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# Optimization and evaluation of an integrated anaerobic digestion waste-to-energy system for energy recovery from food waste

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# Presentation Structure

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**1. Background**

**2. Anaerobic Digestion Technologies**

**3. Waste-To-Energy systems**

# 1. Background

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- **Energy and Environment**
- **Environmental Concerns**



- **Energy Crisis**
  - ◆ **Fossil fuel: Non-renewable**
  - ◆ **Nuclear energy: High risk**
  - ◆ **Renewable energy: Biomass energy**

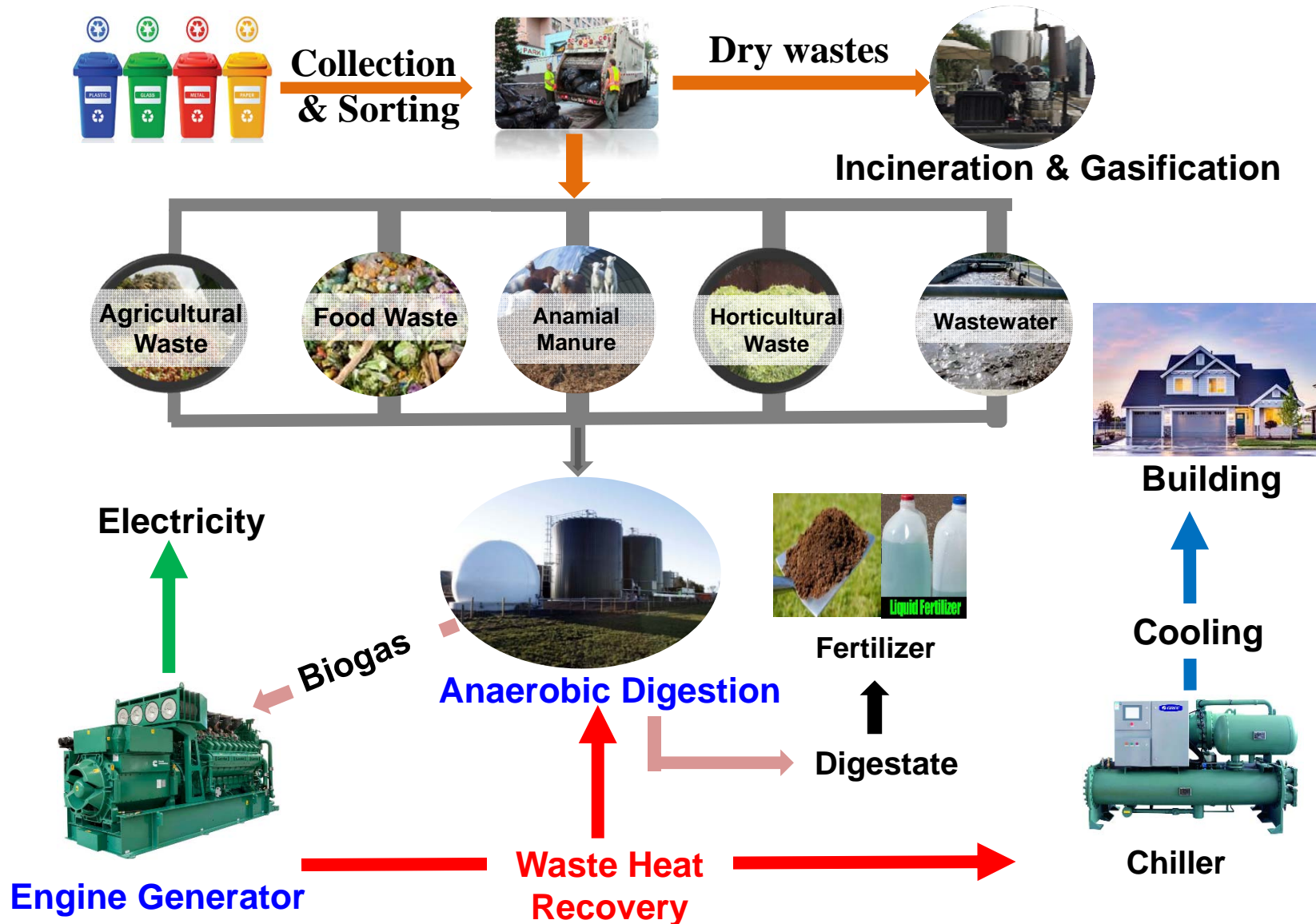


**National Demand: Environmental pollution control and Sustainable energy resource - “Waste-To-Energy”**

# Waste management in Singapore



# □ Anaerobic Digestion Waste-to-Energy system



# □ Challenges and Demands

## Challenges

- ❖ Waste sorting
- ❖ Sensitive
- ❖ Energy Intensive
- ❖ Low energy recovery



## Demands

- High sorting efficiency
- High treatment capacity
- Low energy consumption
- Efficient energy recovery

## **□ Objectives and contributions**

### **Objectives :**

- **To develop a novel method or apparatus for high efficient anaerobic digestion of organic wastes.**
- **To design and fabricate a sustainable and efficient waste-to-energy system for electricity generation and heat recovery**

### **Contributions :**

- **Waste Reduction, Environmental Pollution Control, Zero Waste**
- **Net energy (electricity and heat) or resource (fertilizer) output**

## **2. Anaerobic Digestion Technologies**

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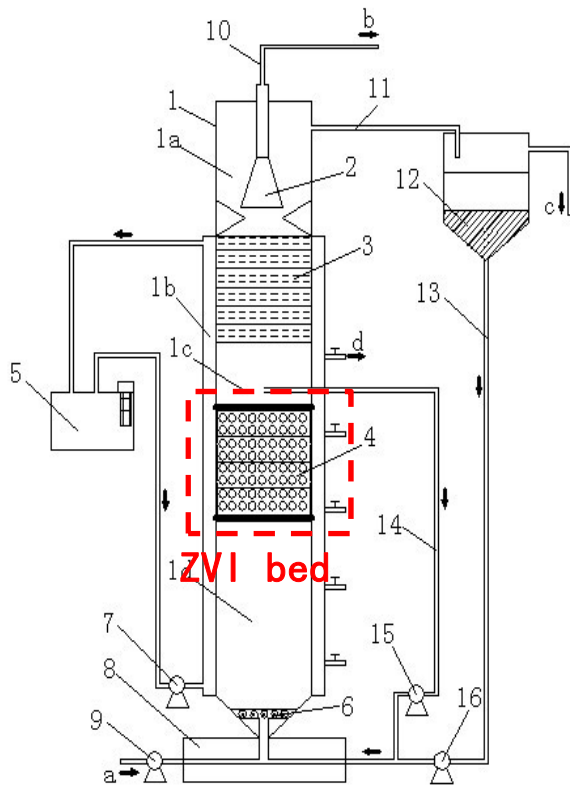
**Anaerobic digestion (AD) – Technology level**



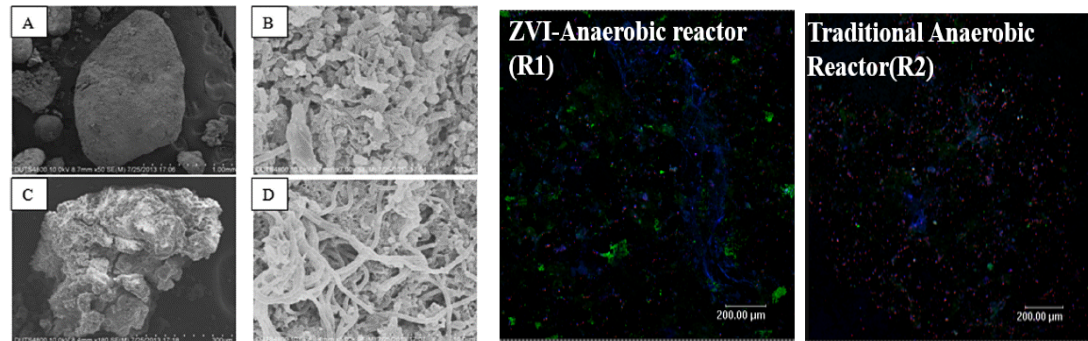
# □ Bioreactor design

## 1. Zero Valent Iron (ZVI) – Anaerobic digester

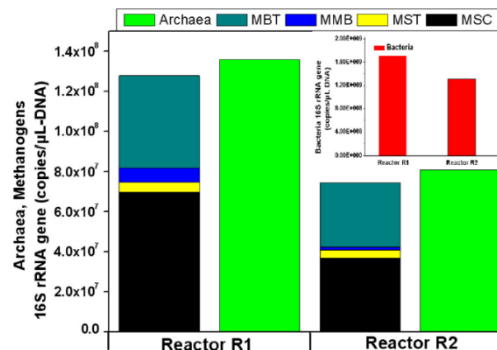
ZVI is a reductive material that can serve as electron donor for methanogenesis ( $8\text{H}^+ + 4\text{Fe}^0 + \text{CO}_2 = 4\text{Fe}^{2+} + \text{CH}_4 + 2\text{H}_2\text{O}$ ).



**ZVI – Anaerobic Digester**



**ZVI accelerate granulation**    **High abundance of methanogens**



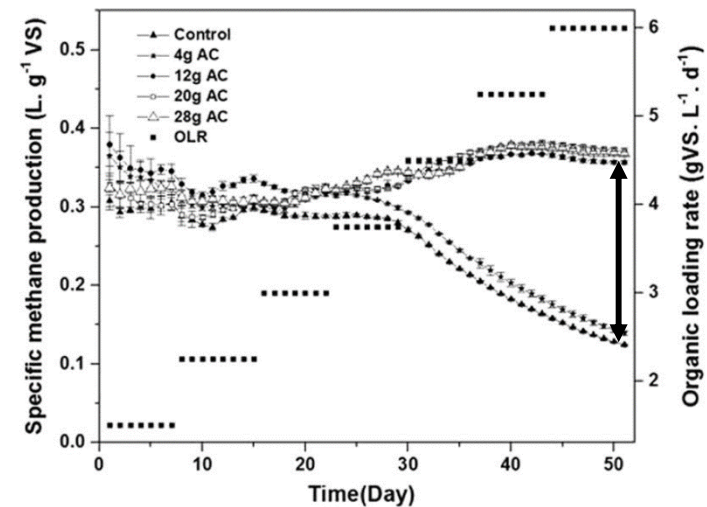
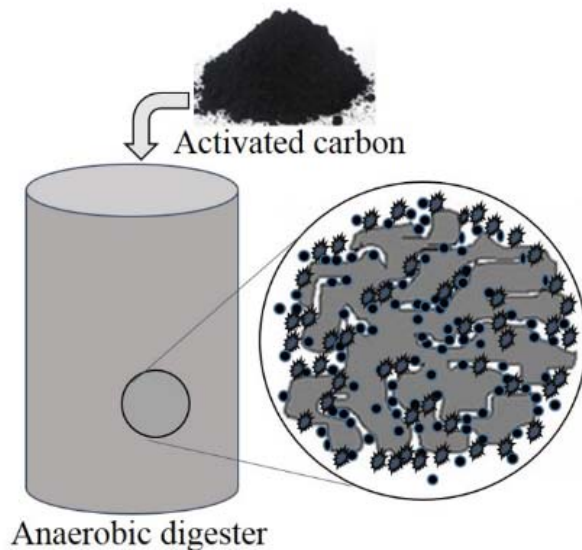
**Higher Methane Yield;**  
**Buffering Organic acids;**  
**Neutral pH;**  
**Stable operation;**  
**Higher treatment capacity.**

**H<sub>2</sub> utilizing methanogens ↑**

# □ Biological enhancement additives

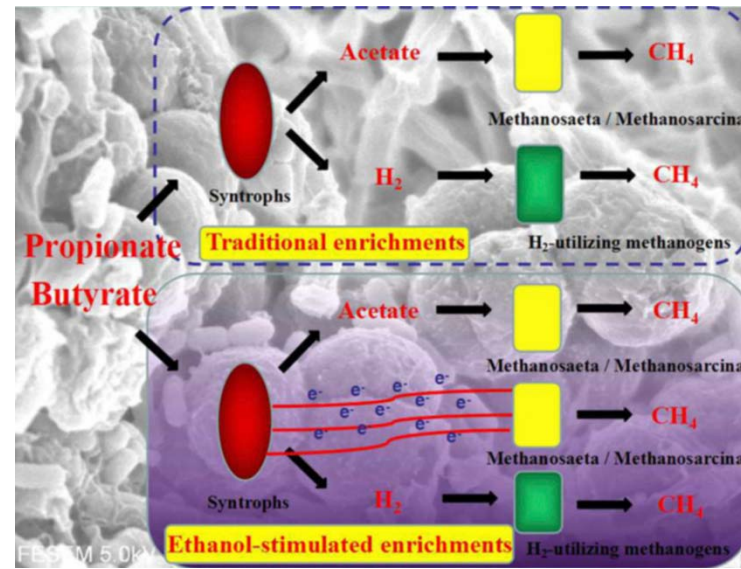
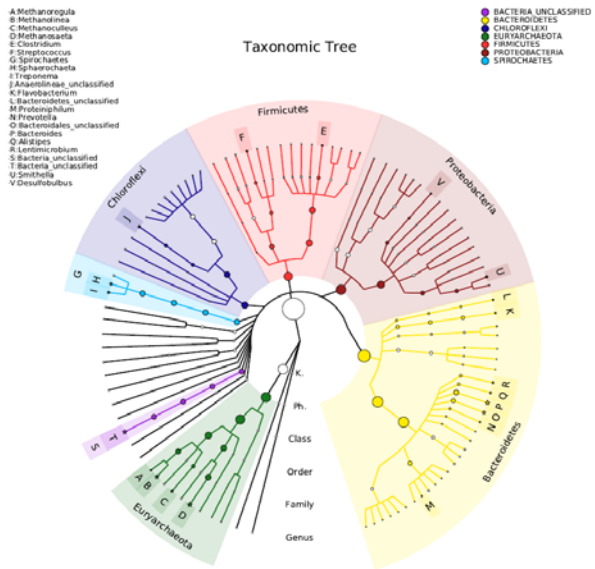
## Activated carbon and biochar

“Activated carbon derived from char from biomass gasification and its application for dye removal and wastewater treatment”

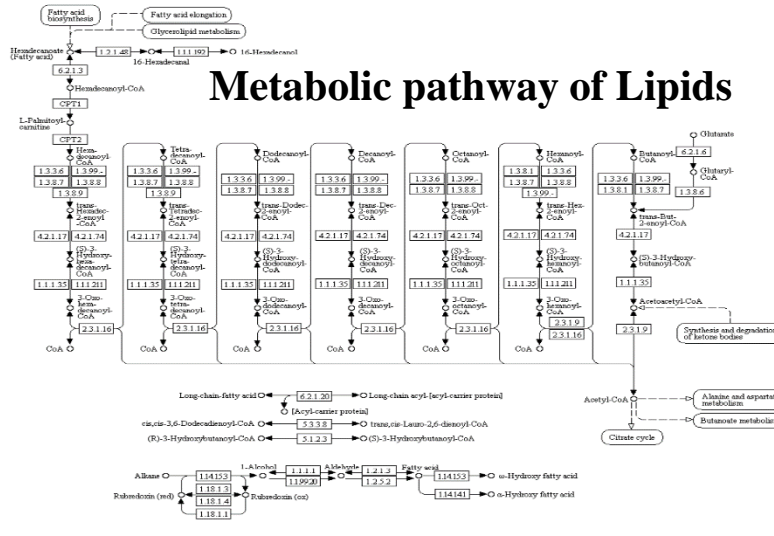
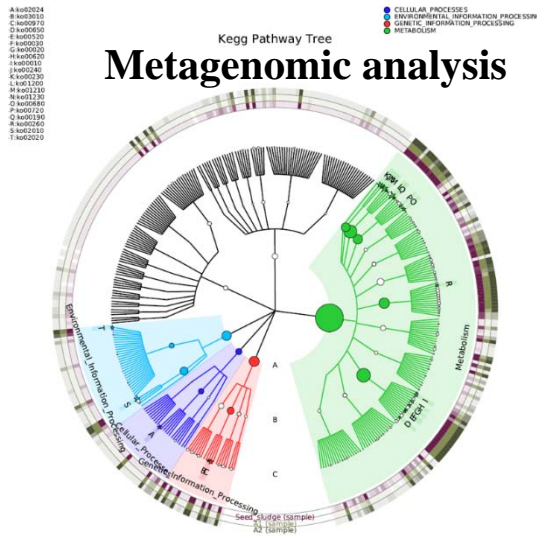


Activated carbon improved **230%** CH<sub>4</sub> yield **10**

# Metabolic mechanisms



Potential **Direct interspecies electron transfer** for syntrophic metabolism

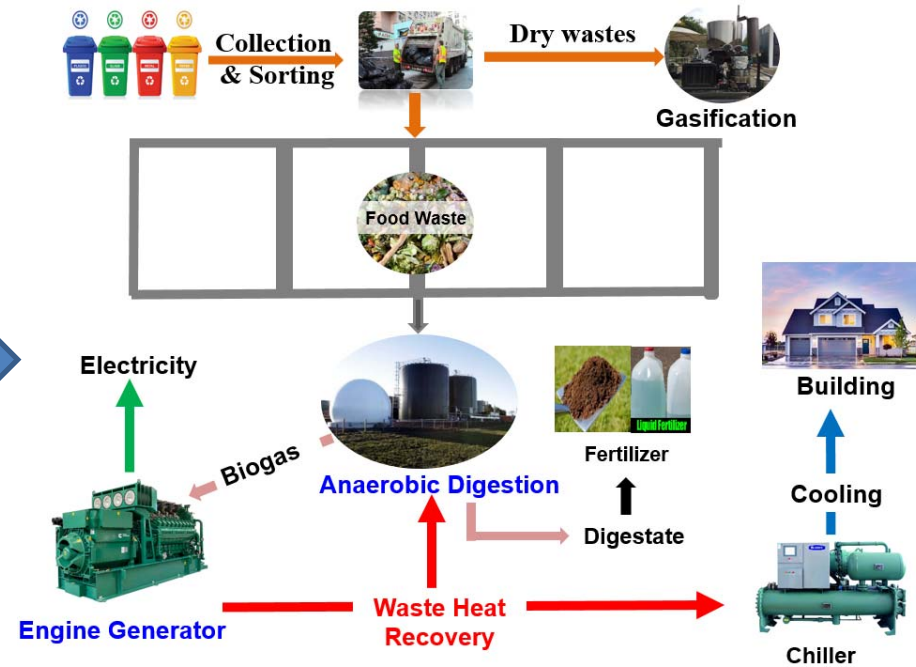
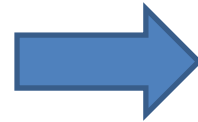


Dominant metabolic pathways: **Lipid, Propanoate and Energy Metabolism**

# (3) Waste-To-Energy systems



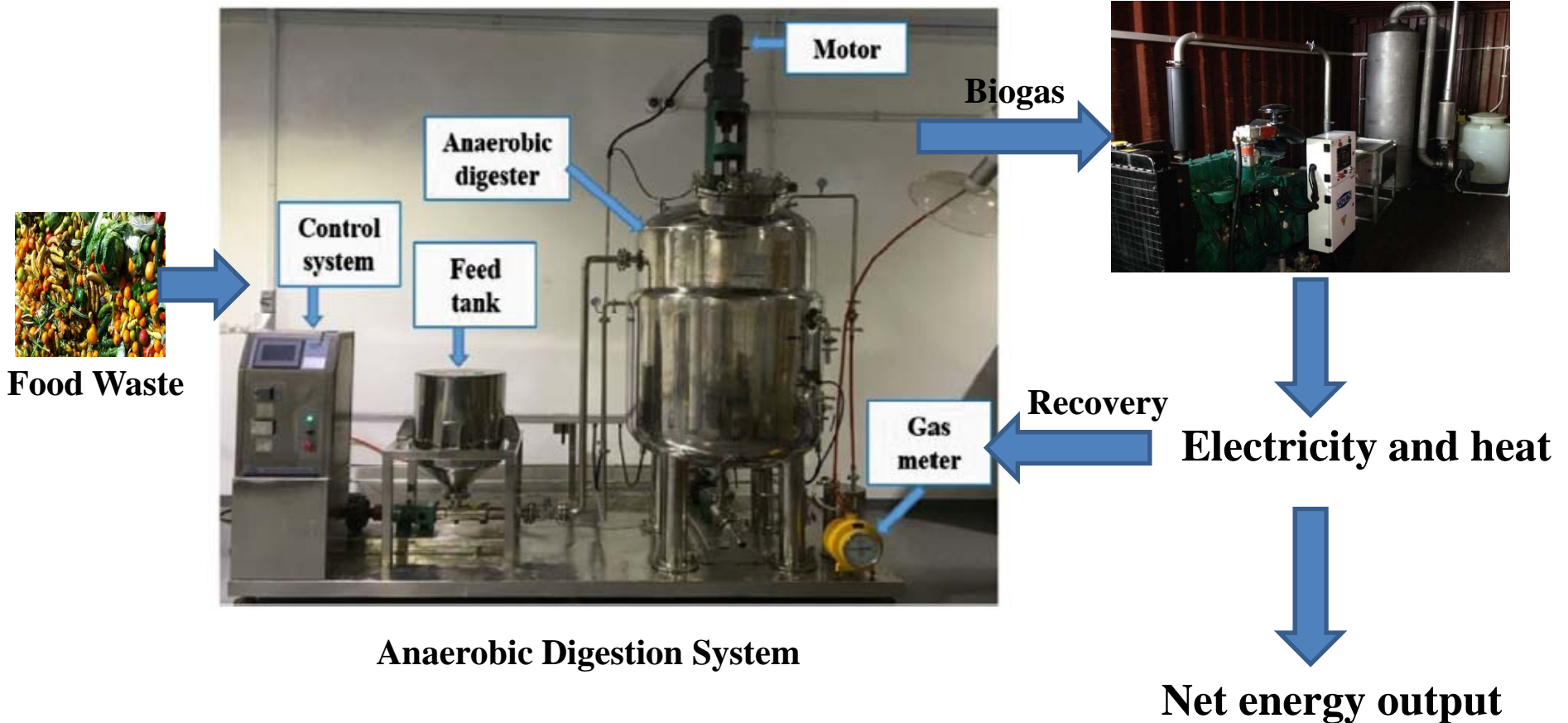
**Anaerobic digestion  
(Technology level)**



**Energy System  
(System level)**

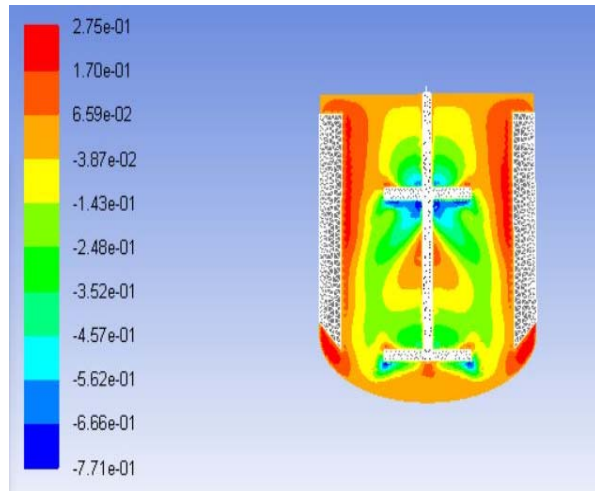
# □ Food Waste-To-Energy system

## Combined Heat and Power System

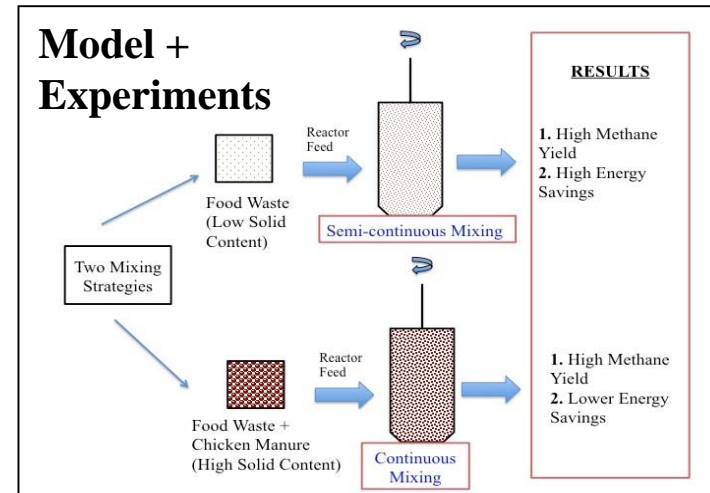


**Reduction of energy consumption of the whole AD energy system**

# Reduction of Energy Consumption in the Energy System



**Computational Fluid Dynamics (CFD) modelling for mixing**



**Semi-continuous mixing strategy**



**Different Scales of Engine Generator systems**

# □ Demonstration of NUS-SJTU in Singapore

Anaerobic digestion waste-to-energy eco-system for food waste in Raffles Hall Canteen



**Treatment Capacity: 50 kg/day**

**Reactor volume: 1 m<sup>3</sup>**

**Location: Opposite Raffles Hall Canteen**

**Output: Electricity, Heat and fertilizer**

**Container: 20 feet**



Thank you for  
your attention!

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