有機物產氫與產甲烷技術開發

林秋裕

逢甲大學綠色能源發展中心

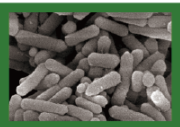
2015/7/17

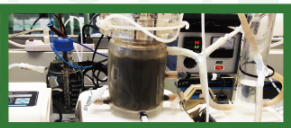
大綱

1. 厭氧消化之意義(產氫與甲烷)

2. 廢棄物/廢水變氣態生質能源

3.氣態生質能源的未來





Environmental Science & Technology

FEATURE

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Domestic Wastewater Treatment as a Net Energy Producer—Can This be Achieved?

Perry L. McCarty,*[,†,‡] Jaeho Bae,[‡] and Jeonghwan Kim[‡]

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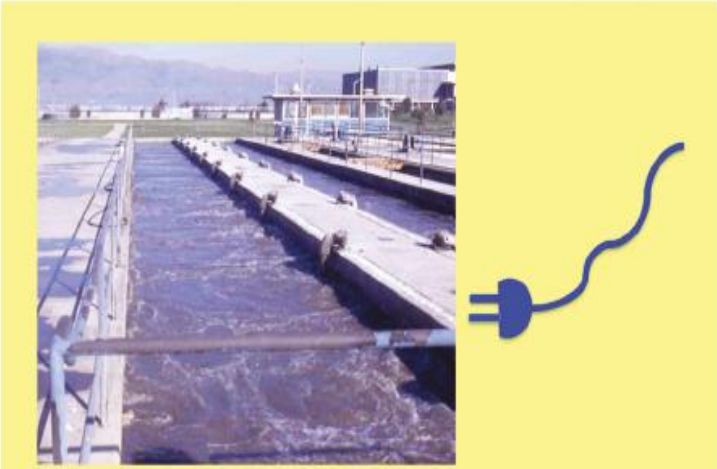
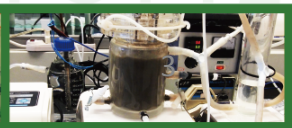


more efficient water and nutrient recovery from wastewater are important goals in themselves, the focus of this article is how we can more completely recover wastewater's energy content.

Wastewater treatment accounts for about 3% of the U.S. electrical energy load,[4] similar to that in other developed countries.[5] The energy needs for a typical domestic wastewater treatment plant employing aerobic activated sludge treatment and anaerobic sludge digestion is 0.6 kWh/m^3 of wastewater treated, about half of which is for electrical energy to supply air for the aeration basins.[3,5] With conventional approaches involving aerobic treatment a quarter to half of a plants energy needs



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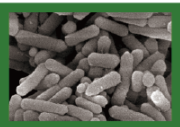
Can two-stage instead of one-stage anaerobic digestion really increase energy recovery from biomass?

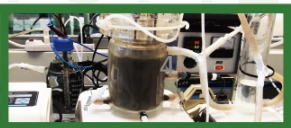
A. Schievano *, A. Tenca, S. Lonati, E. Manzini, F. Adani

Gruppo Ricicla – Department of Agricultural Environmental Science (DISAA), Università degli Studi di Milano, Via Celoria, 2, 20133 Milano, Italy

HIGHLIGHTS

- Two-stage anaerobic digestion should be more productive than traditional process.
- Energy recoveries ($H_2 + CH_4$ *vs* CH_4) were compared through a new method.
- Four different substrates at nine different experimental conditions were tested.
- Two-stage recovered 8%–43% more energy than one-stage and never significantly less.
- Deeper research should be addressed to prove the convenience of two-stage approach.

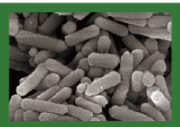


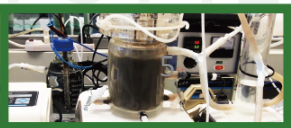


厭氧消化與醱酵之意義

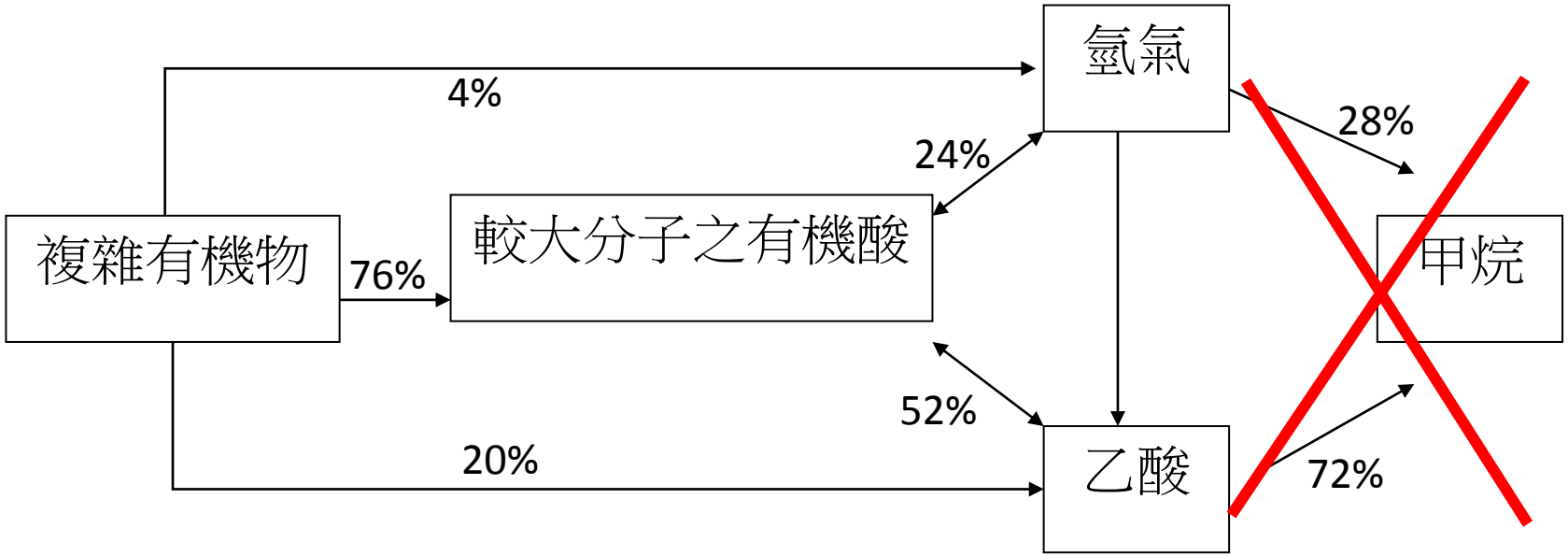
- 厭氧消化(anaerobic digestion)
  - —強調有機廢棄物之分解
  - —例:污泥消化

- 厭氧醱酵(anaerobic/dark fermentation)
  - —強調有機物分解之產物
  - —例:甲烷醱酵、氫醱酵、丁醇醱酵





厭氧分解－自然界存在的！



水解作用
(第一步)

酸化與去氫作用
(第二步)

甲烷形成作用
(第三步)

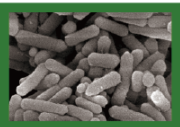
常被消化/酸酵的有機物--生物質 (Biomass)

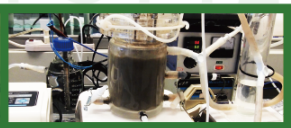
◆人類活動產生的有機物

- 污水下水道：水肥、污水處理廠污泥
- 一般廢棄物：廚餘、垃圾
- 農業廢棄物：禽畜糞尿、木材、稻殼及蔗渣等
- 工業廢棄物：有機污泥、廢塑橡膠及廢紙

◆生物質量/生物質（biomass）

- 係指生態系中所有生物的總質量。
- 泛指生態系中能做為生質能源料的有機物。





生質能定義

我國再生能源發展條例 (2009.7.8) 第三條

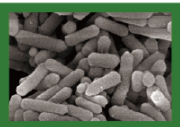
3.1、再生能源：指太陽能、生質能、地熱能、海洋能、風力、非抽蓄式水力、國內一般廢棄物與一般事業廢棄物等直接利用或經處理所產生之能源，或其他經中央主管機關認定可永續利用之能源。

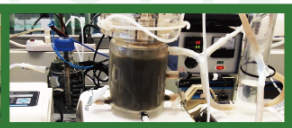
3.2、生質能：指農林植物、沼氣及國內有機廢棄物直接利用或經處理所產生之能源。

3.6、氫能：指以再生能源為能量來源，分解水產生之氫氣，或利用細菌、藻類等生物之分解或醱酵作用所產生之氫氣，做為能源用途者。

3.7、燃料電池：指藉由氫氣及氧氣產生電化學反應，而將化學能轉換為電能之裝置。

3.8、再生能源熱利用：指再生能源之利用型態非屬發電，而屬熱能或燃料使用者。

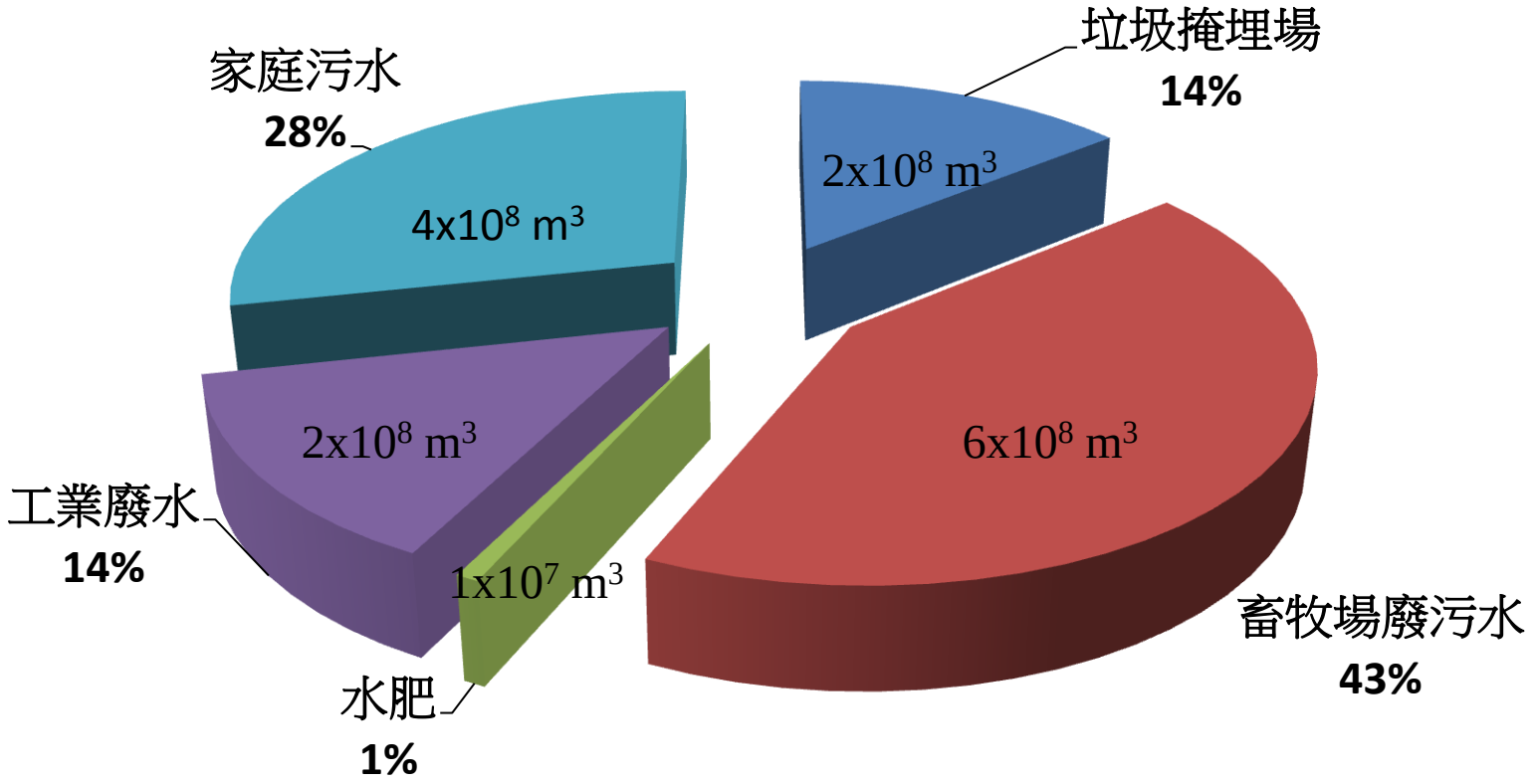




沼氣

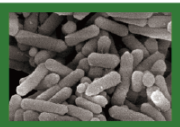
生質能

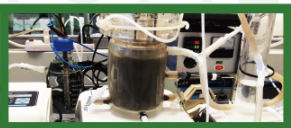
台灣各事業沼氣年產量潛能評估



全台各事業每年生產沼氣潛能約 1.5 x 10^9 立方米， 若完全發電可產生 19 億度，佔台灣總用電量 0.9~1.0%.

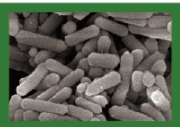
Source: 曾慶平教授，建立畜殖廢棄物沼氣發電系統與微藻減碳及產製藻油生質柴油

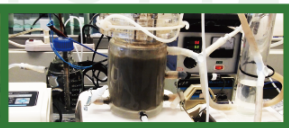




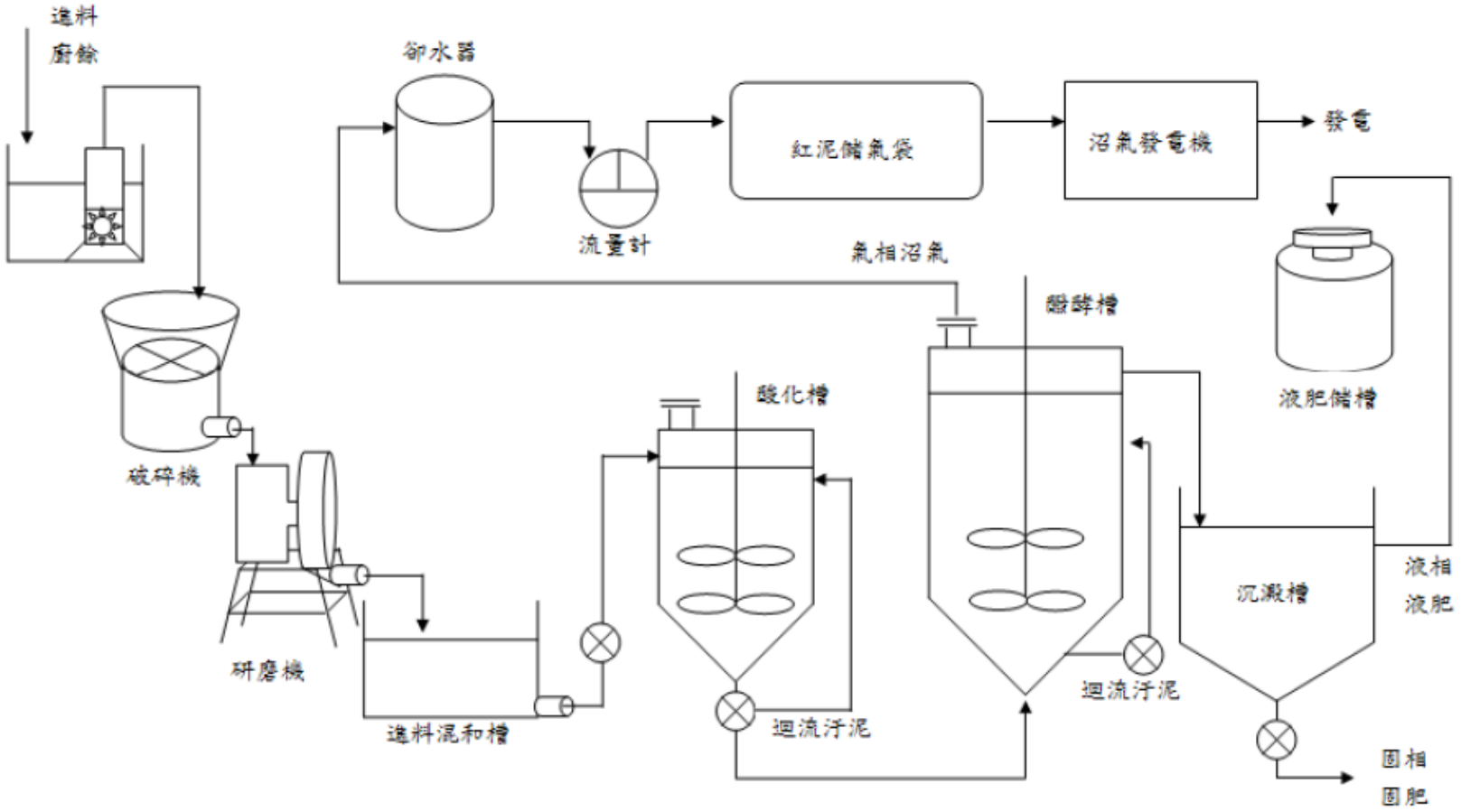
沼氣醱酵實績-八里污水處理廠

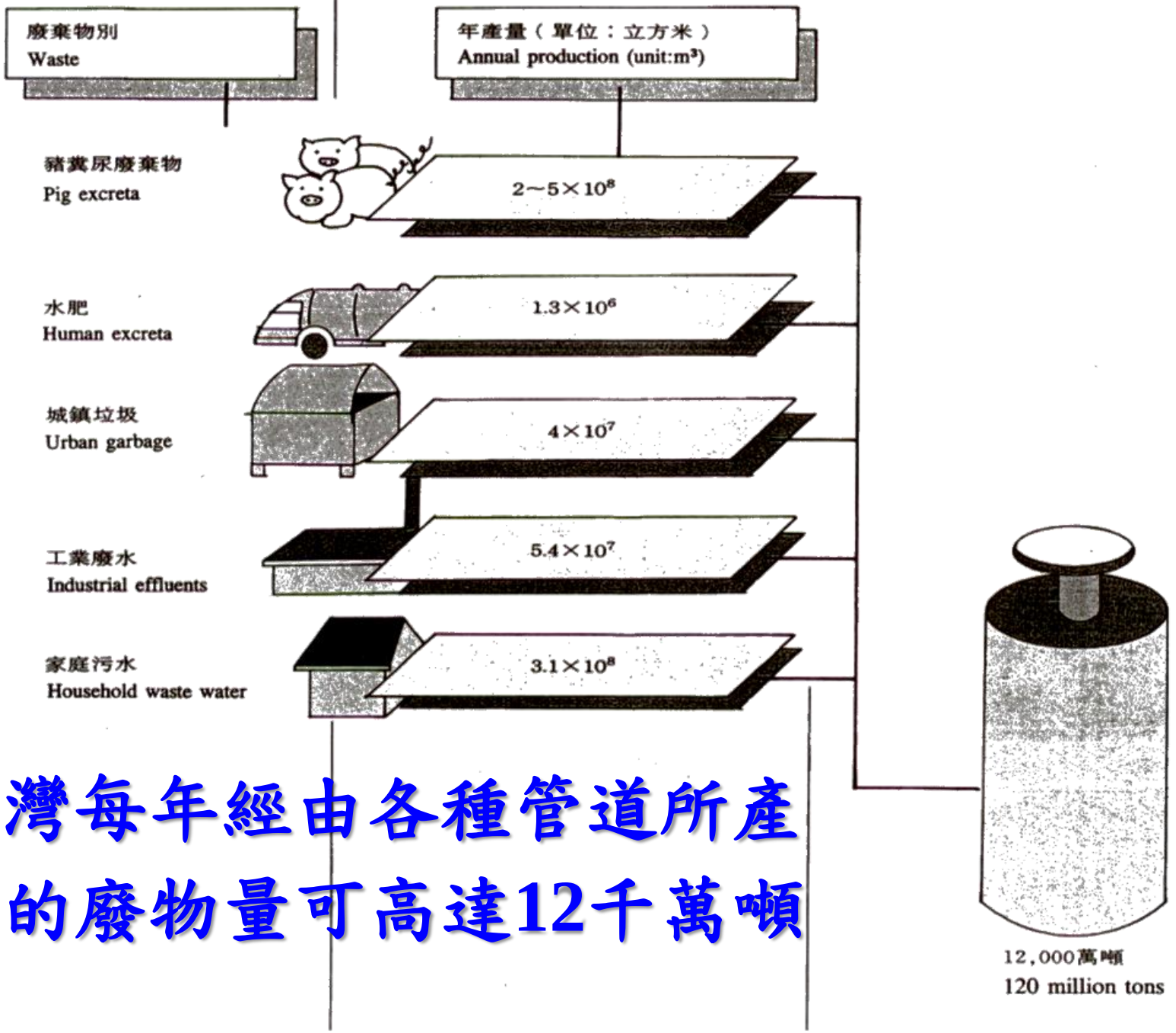
Source: YouTube 八里污水處理廠產生沼氣原理





屏東六塊厝厭氧醱酵系統處理流程

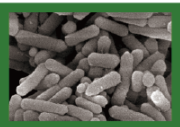


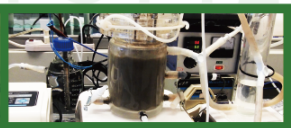


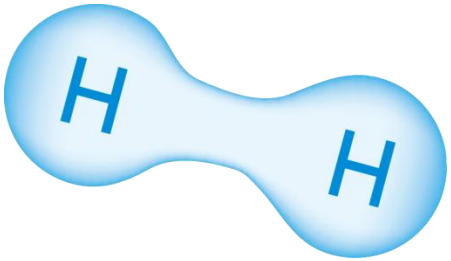
台灣每年經由各種管道所產生的廢物量可高達12千萬噸

氫氣

生質能







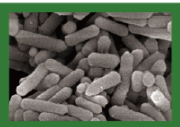
氫

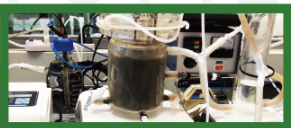
＋

燃料電池

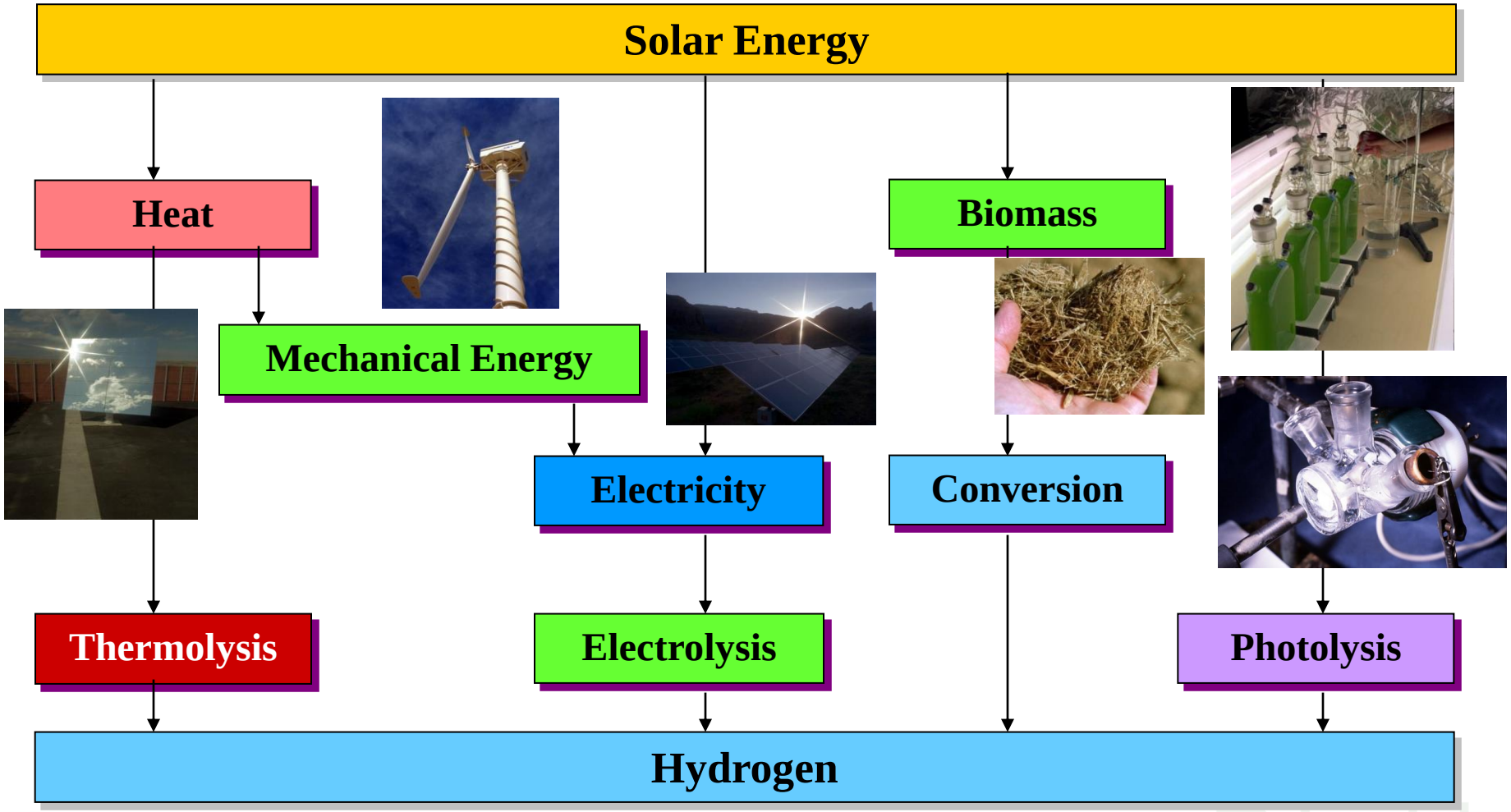
＝

水





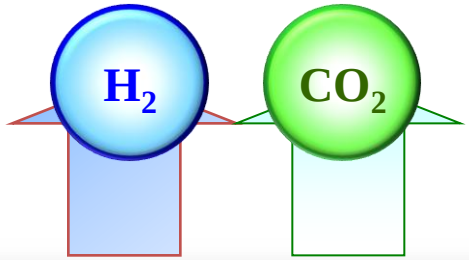
永續的產氫程序

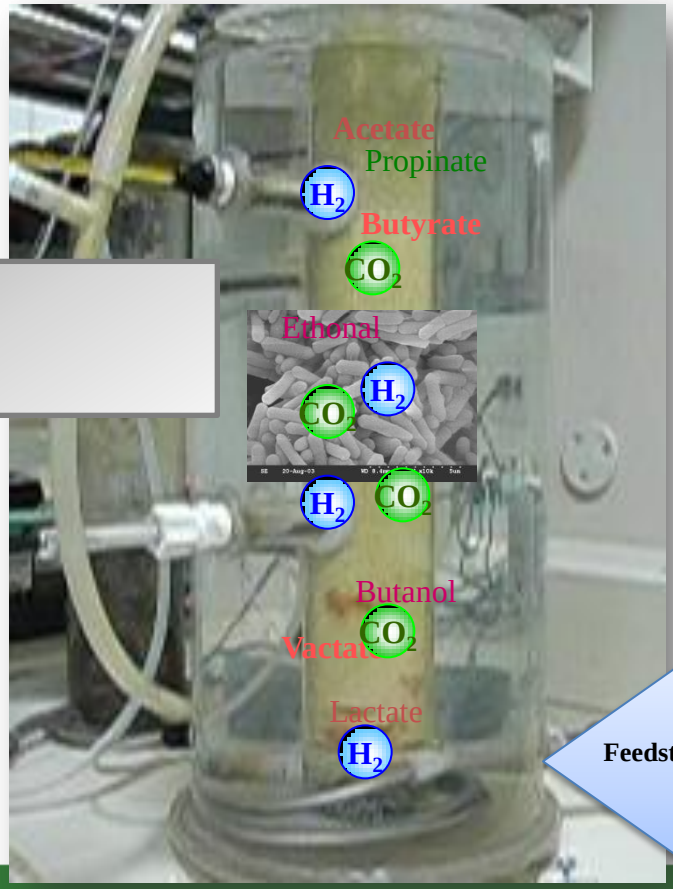


Source: Peter Lindblad, Photochemistry & Molecular Science Uppsala University, Sweden

逢甲大學HyMeTek產氫技術演進圖

厭氧產氫反應



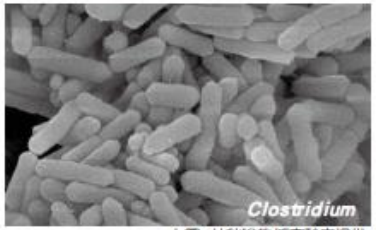


VFAs
Alcohol

Feedstock **Feedstock** **Feedstock** **Feedstock**

視糞土如黃金

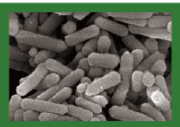
喚醒蟄伏已久的氫能細菌

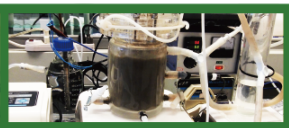


上圖：林秋裕教授實驗室提供

自然界中有很多看不見的細菌，他們對環境卻扮演相當重要的角色。常見的醱酵微生物菌群主要可分為三屬，分別是 *Bacillus*、*Enterobacter* 及 *Clostridium*，其中以 *Clostridium* 具有優異的氫能源生產潛力。而這些微生物，大多隱身在家畜糞便（如牛糞、豬糞等）、廢水廠污泥、海邊的爛泥、竹林中的腐爛泥土等。

所以，要做厭氧產氫實驗的第一步，就是得先蒐集這些大家避之唯恐不及的"黃金"，再從裡面喚醒"氫能細菌"。





製作固定化細胞

Cells with high H_2 producing activity

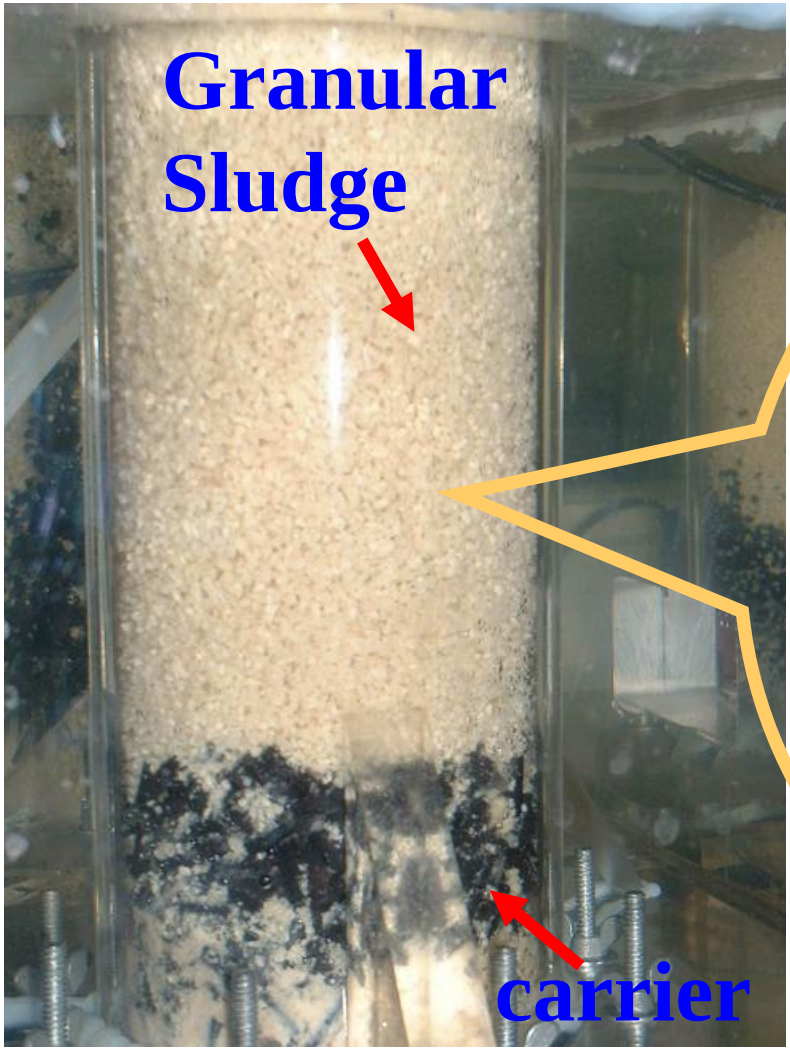
Mixed with AC and poly meric matrix

Making immobilized cells

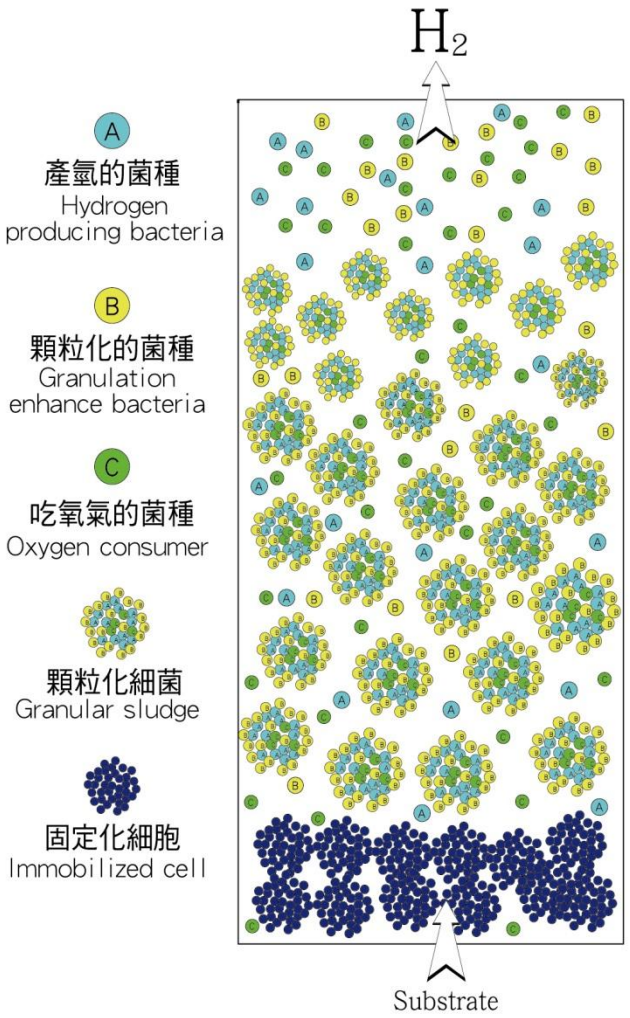
Introduced into a bioreactor

Bioreactor operation

高速率厭氧生物反應槽

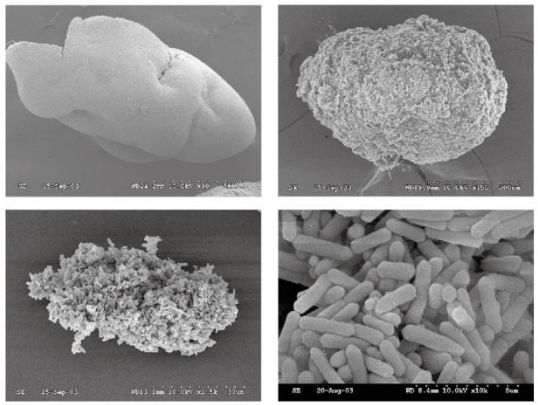


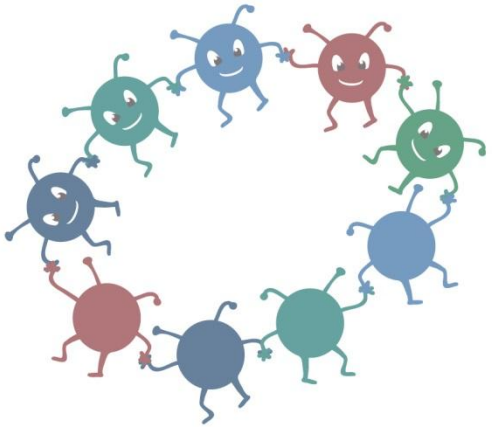
微生物的顆粒化 Granulation of Sludge Bacteria



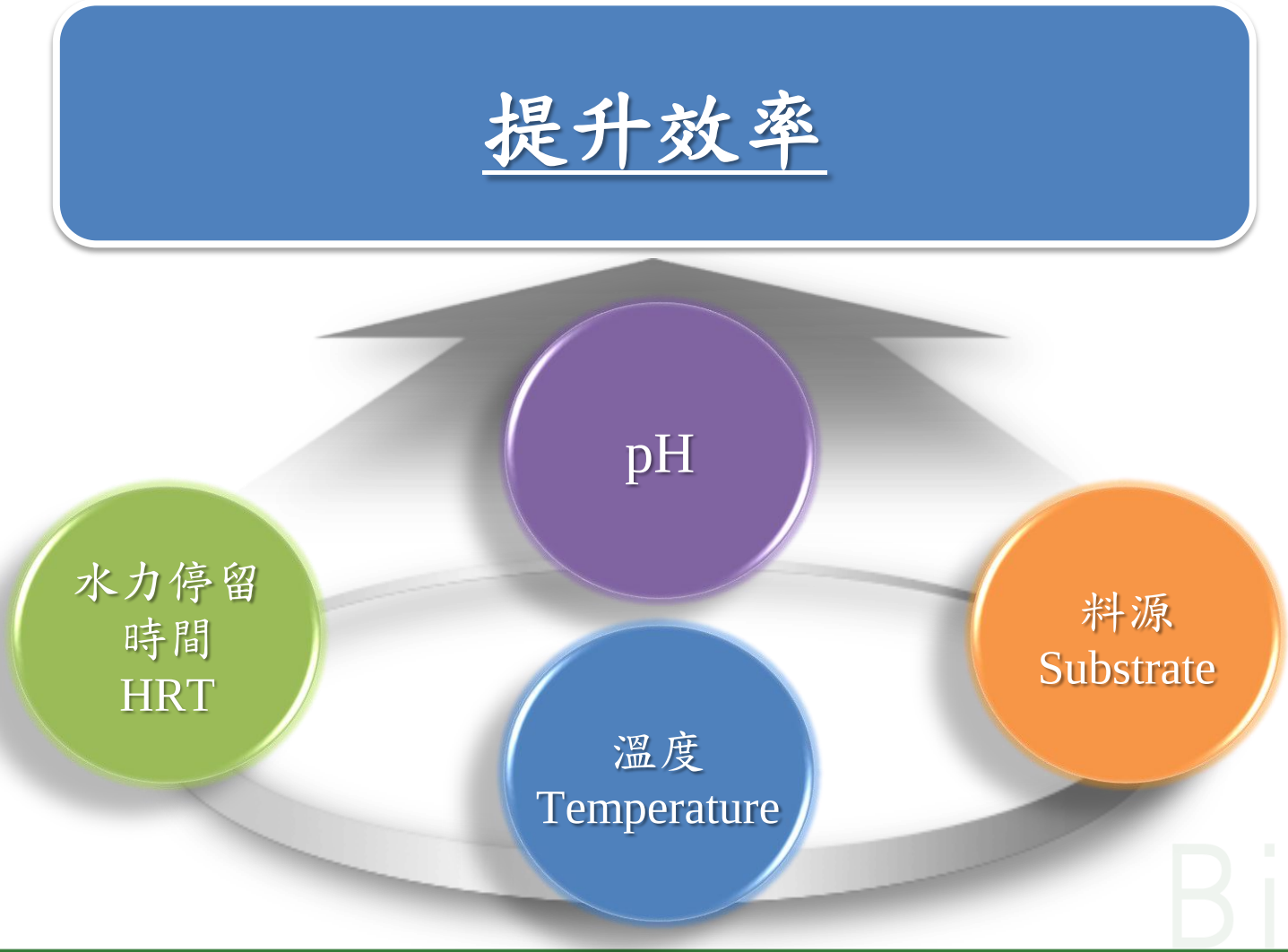
大量的微生物互相黏附而形成顆粒狀，稱為顆粒性微生物。細菌經過顆粒化後，由於濃度提升可使醱酵槽以高進料速率操作，提升氫氣產製的速率。

Formation of granular sludge is formed by bacterial aggregation. High biomass concentrations can enhance the hydrogen production rate at high organic loading-rate.

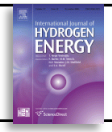




影響厭氧產氫/甲烷效率的主要因子



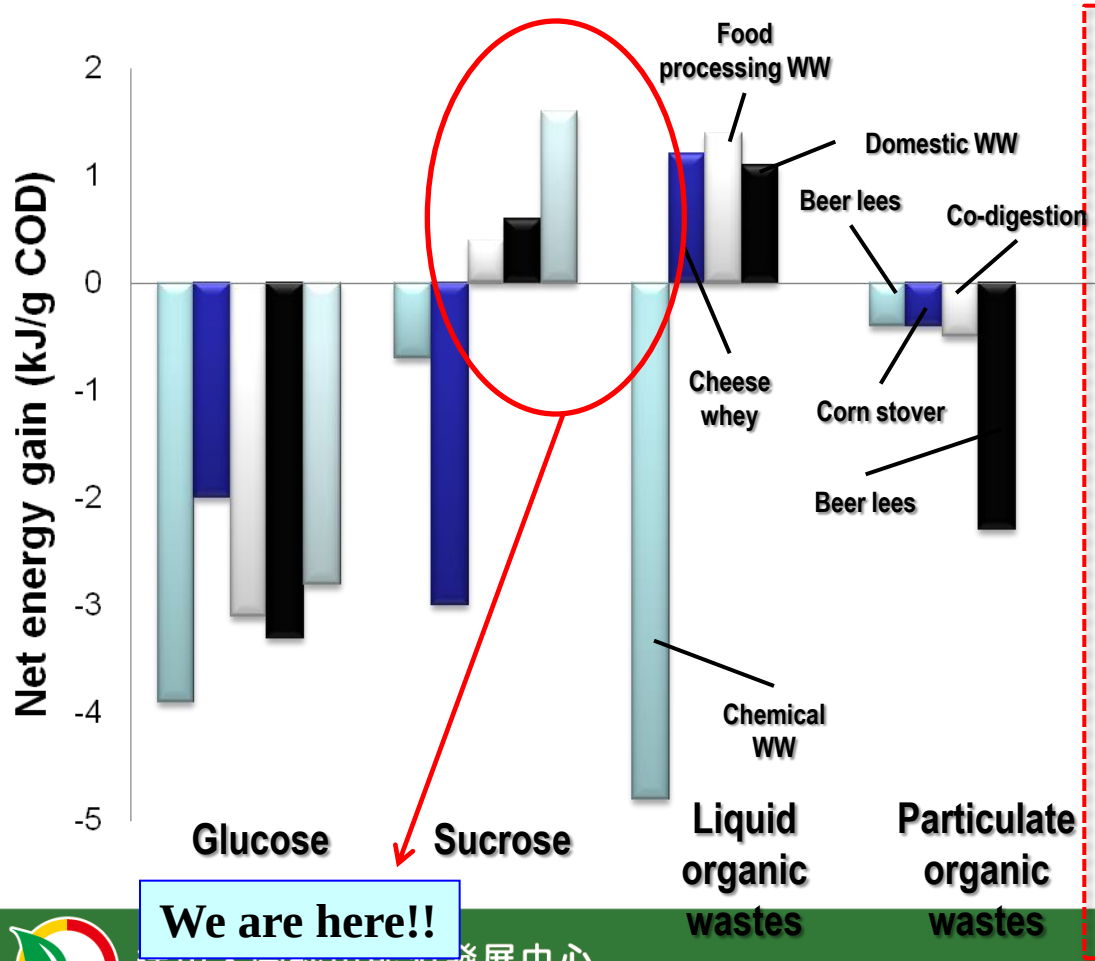
The highest volumetric rate of –H_2 production (15L/L/h) in the literatures by FCU's HyMeTek

Time	2004	2007	2008
Affiliations	Victoria Univ., Canada	Glamorgan Univ., UK	Nanyang Technological Univ., Singapore
Commentator			Zhang et al.
Journals			

1st world record in peer Journal revealed.

Time			2012
Affiliations	KA…	…man, Malaysia	Institute of Basic Biological Problems, Russian Academy of Sciences
Commentator	Shin et al.	Show et al.	Tekucheva and Tsygankov
Journals	Bioresource Technology	International Journal of Hydrogen energy	Applied Biochemistry and Microbiology

逢甲大學生物產氫技術是國際少數可獲得正能源回收者



In this study

Raw: 0.97 kJ/g COD

Thermal: 1.54 kJ/g COD

After pretreatment:

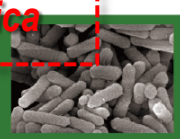
Net energy gain: + 0.57 kJ/g COD

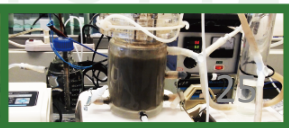
But.. Thermal pretreatment →

Economic burden !

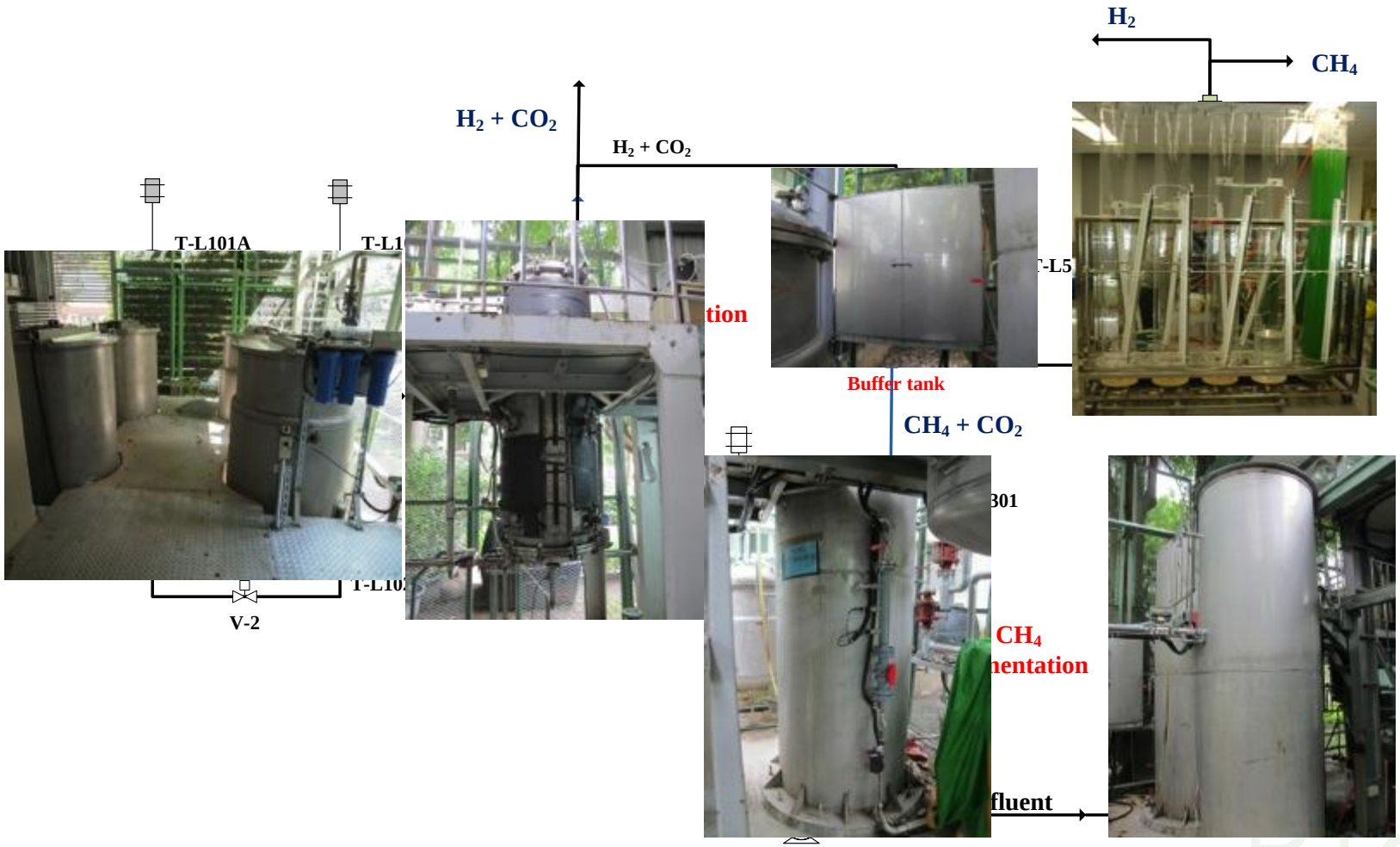
- Utilization of waste heat
- Post treatment system

Perera K.R.J., 2010



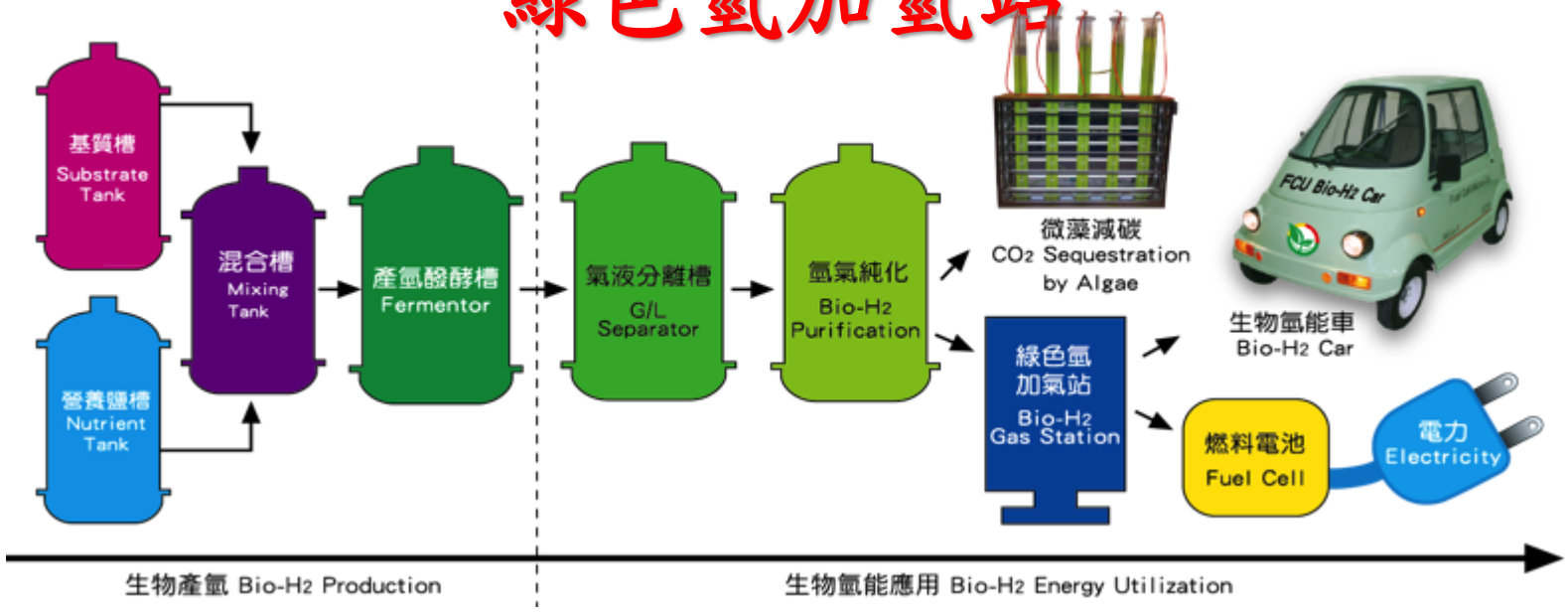


HyMeTek and Microalgae CO2 Fixation



厭氧生物產氫模場

綠色氫加氫站


基質槽
Substrate Tank
營養鹽槽
Nutrient Tank
混合槽
Mixing Tank
產氫醱酵槽
Fermentor
氣液分離槽
G/L Separator
氫氣純化
Bio-H2 Purification
微藻減碳
CO2 Sequestration by Algae
綠色氫加氣站
Bio-H2 Gas Station
燃料電池
Fuel Cell
電力
Electricity
FCU Bio-H2 Car
生物氫能車
Bio-H2 Car
生物產氫 Bio-H2 Production
生物氫能應用 Bio-H2 Energy Utilization


綠色氫加氣站


綠色氫加氣站
EV
EV

Bio-H2 gas-Fuel Station and mini-Fuel Cell Car

商業化氫能車與加氫站


Hydrogen Station
水素ステーション


Zero Emission Hydrogen Fuel Cell Bus


FCV-R

逢甲大學開發的低能耗射頻電漿氫氣重組器
Low energy consumption RF plasma-based H_2 reformer

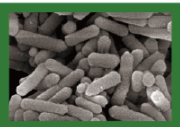
型號/規格
H_2 reformer R1

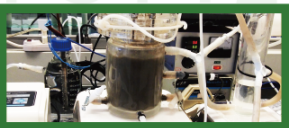
- **可直接導入甲烷氣體重組**
  Compatible for current anaerobic digester
- **高甲烷轉化氫氣效率**
  High methane conversion rate
- **常溫操作低耗能設計**
  Operation at room temperature with low energy consumption
- **客製化設計**
  Customized design

逢甲大學是國際綠色氫能研究重鎮

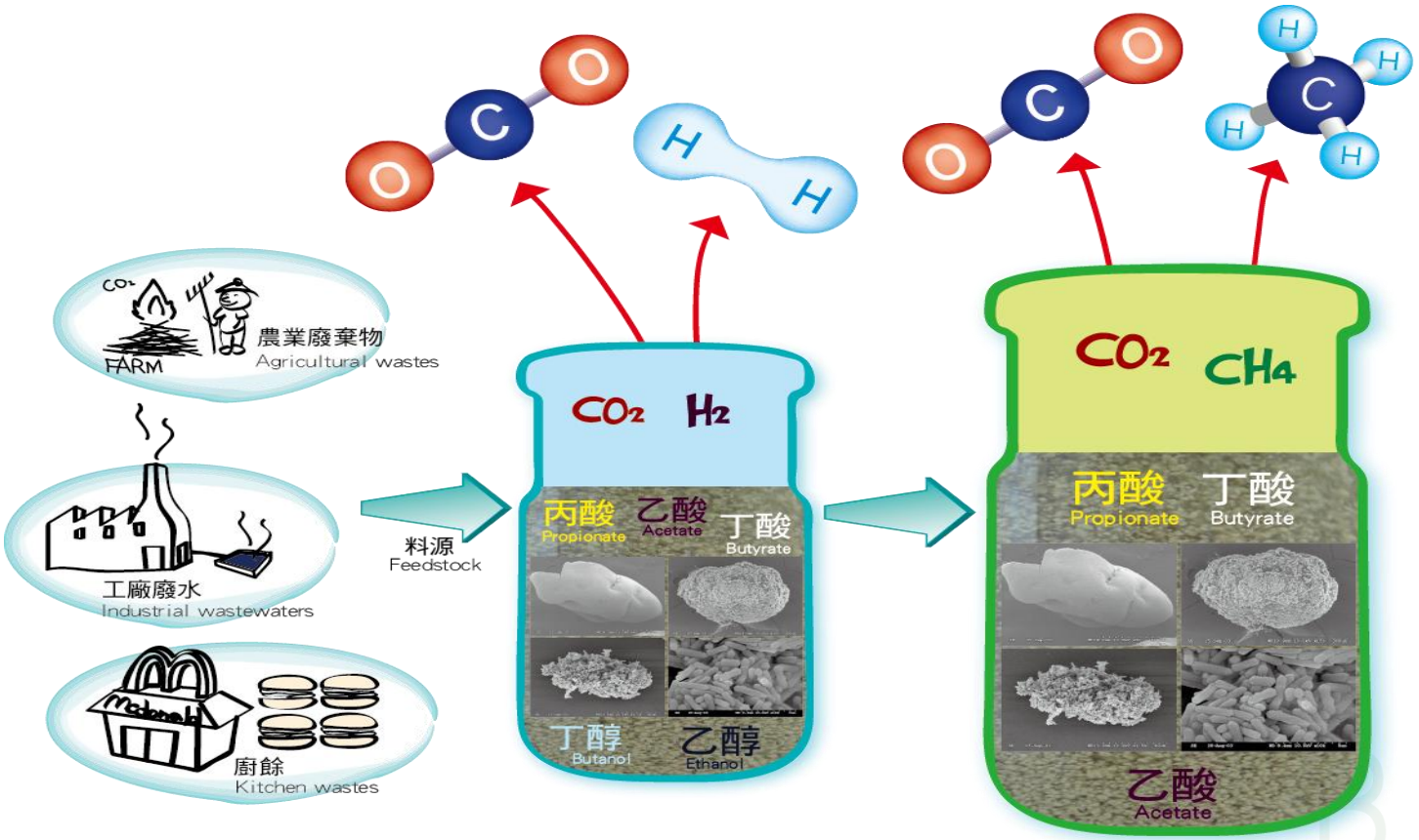
氫烷氣

生質能





逢甲大學HyMeTek 技術之原理
(兩階段式產氫與甲烷)
(Innovative Hydrogen and Methane Production Technology)

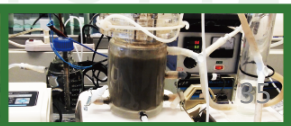


氫烷氣(hythane)之優點

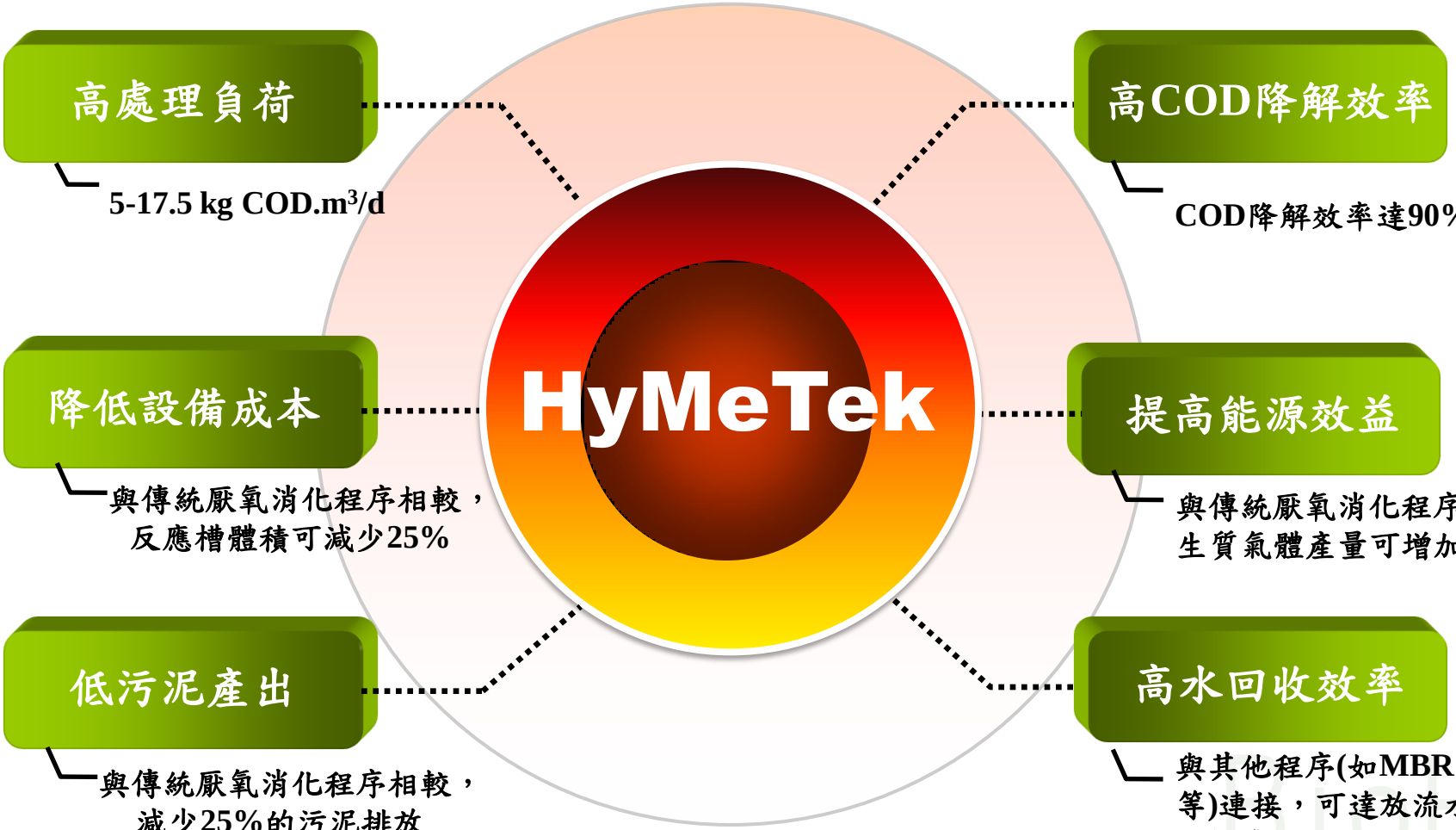
- 何為Hythane: 氫氣 10-60% (v/v) + 甲烷 [1]
- 加入內燃機燃燒比天然氣的優勢
  - 增加燃燒效益：將氫氣與甲烷以不同之混合比例(3:7以內)，其燃燒效率可提高20-30%。
  - 減少燃料消耗
  - 顯著減少CO, CO_2,以及氮氧化物 [2]
- 目前Hythane均由天然氣經觸媒轉換而得(效率低且非永續燃料)
- 厭氧醱酵產氫+甲烷是一個可以產出質量兼具biofuel的永續製程 (Bio-Hythane Process) [3,4]
- 因此， Bio-Hythane是最具潛力的替代能源之一
- 目前文獻最佳的Hythane燃燒氣體組成為:甲烷44.8%, $CO_2$38.7%, 氫氣16.5% [5]。 Bio-Hythane Process可輕易達成。

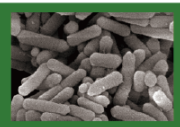
[1] Gattrell et al., Energy Convers. Mgmt. 2007, 48(4), 1255-1265.
[2] Alavandi, S. and Agrawal, A., Int. J. Hydrogen Energy 2008, 33(4), 1407-1415.
[3] Cavinato et al., Bioresour. Technol. 2010, 101(2), 545-550.
[4] Lee et al., Bioresour. Technol 2010, 101(1S), 42-47.
[5] Porpatham et al., Int. J. Hydrogen Energy 2007, 32(12), 2057-2065.

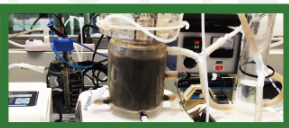




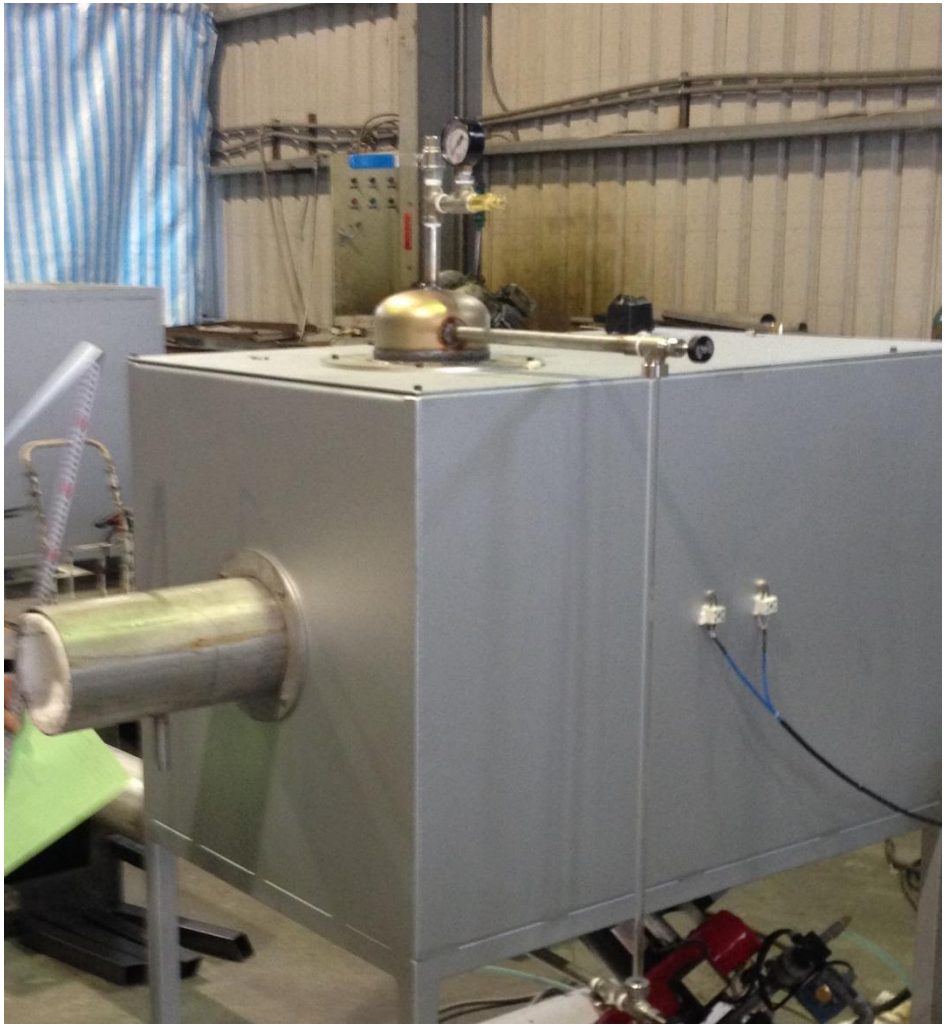
HyMeTek技術優點

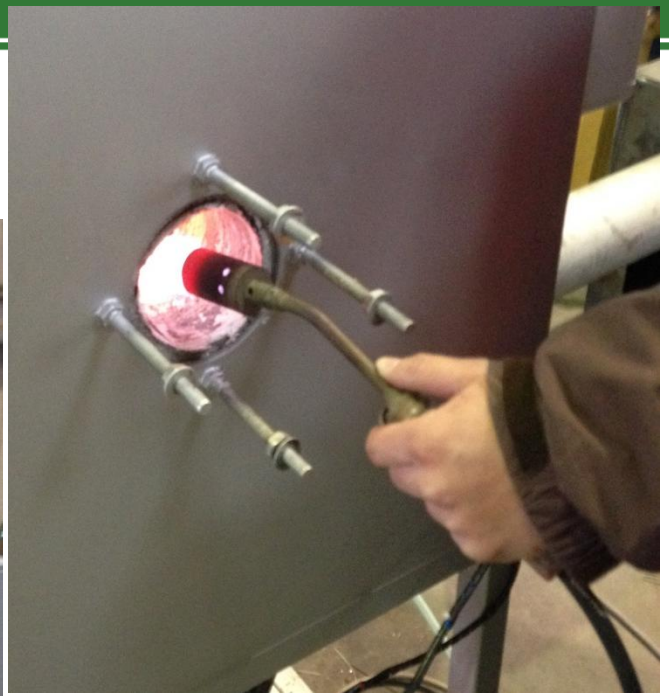


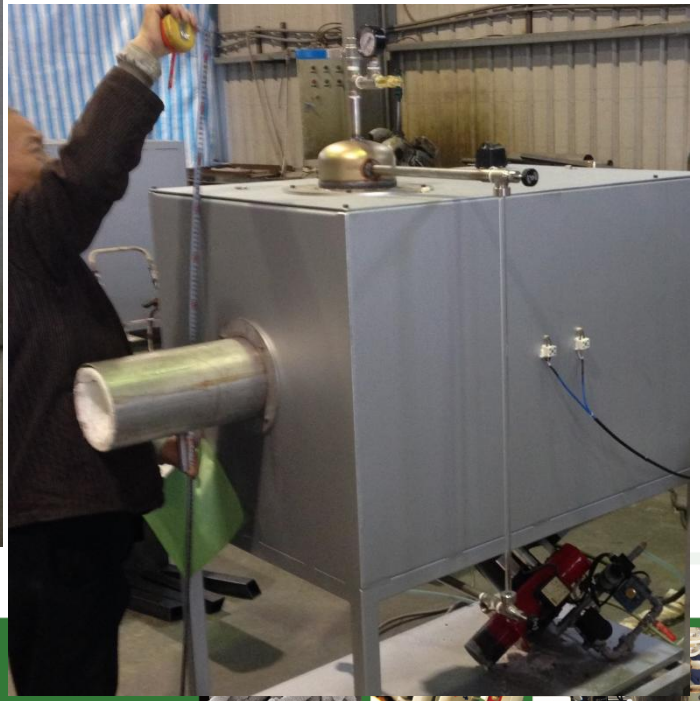




逢甲大學自製氫烷氣燃燒爐







逢甲開發的 HyMeTek Modules產品

➢ Mini $BioH_2/CH_4$ Production System for Laboratory

Module No./Specification

HyMeTek T01 (52 cm*38 cm*30 cm)

HyMeTek T01 (60 cm*60 cm*30 cm)

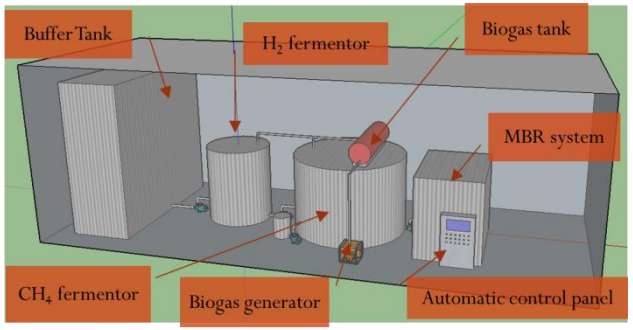
➢ $BioH_2/CH_4$ Production System for Mobile Task

Module No.: HyMeTek P35

Specification:

Size: 6.0 m*2.4 m*2.6 m

Capacity: 3.5 CMD



➢ Commercialized $BioH_2/CH_4$ Production System

Module No./Specification

HyMeTek C1 (50 CMD)

HyMeTek C6 (300 CMD)

1. **HPR: 2.2 m3 H2/m3/d**
2. **Hydrogen Content 48%**
3. **Total COD RE: 90%**

逢甲開發”氫氣+甲烷氣的移動型發電站”

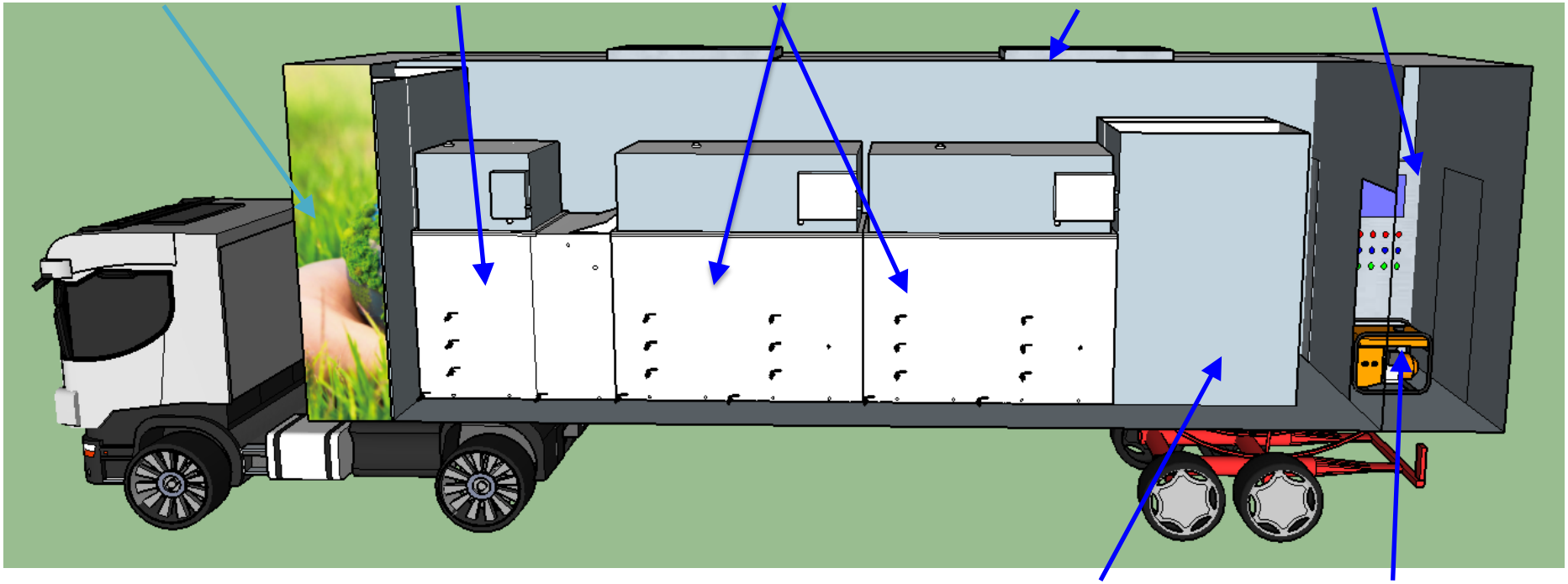
料源儲槽
Feedstock tank

產氫(酸化)槽
H_2 fermentor

甲烷醱酵槽
CH_4 fermentor

太陽能板
Solar Panel

自動控制系統
Auto Control System

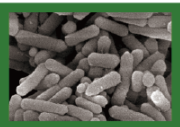


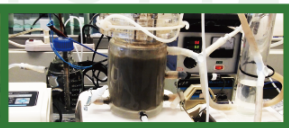
沼氣純化系統
Purification system

沼氣儲氣袋
Biogas bag

薄膜生物反應槽
MBR

沼氣發電機
Biogas generator



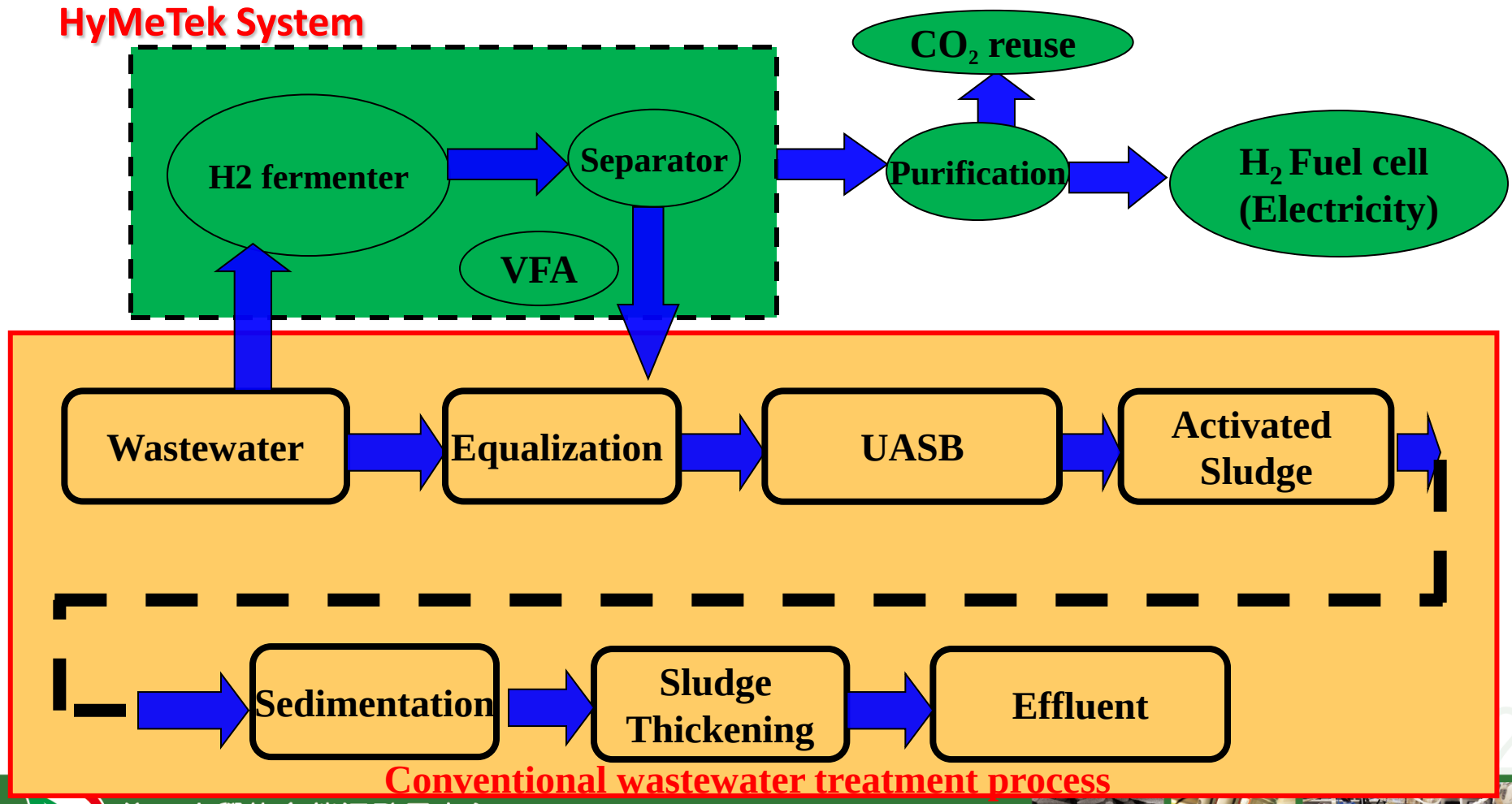


This system will test run in Beer and Paper Manufacturing Factories this year.

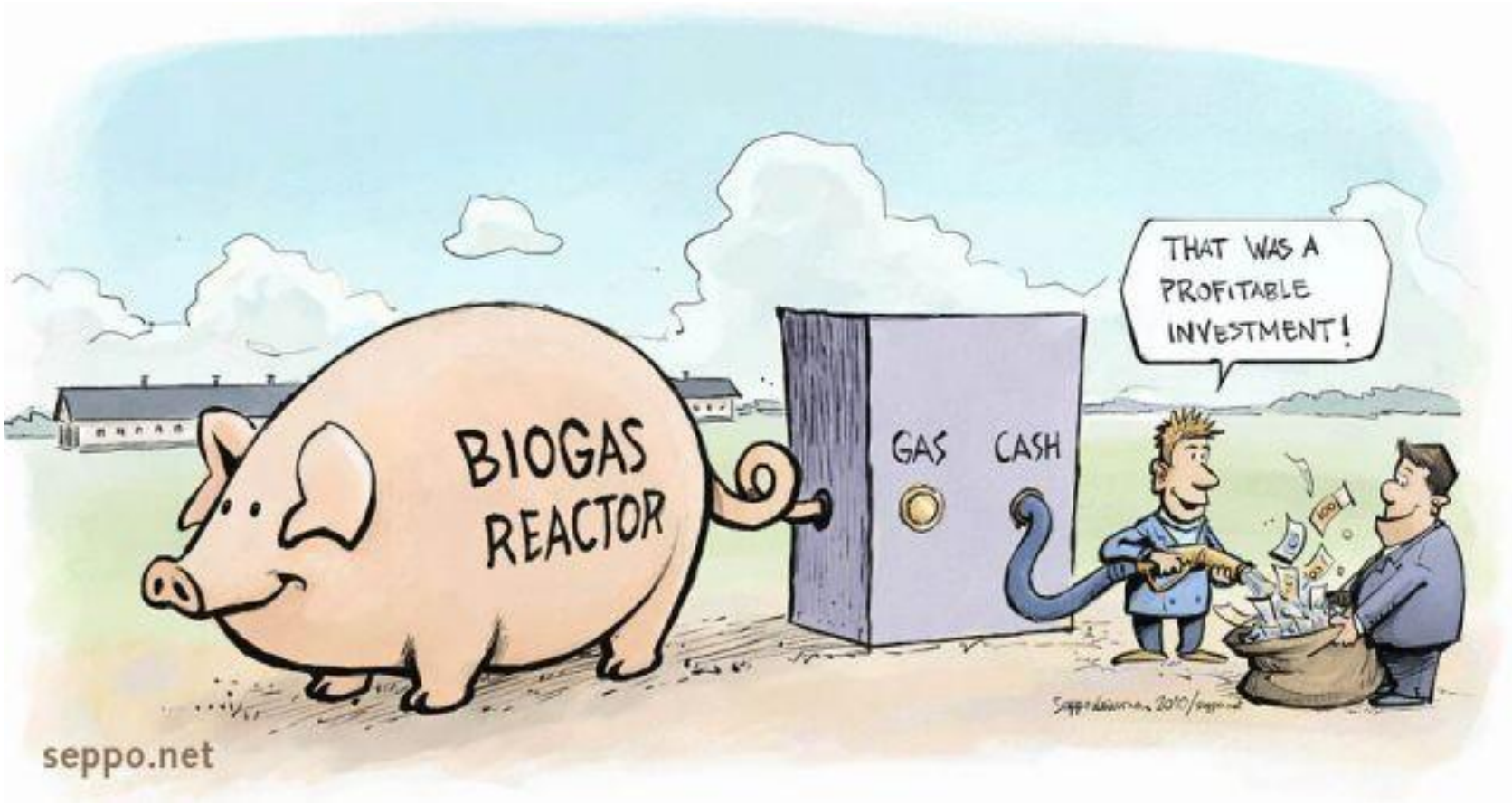
Most important stage to commercialize - Demo plant (H_2 = 2 m^3; CH_4 = 50 m^3)

– HyMeTek in Food Factory

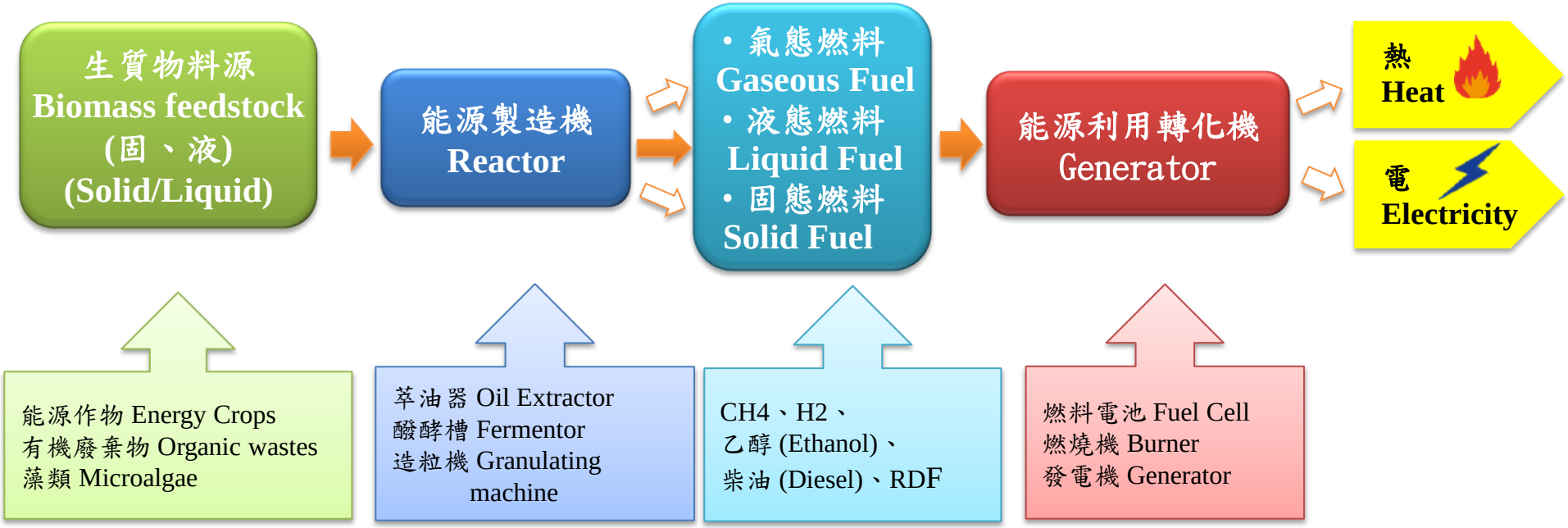
HyMeTek system 能簡單的串接
既有廢水處理系統



http://www.seppo.net/cartoons/displayimage.php?pid=901



生質能源技術鍊


生質物料源
Biomass feedstock
(固、液)
(Solid/Liquid)
能源製造機
Reactor
• 氣態燃料
Gaseous Fuel
• 液態燃料
Liquid Fuel
• 固態燃料
Solid Fuel
能源利用轉化機
Generator
熱
Heat
電
Electricity
能源作物 Energy Crops
有機廢棄物 Organic wastes
藻類 Microalgae
萃油器 Oil Extractor
醱酵槽 Fermentor
造粒機 Granulating machine
CH4、H2、
乙醇 (Ethanol)、
柴油 (Diesel)、RDF
燃料電池 Fuel Cell
燃燒機 Burner
發電機 Generator

歡迎加入逢甲大學建立之生質能產業聯盟

上游
料源供應

廢棄物、農林資材、有機污染、畜牧廢棄物

1. 鴻曜塑膠
2. 白歐生物科技
3. Biomar Industries SDN, BHD
4. 光宇電能

中游
設廠規劃及設備供應

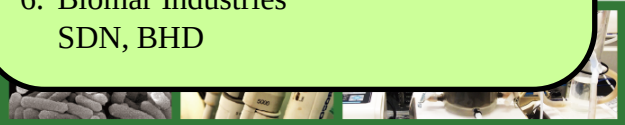
熱電轉換技術、焙燒器、生質煤、燃油轉換設備、燃料電池、焚化爐、醱酵反應槽、太陽能板、風力機、水力機、發電機

1. 鴻曜塑膠
2. 元寧企業
3. 夆潤科技
4. 白歐生物科技
5. 昌正科技
6. Biomar Industries SDN, BHD
7. 綠川工程顧問
8. 上展玻璃
9. 昱晶能源
10. 中國新能源
11. 厚德環境科
12. 石材暨資源研究中心
13. 聯曜實業

下游
產品應用及銷售

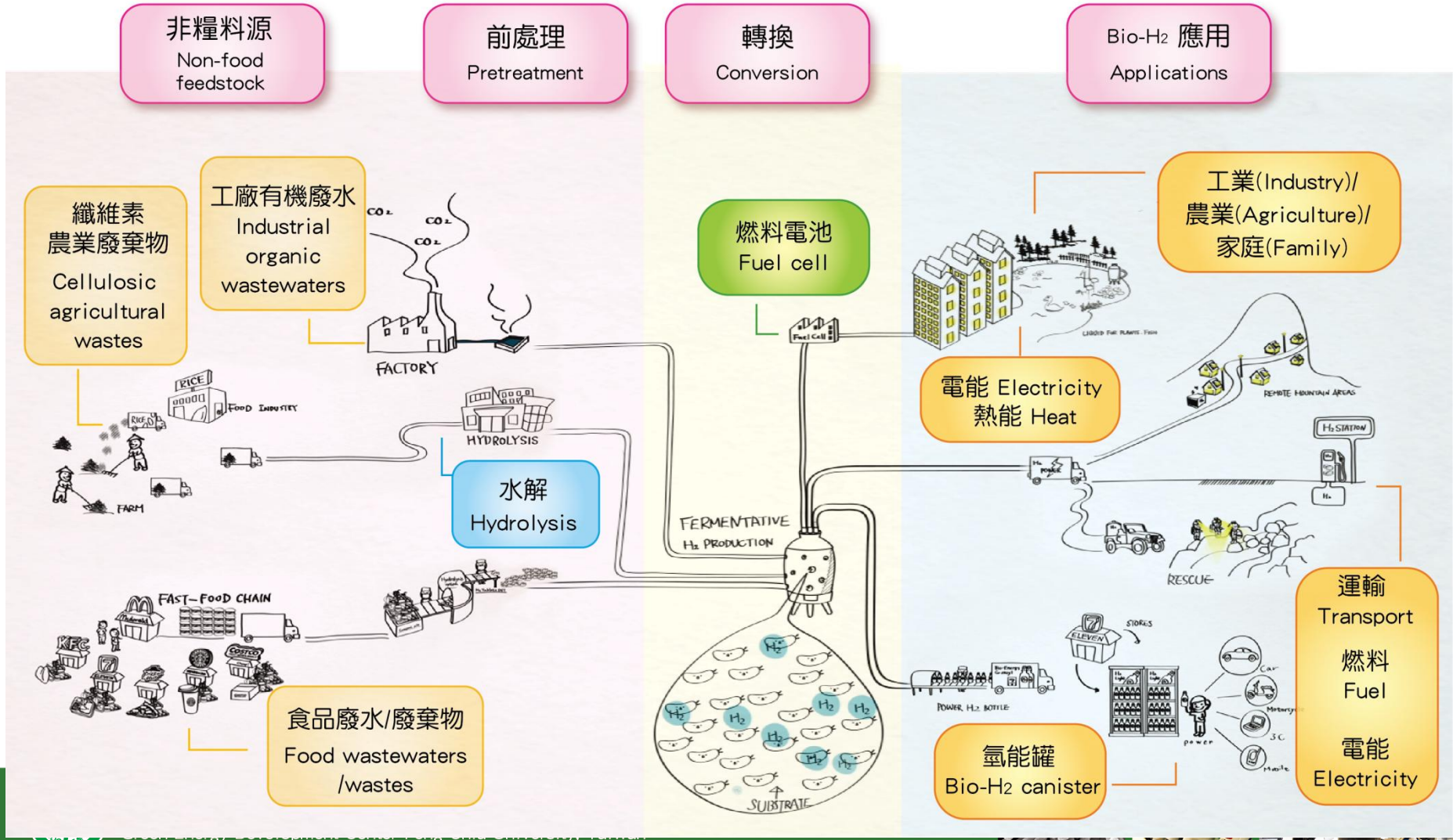
貿易商、加電站、電池、系統整合商、

1. 鴻曜塑膠
2. 元寧企業
3. 夆潤科技
4. 白歐生物科技
5. 昌正科技
6. Biomar Industries SDN, BHD
7. 綠川工程顧問
8. 厚德環境科
9. 台灣神戶電池



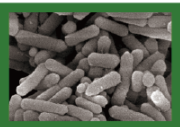
逢甲的Bio-H2 Utopia

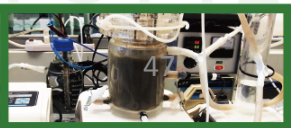
Video



結語

- 有機物產氫與甲烷是國際之環境與能源工程趨勢。
- 台灣已有國際領先的生物產氫技術。
- 善加利用厭氧消化技術來增加收益吧!





Links

- **Research Center for Energy and Resources, RCER (Green Energy Development Center for, GEDC)**

  http://www.greenenergy.fcu.edu.tw

- **International Association for Hydrogen Energy (IAHE-Taiwan Chapter)**

  http://www.iahe-taiwan.org

- **Asia Bio-HyLinks**

  http://www.asia-biohylinks.org

- **APEC research center for advanced biohyd**

  http://www.apec-bioh2.org

Thank you for your attention

http://www.greenenergy.fcu.edu.tw

E-mail: greenenergy@fcu.edu.tw