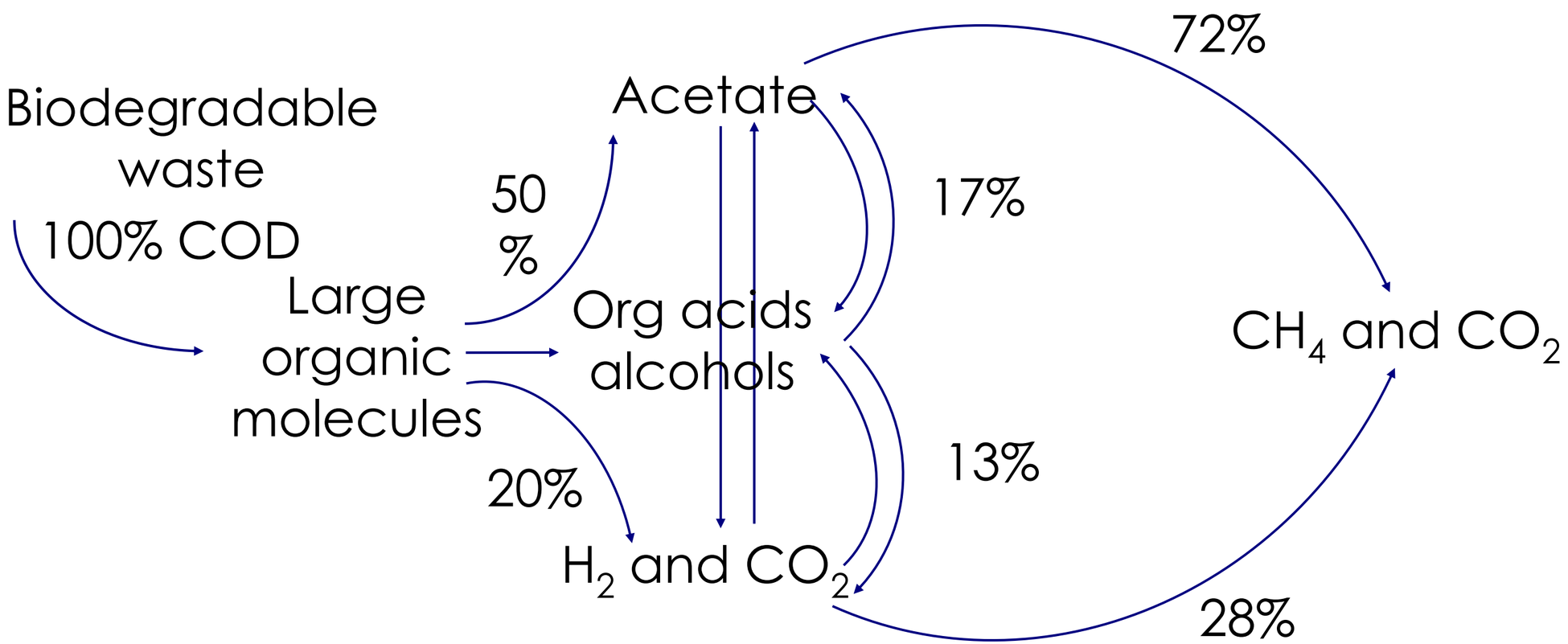
## Hydogenotrophic Methanogenesis

$H_2 + CO_2 \longrightarrow CH_4$

## Methyltrophic Methanogenesis

Methanol $\longrightarrow$ $CH_4 + H_2O$

# Overview of Microbial Transformation




BIOGAS PLANT


BIOGAS PLANT

# Other Biogas Programs in India

## On-going Programs:

- Biogas based distributed/ grid power generation programme.
- Programme on energy recovery from urban wastes.
- Programme on energy recovery from municipal solid wastes.
- Programme on recovery of energy from industrial wastes.
- Demonstration of integrated technology package on biogas-fertilizer plants (BGFP) for generation, purification/ enrichment, bottling and piped distribution of biogas.
- Establishment of business model for demonstration of an integrated technology package for creation of smokeless villages using biogas/ bio-energy systems and meeting ‘life-line energy’ envisaged in ‘integrated energy policy’

# Biomass Cook stove

- Nearly three-fourths of Indian households use open fires or *chulhas*
- 400,000 deaths to children under 5 years of age and 34,000 deaths to women due to chronic respiratory disease. (IAP)
- Aims to distribute approximately 150 million high efficiency stoves in the next 15 years.

# Remote Village Electrification Program

- MNRE is implementing Remote Village Electrification (RVE) program for providing financial support for lighting/basic electricity using renewable energy sources.
- MNRE provides Central Financial Assistance of upto 90% of the cost of renewable energy systems.
- Nearly 13,059 villages and hamlets are benefited till now through this scheme

# Thank You