

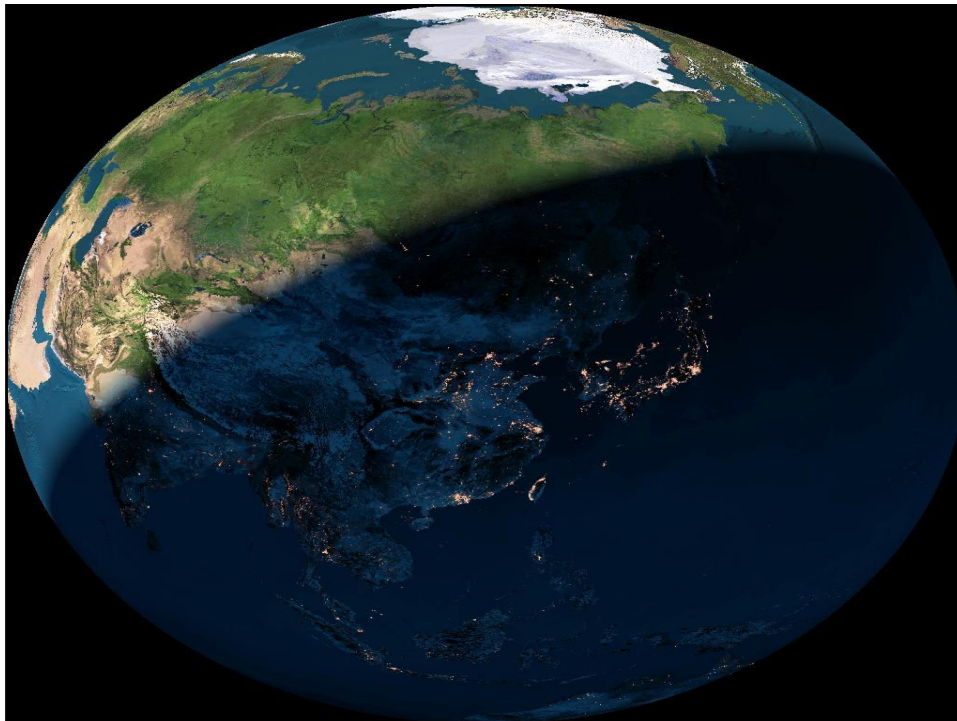


## **Municipal Organic Solid Waste as an Alternative Urban Bioenergy Source**

**WANG Jing-Yuan**

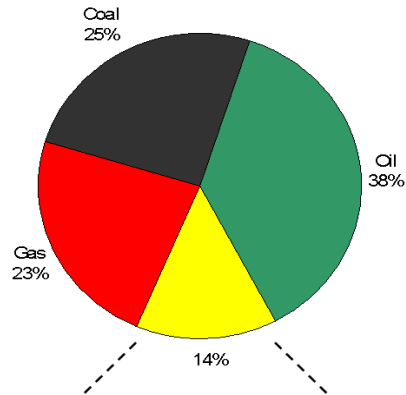
Associate Professor, School of Civil & Environmental Engineering  
Director, Environmental Engineering Research Centre

23 – 25 January 2008



# World Energy Consumption

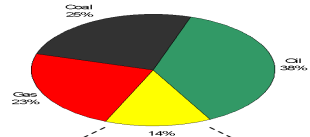
15 TW .



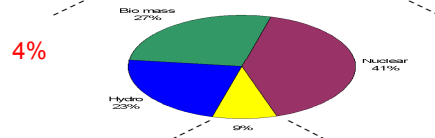
(from Wikipedia)

# World Energy Consumption

15 TW .

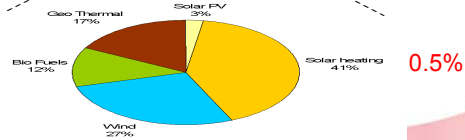


2.2 TW .



4%

215 GW .



0.5%

0.3%



(from Wikipedia)

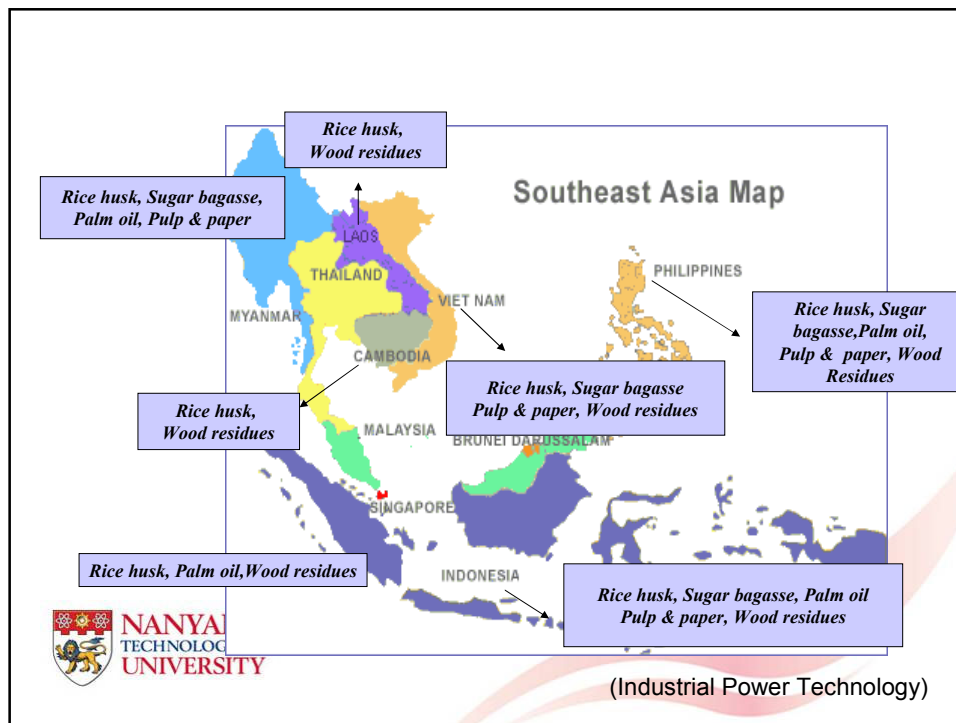
## Energy, energy, and energy

- Increasing energy demand due to rapid urbanization (especially mega cities) and industrialization
- Depletion of fossil fuel resource and rising oil price
- Oil, gas, and coal would still continue to be important components of global energy supply (~80+%)
- Alternative energy sources such as solar energy, wind energy, and bioenergy will gain more attention
- In South and Southeast Asia, more than 1 billion population has no grid connected electricity

Decentralized bioenergy



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TODAY'S NEWS, TOMORROW'S WASTE

# PAPER WAR

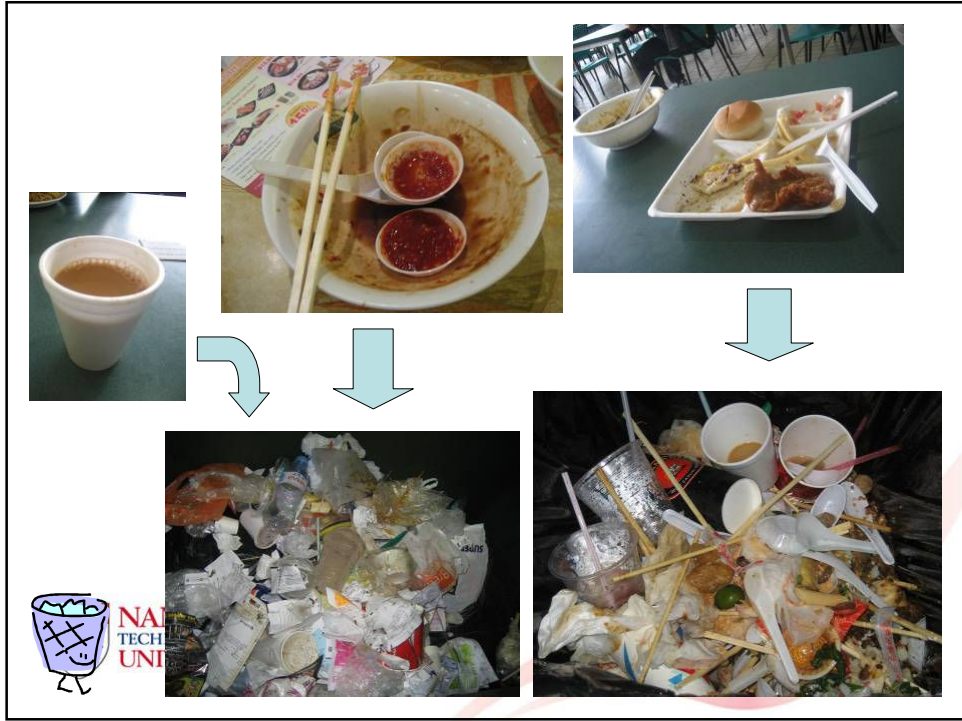
Good news for 'karung-guni' men?



As three new newspapers hit the streets soon, the people who may be smiling all the way to the bank could be the rag-and-bone men who collect old newspapers for recycling.

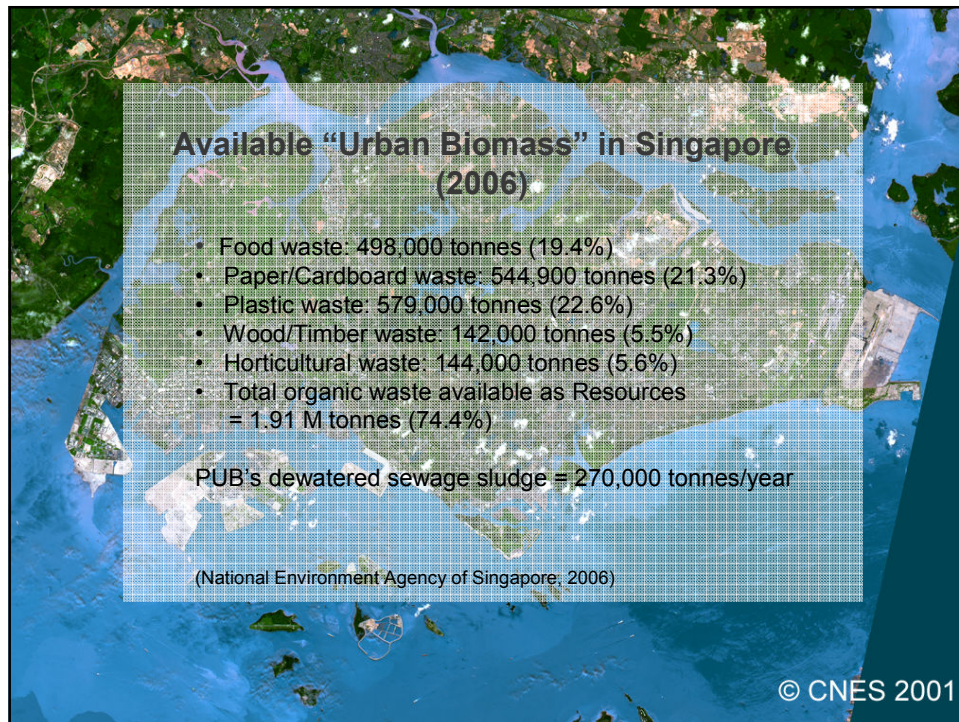
◆ Report by CHUA CHIN HON PAGE 29

(The Straits Times)









**Biomass to Energy Technologies  
(Oregon Department of Energy)**

Technology	Conversion Process Type	Major Biomass Feedstock	Energy or Fuel Produced
Direct Combustion	thermochemical	wood agricultural waste municipal solid waste residential fuels	heat steam electricity
Gasification	thermochemical	wood agricultural waste municipal solid waste	low or medium-Btu producer gas
Pyrolysis	thermochemical	wood agricultural waste municipal solid waste	synthetic fuel oil (biocrude) charcoal
Anaerobic Digestion	Biochemical (anaerobic)	animal manure Agriculture waste	Medium Btu gas (methane)
Ethanol Production	biochemical (aerobic)	sugar or starch crops wood waste pulp sludge grass straw	ethanol
Biodiesel Production	chemical	rapeseed soy beans waste vegetable oil animal fats	biodiesel
Methanol	thermochemical	wood agricultural waste municipal solid waste	methanol



## Key Challenges and Opportunities

Output	Feedstock	Preparation	Key transformation	Refining	Distribution / Usage	Co-products
<b>Transportation</b>						
Ethanol (starch)	Designer crop	De-watering	Continuous flow Microbials	Mostly resolved	Sediment	Market for DDG
Ethanol (cellulose)	Beyond clean straws to waste cellulose	<b>Acid and enzyme Pre-treatment De-watering</b>	Right-sizing / business model	Mostly resolved	Sediment	<b>What to do with C5 sugars</b>
Biodiesel	<b>Beyond food crops Blue-green algae?</b>	Purity/consistency of non-virgin oils De-watering	Higher efficiency catalyst Containment of catalyst	Product consistency Standards	Water contamination	<b>Glycerine quality / markets</b>
<b>Heat and Electricity</b>						
Biogas (Anaerobic Digestion)	Beyond manure SRM Recipes	<b>Particle size De-watering</b>	Well understood Microbial efficiency and nutrition	Gas clean-up Gas compression	Generator efficiency and robustness	<b>Markets for spent digestate</b>
Syn Gas (Gasification)	Beyond homogeneous feedstock	<b>Sorting technology Moisture removal De-watering</b>	Heat transfer Material handling	Gas clean-up Gas compression	Generator efficiency and robustness	Market development for CO2
Bio Oil (Pyrolysis)	Beyond homogeneous feedstock	Particle size De-watering	Mostly worked through	<b>Chemical characterization and extraction</b>	<b>Generator efficiency and robustness</b>	Use of fuel as the co-product



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(Randal Goodfellow)

## Biomass-to-Energy Application in Singapore

- Bio-diesel using used cooking oil (2006)
- Four bio-diesel plants to be established on Jurong Island (2006); palm oil (3) and Jatropha (1)
- Mixing 5% bio-diesel in the regular diesel
- Clean energy hub (S\$170M): solar, biomass / biofuel and hydrogen/fuel cell
- Food waste to compost and methane (2007)



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(World Biomass Energy)

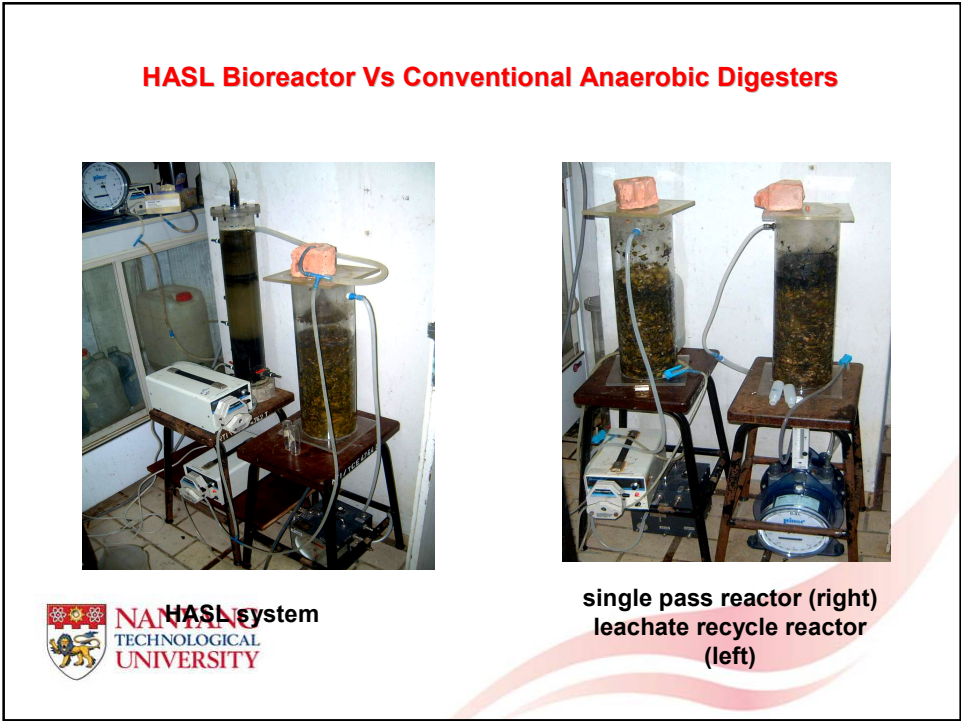
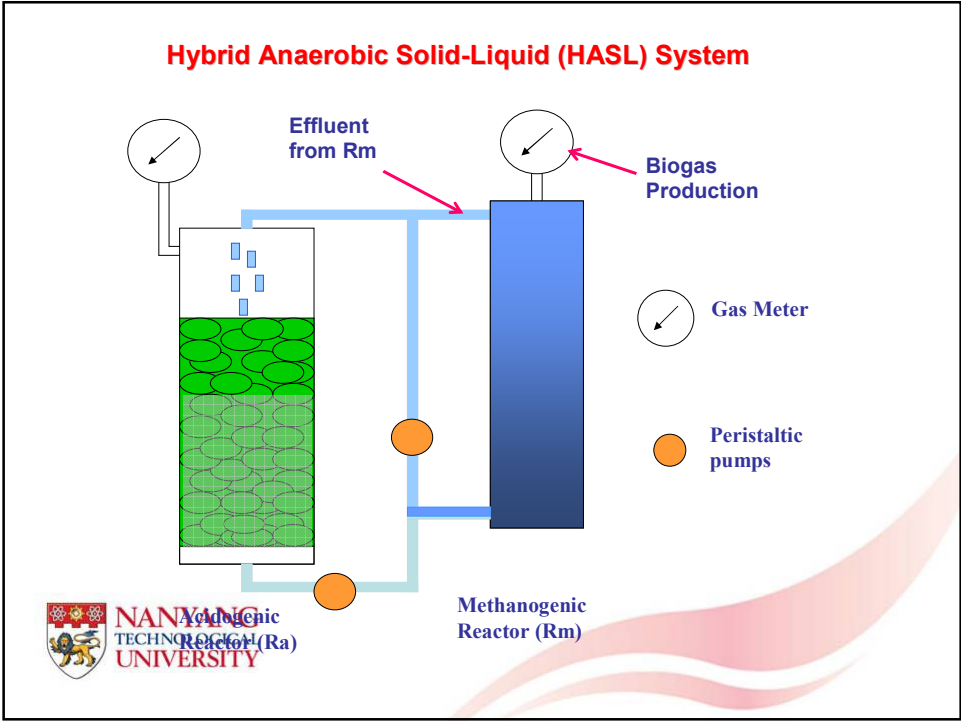


## NTU's Waste to Bioenergy Research

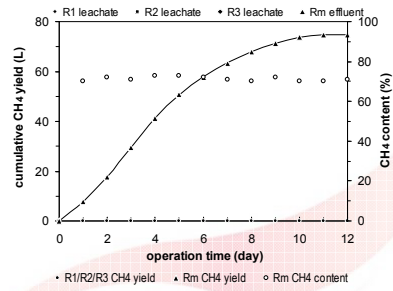
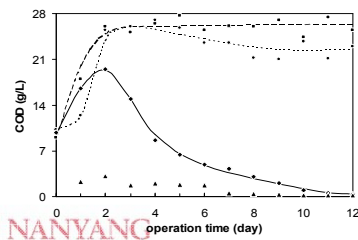
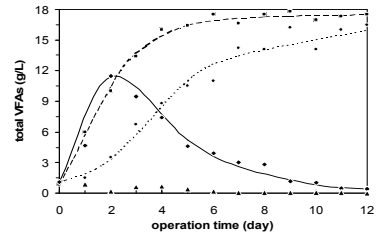
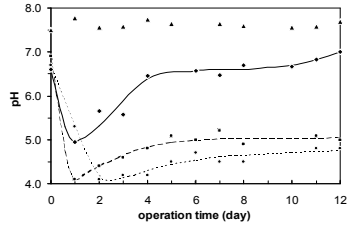
### NTU's Waste to Bioenergy Research

- Co-production of bio-hydrogen and bio-methane using a three-phase hybrid anaerobic solid-liquid digestion system
- Bioconversion of green waste to sugars for bio-ethanol production
- Organic waste degradation and electricity generation using microbial fuel cells
- Energy recovery from post-consumer plastic waste using pyrolysis
- Algae biofuel production using photobioreactors
- Biomass Derived Fuel (BDF)



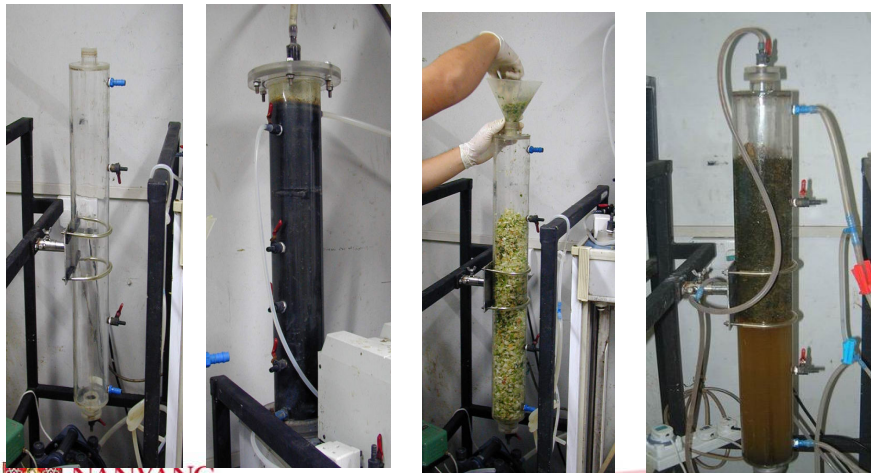


## HASL BIOREACTOR Vs CONVENTIONAL AD REACTORS



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## Semi-continuous HASL System



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The semi-continuous HASL system

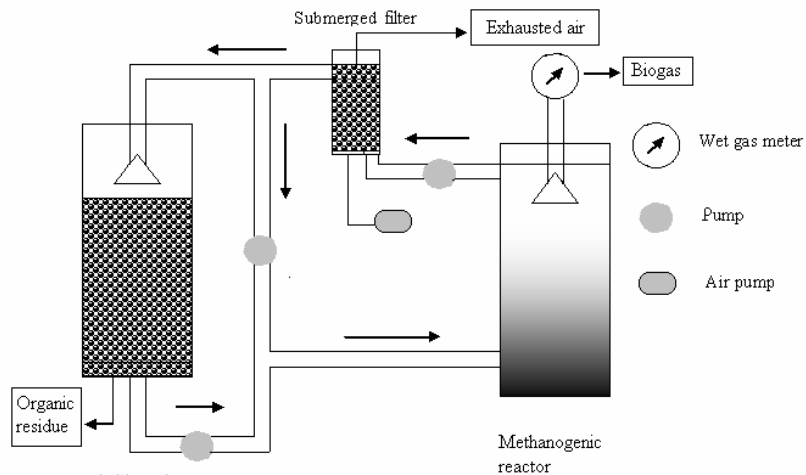
## HASL Bioreactor vs Conventional Anaerobic Digesters



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The mini pilot-scale HASL system

## The enhanced HASL system with submerged biofilter



Acidogenic  
reactor  
UNIVERSITY

## HASL Bioreactor vs Conventional Anaerobic Digesters



 **Submerged biofilter**  
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**Carrier and biofilm**

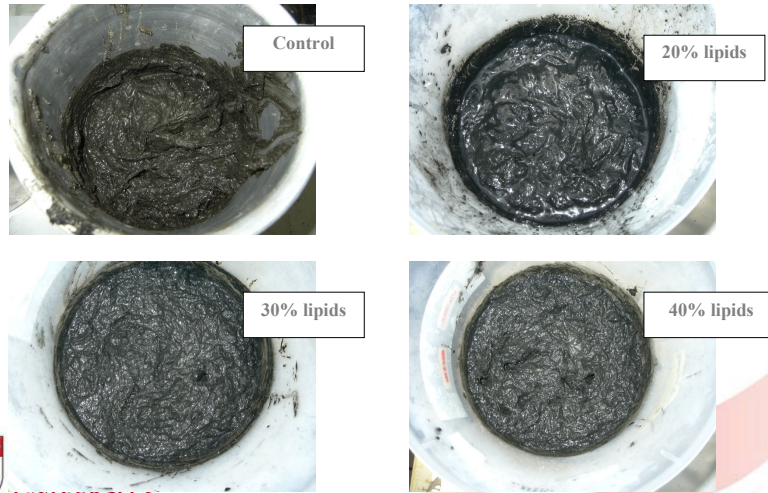
## Effects of lipid on HASL performance



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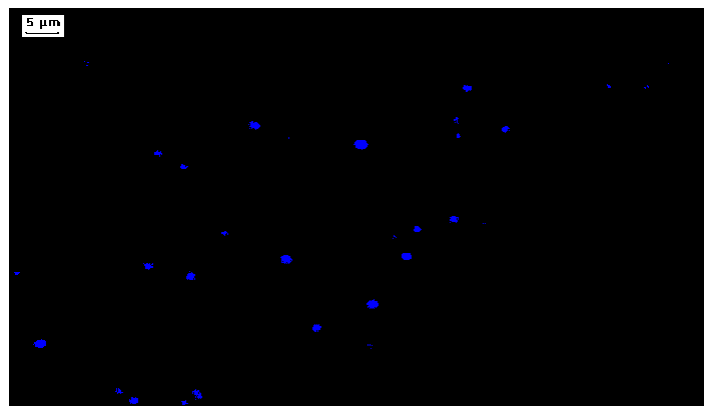
**Experimental setup**

## Effects of lipid on HASL performance



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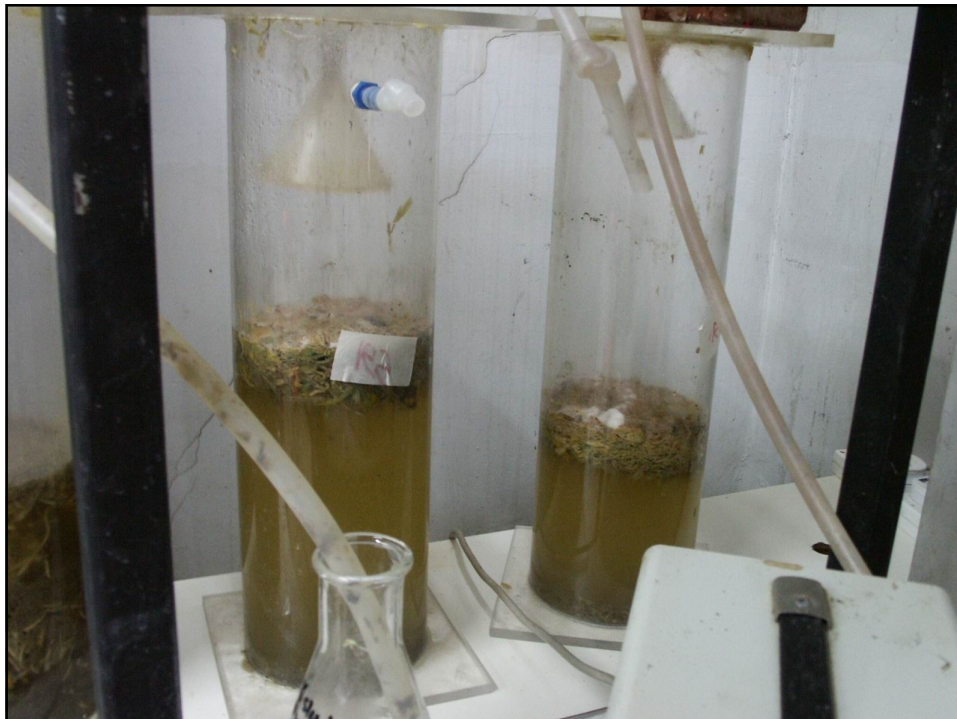
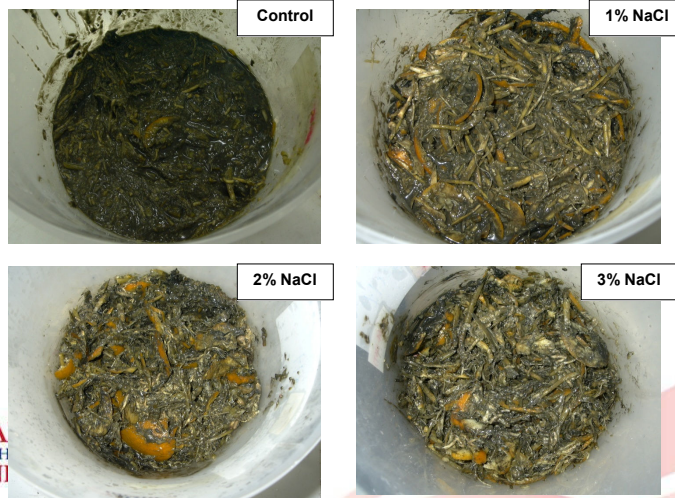
## Methanogenic bacteria



**NANYANG** methanogenic bacteria with autofluorescence  
TECHNOLOGICAL UNIVERSITY under epifluorescence microscope



## Effects of salt on HASL performance



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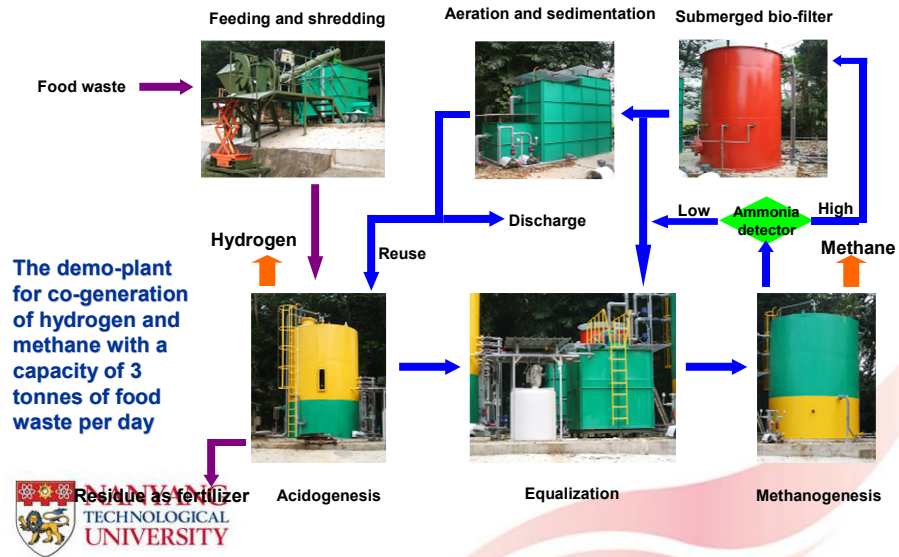
Effects of food waste fertilizers added in different dosages to subsoil on Kang Kong growth

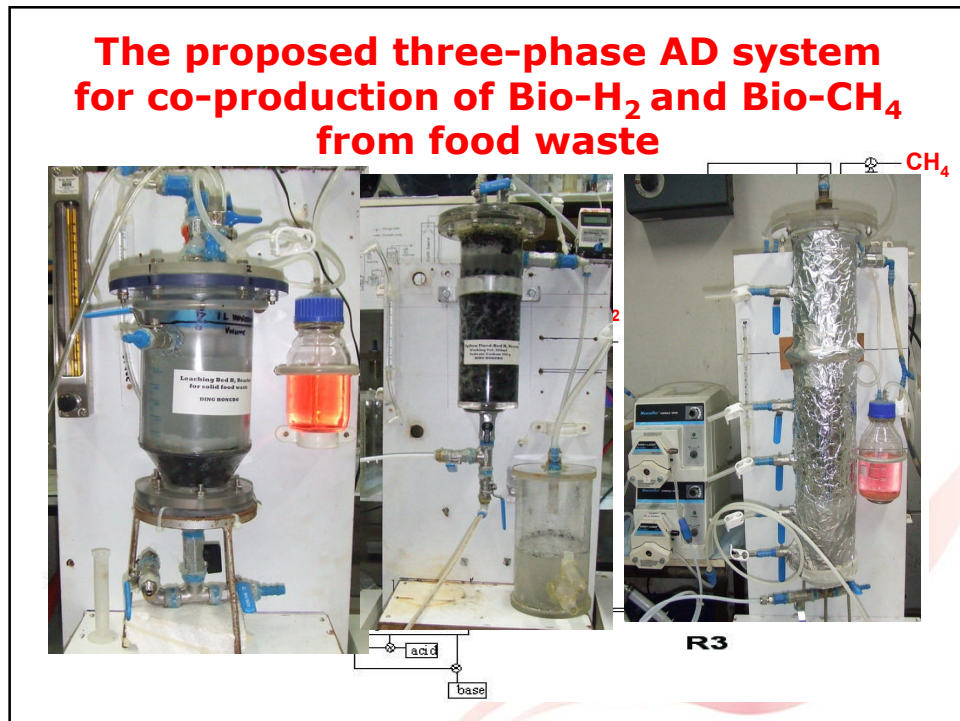
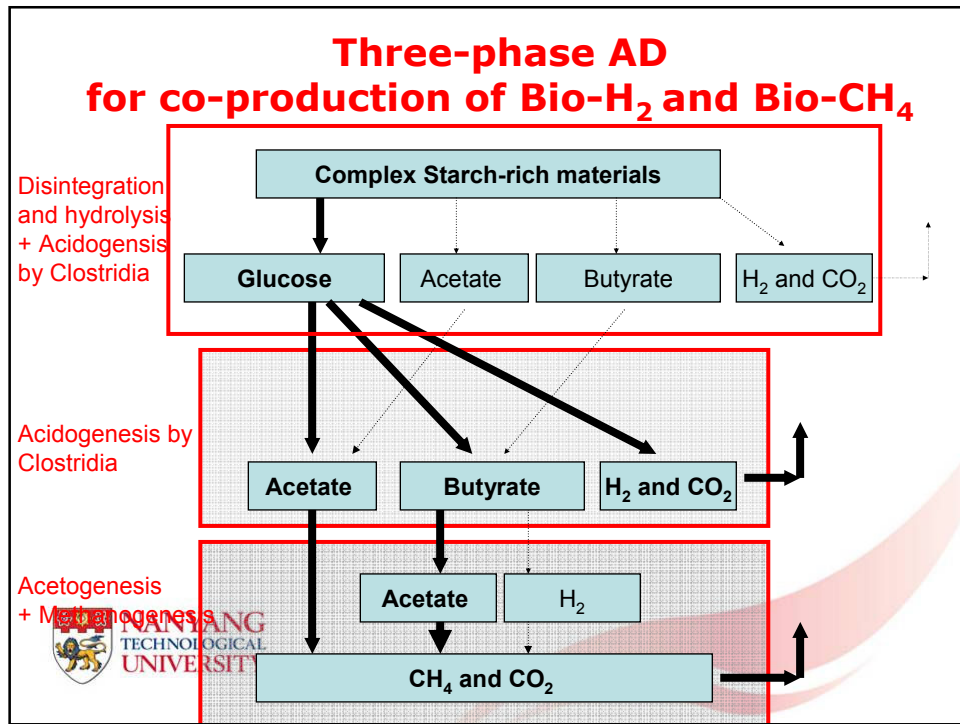
## HASL Pilot Plant @ NTU

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# NTU Research Activities (waste)

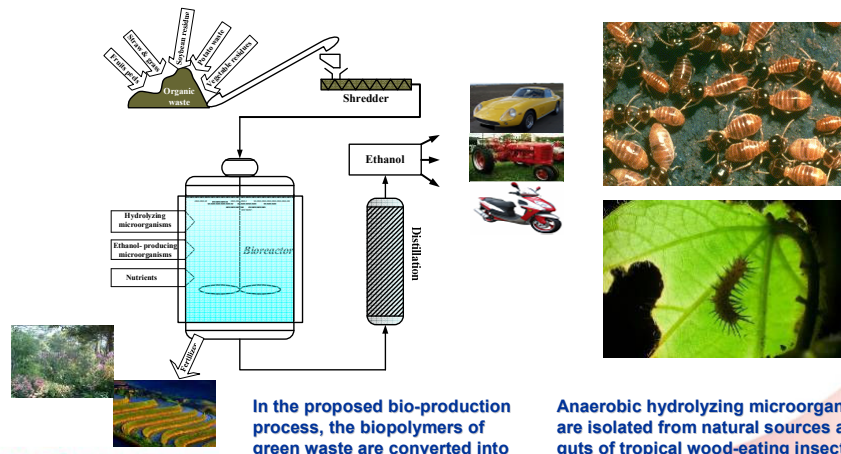
*NTU unleashes energy hidden in food waste*





# NTU Research Activities (Waste)

## Bio-ethanol Production from Green Wastes



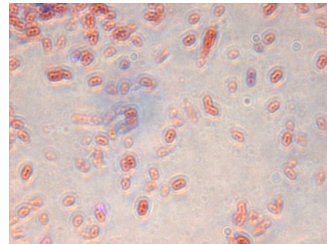
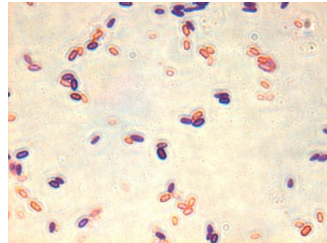
In the proposed bio-production process, the biopolymers of green waste are converted into ethanol due to the simultaneous activities of hydrolyzing and ethanol-producing microorganisms

Anaerobic hydrolyzing microorganisms are isolated from natural sources and guts of tropical wood-eating insects, like termites and caterpillars, to convert green waste into sugars as substrate for ethanol production

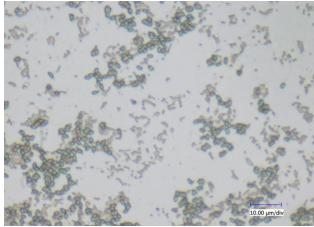
(unknown net source – thanks)



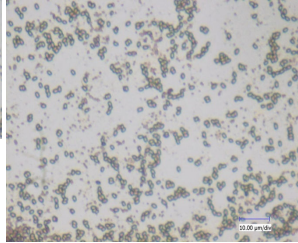
## Termites and their Intestinal Microbes



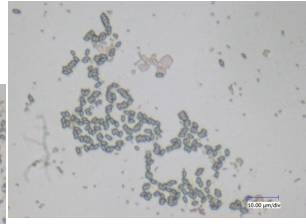
## Gram staining



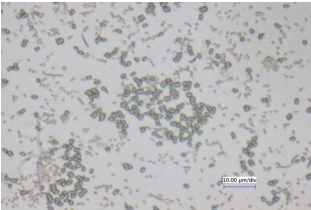
Isolation from 1yr compost (x3000)



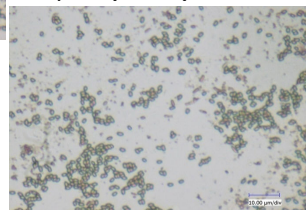
Isolation from termite guts (x3000)



Isolation from 3-4 M compost (x3000)



Isolation from aerobic sludge (x3000)

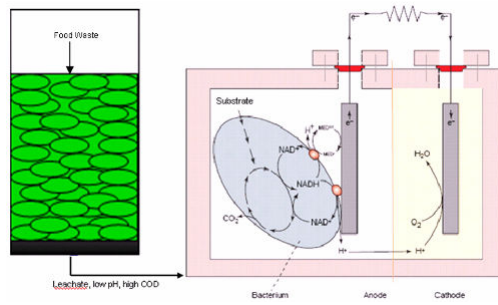


Isolation from garden soil (x3000)



## NTU Research Activities (waste)

### Waste to Electricity with Microbial Fuel Cell

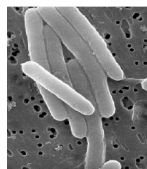


➤ Innovations: Mediator-less, membrane-less, electrode with big surface area

➤ Using naturally-occurring microorganisms or facultative anaerobic iron-reducing bacteria

➤ Changing bioreactor design configuration to avoid the use of membranes

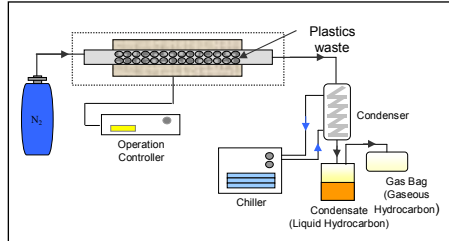
➤ Using an electrode with very large surface area to enhance electron transfer



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## NTU Research Activities (Waste)

### Energy Recovery from Plastics Waste using Pyrolysis

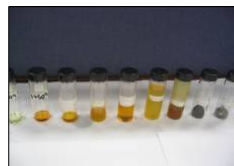


Pyrolysis diagram

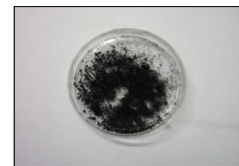


Experimental setup

- Recover energy from plastics waste with thermal treatment
- Products (gas, liquid, solid) with high potential for reuse
- Good for waste minimization



Liquid products from pyrolysis

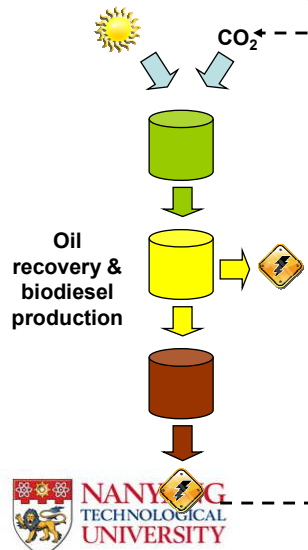


Ash collected



## NTU Research Activities (Waste)

### Algae Biofuel



- As primary producers, algae presents a great potential for converting sunlight into chemical energy. This project explores the potential of biofuel production from algae in Singapore.

- Alpha Synovate Pte. Ltd.  
Alpha Biofuels Singapore

Benoit Guieysse, Wang Jing-Yuan,  
Tan Hai Woon and Allan Lim



# NTU Research Activities (Waste)

## *Biomass Derived Fuel (BDF)*



(Global Environment Centre Foundation)







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**Thank You**

## **Energy Resource Management (Diversification)**



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## Energy Resource Management (Integration)



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## Energy Resource Management (Decentralization)



(unknown net source – thanks)

## Energy Resource Management (Conservation)



(unknown net source – thanks)

## Energy Resource Management

开源 · 节流

