



Asia-Pacific  
Economic Cooperation



**Invited Presentation:**

# **APEC Research Network for Advanced Biohydrogen Technology**

**Prof. SY Wu**  
**Feng Chia University, Chinese Taipei**

**APEC-EGNRET 37 Meeting**  
**Grand Hyatt Taipei, Taipei, Chinese Taipei**  
**Tuesday, 23 August, 2011**

# Rationale – Why biohydrogen?

## ➤ Bio-Hydrogen is promising

- Using hydrogen as fuel leads to **remarkable reduction in CO2 emission** and in fossil resources dependence.
- Most experts predict **hydrogen society** as the final solution of global energy problems.
- Bio-hydrogen is a **clean and green technology** providing the most environmental-compatible, sustainable and renewable way of producing hydrogen.
- Asian countries possess the **world-leading biohydrogen technology** representing a dense population in biohydrogen R&D.
- Asian countries are **abundant in biomass resources**, indicating the high competitiveness and urgent demands in developing biohydrogen technology.

# The purpose of the project

- **Aims**

- The APEC Research Center to develop an **advanced technology of bio-hydrogen** production and to **organize a platform** for the experts of bio-hydrogen technology from the APEC member economies.

- **when and where :**

- Set up a **website**.
- Organizing a **symposium**.
- A **non-food feedstock bio-hydrogen pilot plant** is for research and training courses at FCU.

# The keys objectives (1)

- To develop the advanced technology of bio-hydrogen production (**new generation**) .
  - To identify suitable **non-food feedstock (e.g., agricultural waste)**
    - as the substrate for the bioprocess. The feedstock will be focused on non-food biomasses that are dominantly produced in the region of APEC member economics.
  - To innovate **a high rate biohydrogen production system**,
    - including bacterial screening, cultivation, bioreactor design, optimum operation, scale-up technology, biogas purification, applications of high value-added liquid products, reuse of organic wastes, as well as the molecular monitoring techniques on the biohydrogen bioprocess.



**non-food feedstock**



**a high-rate biohydrogen production system**

# The keys objectives (2)

- **To offer the facilities in the research center**
  - such as laboratories open to the students from the APEC member economies **for short-term study or visiting.**
- **To organize a symposium**
  - for the biohydrogen technology experts from the APEC member economics
  - to extend and expand the biohydrogen technology to the APEC member economics

**short-term study**



**visiting**



# Dissemination of Technology Output



**Biomass**



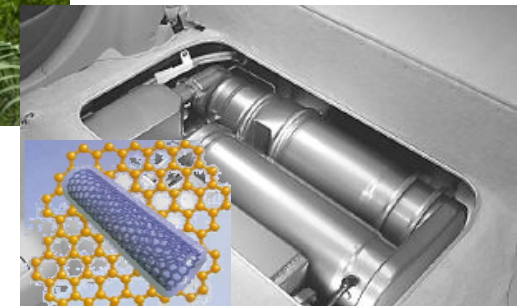
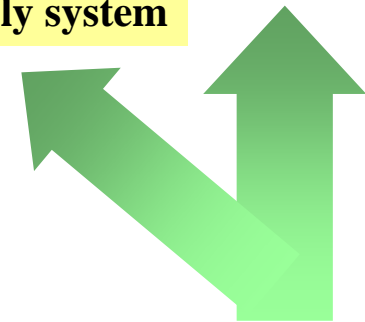
**Biohydrogen production system**



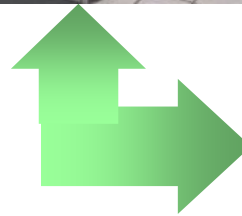
**Electric supply system**



**Hydrogen car**



**Hydrogen storage system**



# FCU Biohydrogen Research Team

- Prof. Chiu-Yue Lin's Lab  
Depart of Environmental Engineering and Science, FCU
- Prof. Shu-Yii Wu's Lab  
Depart of Chemical Engineering, FCU
- Prof. Ping-Jei Lin's Lab  
Depart of Chemical Engineering, FCU
- Prof. Chun-Hsiung Hung's Lab  
Depart of Environmental Engineering, NCHU
- Prof. Jo-Shu Chang's Lab  
Depart of Chemical Engineering, NCKU



# Ways of producing biohydrogen

BioH <sub>2</sub> System	H <sub>2</sub> Rate	Size of BioReactor to Generate:	
		1.5 kW	5.0 kW
Direct Photolysis	0.07 mmoles H <sub>2</sub> /hr/L	512,000 L	1,710,000 L
Indirect Photolysis	0.335 mmoles H <sub>2</sub> /hr/L	107,165 L	357,313 L
CO-water Shift	96.0 mmoles H <sub>2</sub> /hr/L	374 L	1,250 L
Photo Fermentation	150.0 mmoles H <sub>2</sub> /hr/L	239 L	798 L
Dark Fermentation	350.0 mmoles H <sub>2</sub> /hr/L	102 L	345 L





# H2 Production Concept

Complex Organics (**non-food feedstock**)



Monomers (sugars, aminoacids...)



VFAs + alcohol +  $H_2$  +  $CO_2$



$CH_4$  +  $CO_2$

hydrolysis







methanogenesis



acidogenesis

# The evolution for biohydrogen technology at FCU

Since 1998~

Batch Test Basic Research	Continuous reactor	High rate reactor	The pilot plant system
(NSC Project, 150 mL)	(NSC and FCU Projects, 2 L)	(BOE and FCU Projects, 10 L)	(BOE and FCU Projects, 400 L)
			



1998-2000



2000-2005

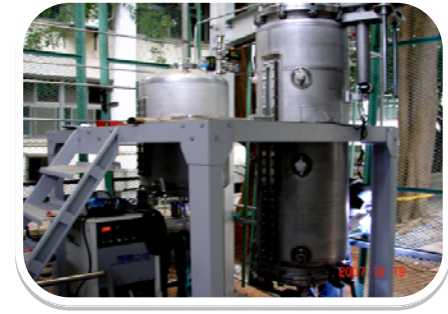
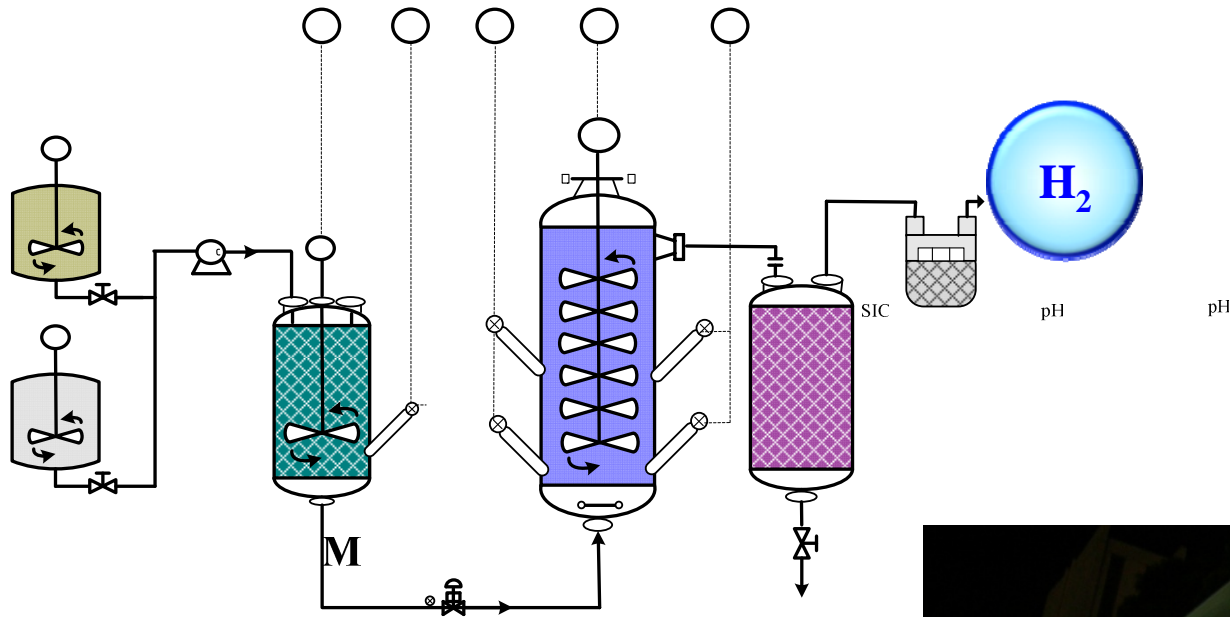


2005-2008



2008~

# Pilot-scale hydrogen fermentation system



M Air Motor



T103 Buffer Tank  
750 L (Work V.600 L)



T301 Preparation Tank  
600 L (Work V.500 L)  
Medium/Buffer



2008.11.13

# Appearance of BioH<sub>2</sub> Pilot Scale



**Feedstock and  
Nutrient mixing  
Tank**

**Feedstock  
Pretreatment  
Tank**

**Automatic  
Control room**

**400 L fermentor and  
Gas/liquid separator**



# Highly evaluation by international experts

<b>Affiliations</b>	Victoria Univ., Canada	Glamorgan Univ., UK
<b>Commentator</b>	Levin et al. 2004	Hawkes et al. 2007
<b>Journals</b>	International Journal of Hydrogen Energy	International Journal of Hydrogen Energy
<b>Comments</b>	<ul style="list-style-type: none"> <li>•Using fixed-bed bioreactors containing an undefined consortium of mesophilic bacteria, FCU team observed rates of H<sub>2</sub> synthesis <b>far greater than other studies</b>.</li> <li>•The system reported <b>by FCU team</b> in particular appears <b>most promising</b>.</li> <li>•A bioreactor of approximately 500 l would provide enough H<sub>2</sub> to power a 2:5 kW PEMFC, while a bioreactor of approximately 1000 l would provide sufficient H<sub>2</sub> to power a 5:0 kW PEMFC.</li> </ul>	<ul style="list-style-type: none"> <li>•The highest volumetric hydrogen production rate <b>to our knowledge ever reported</b> is 15.09 (l/h) at 93% sucrose conversion, OLR 1708 g sucrose (l/d), in a novel continuously stirred granular sludge type reactor seeded with silicone-immobilised sludge <b>by FCU team</b>.</li> <li>•If these rates could be maintained, the granulation approach to conversion of soluble simple sugars is <b>very promising</b>.</li> </ul>

# Project outcomes

- **The Steering Committee Meeting and kick-off Workshop** of APEC Research Network for Advanced Biohydrogen Technology.
- **The website has been established** in Feng Chia University, Chinese Taipei.  
(<http://www.apec-bioH2.org>)
- **APEC biohydrogen newsletter** has been published 4 issues.
- **The 2010 APEC Advanced Bio-Hydrogen Technology Conference** has been held at Feng Chia University, Taichung, on Nov 16th – 18th, 2010.
- **The 2010 APEC Advanced Bio-Hydrogen Technology Short-term Training Course** has been held at Feng Chia University, Taichung, on Nov 16th – 20th, 2010.

# The 2010 steering committee meeting and workshop of APEC research network for advanced biohydrogen technology

- **Date and Venue**

- February 3, 2010, Feng Chia University, Taichung, Chinese Taipei

- **Activities**

- Advanced biohydrogen **technology workshop**
- Visit biohydrogen production pilot plant and laboratory, and exchanged experiences.
- Steering Committee Meeting
- More than **150** industrial and commercial people, scientists and academia joined the workshop.



# The website and the APEC biohydrogen newsletter



<http://www.apec-bioh2.org>



APEC biohydrogen newsletter



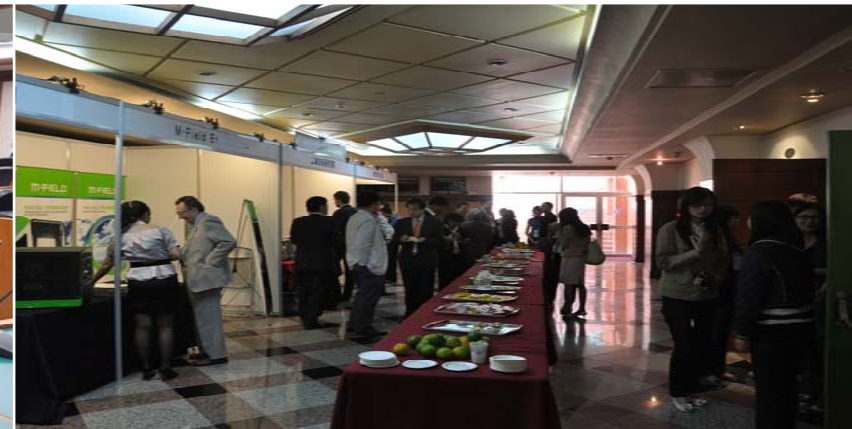
# The 2010 APEC Advanced BioH2 Technology Conference

- **Date and Venue:** Nov. 15th – 20th, 2010, Feng Chia University, Taichung, Chinese Taipei

**Keynote speech**



**Coffee break**



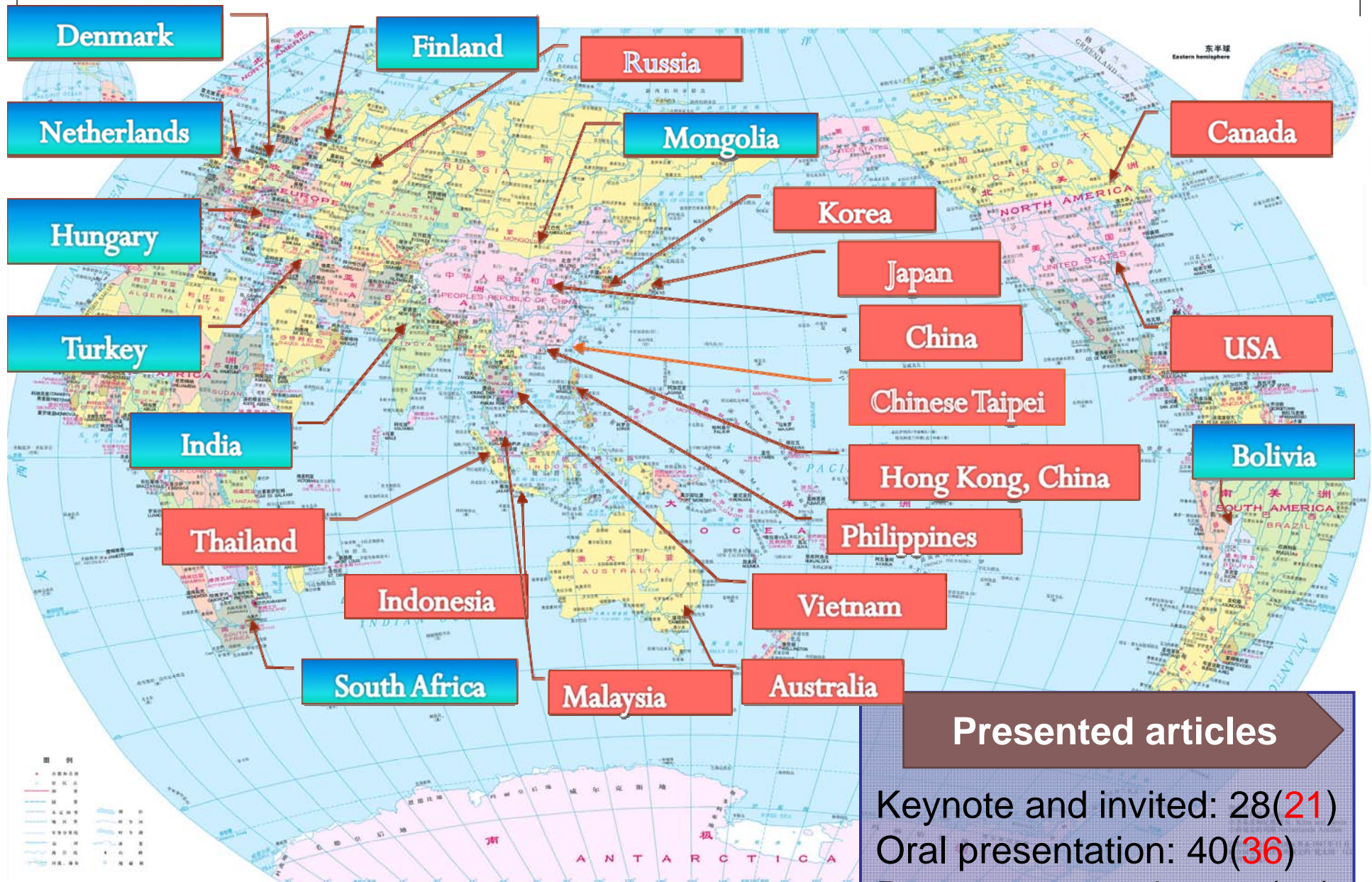
**Banquet**



**Group photo**



# 230 participants from 14 APEC members and 9 other countries



## Presented articles

Keynote and invited: 28(21)

Oral presentation: 40(36)

Poster presentation: 53(50)

# The 2010 APEC Advanced BioH<sub>2</sub> Technology Short-term Training Course

- **Date and Venue:** Nov. 16th – 20th, 2010, Feng Chia University, Taichung, Chinese Taipei

<b>Total Invited Speakers from APEC Members were 20.</b>	
<b>APEC Members</b>	<b>Invited Speaker</b>
USA (3)	Veziroglu Turhan Nejat, Bruce Logan, Michael Seibert
Thailand (1)	Alissara Reungsang
Russia (1)	Vasily Borzenko
Korea (3)	Hang Sik Shin, Mi Sun Kim, Sunghoon Park
Japan (2)	Jun Miyake, Yu-You Li
Indonesia(1)	Dwi Susilaningsih
Canada (1)	Patrick C. Hallenbeck
China (1)	Guangyi Wang
Hong Kong, China (1)	Tong Zhang
Chinese Taipei (6)	Sheng-Shung Cheng, Duu Jong Lee, Jo-Shu Chang, Min-Ray Lin, Chun-Hsiung Hung, Ming-Der Bai
<b>Total Student participants from APEC Members were 65.</b>	
Viet Nam (8), Malaysia (5), Thailand (11), The Philippines (5), Indonesia (12), Chinese Taipei (16), Republic of Korea (8)	



Group photo of students and lecturers



Certification given ceremony

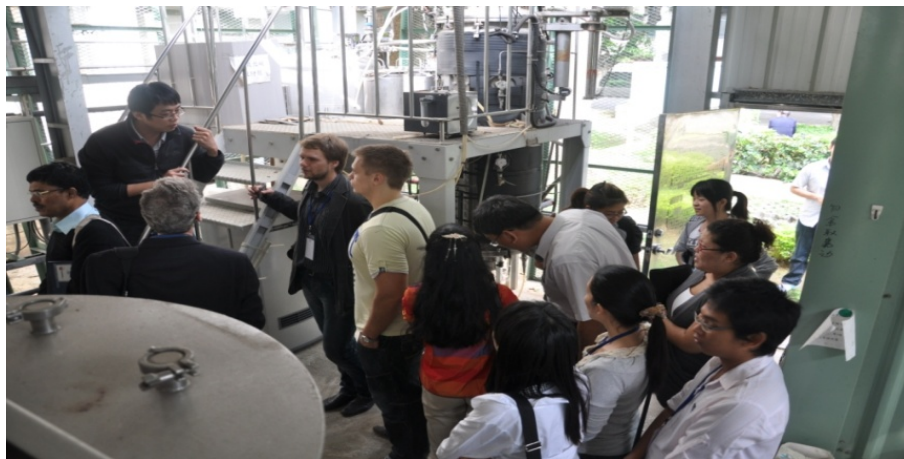
# The Activities on 2010 APEC BioH<sub>2</sub> Short-term Training Course



Group photo of students and lecturers



Technical tour to wastewater treatment plant

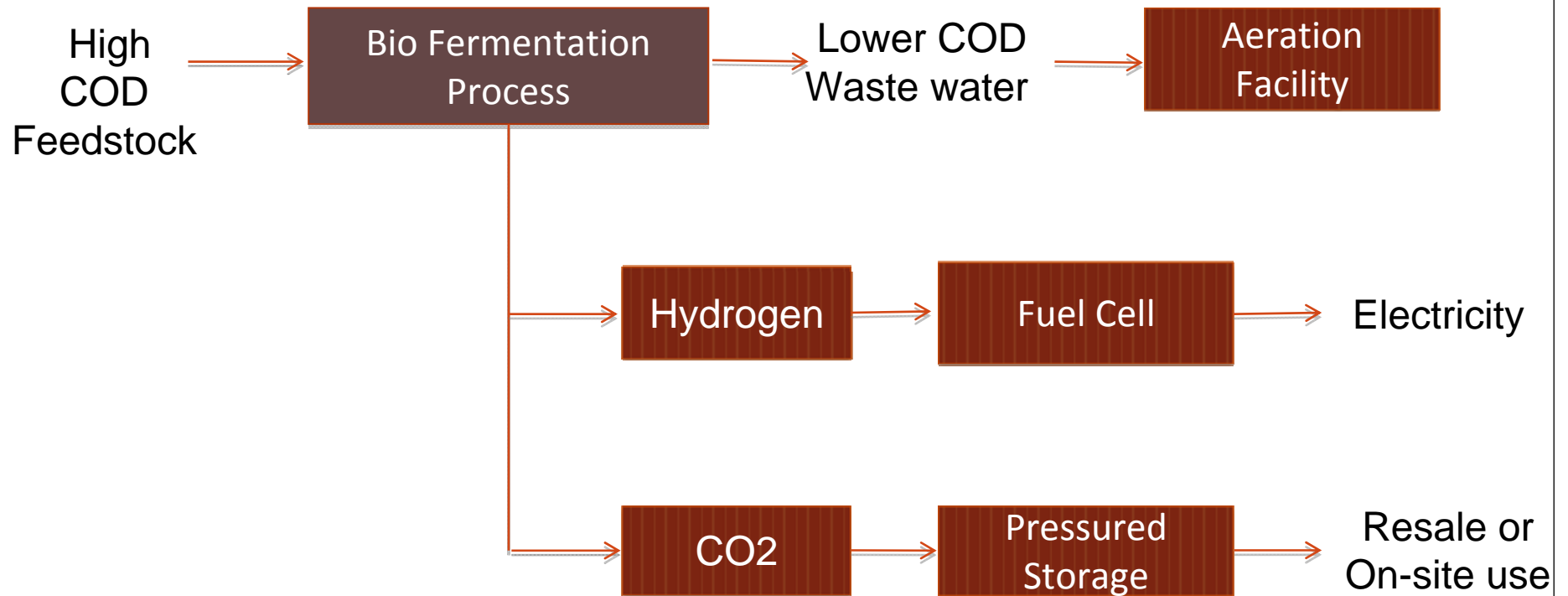


Pilot plant visiting in FCU

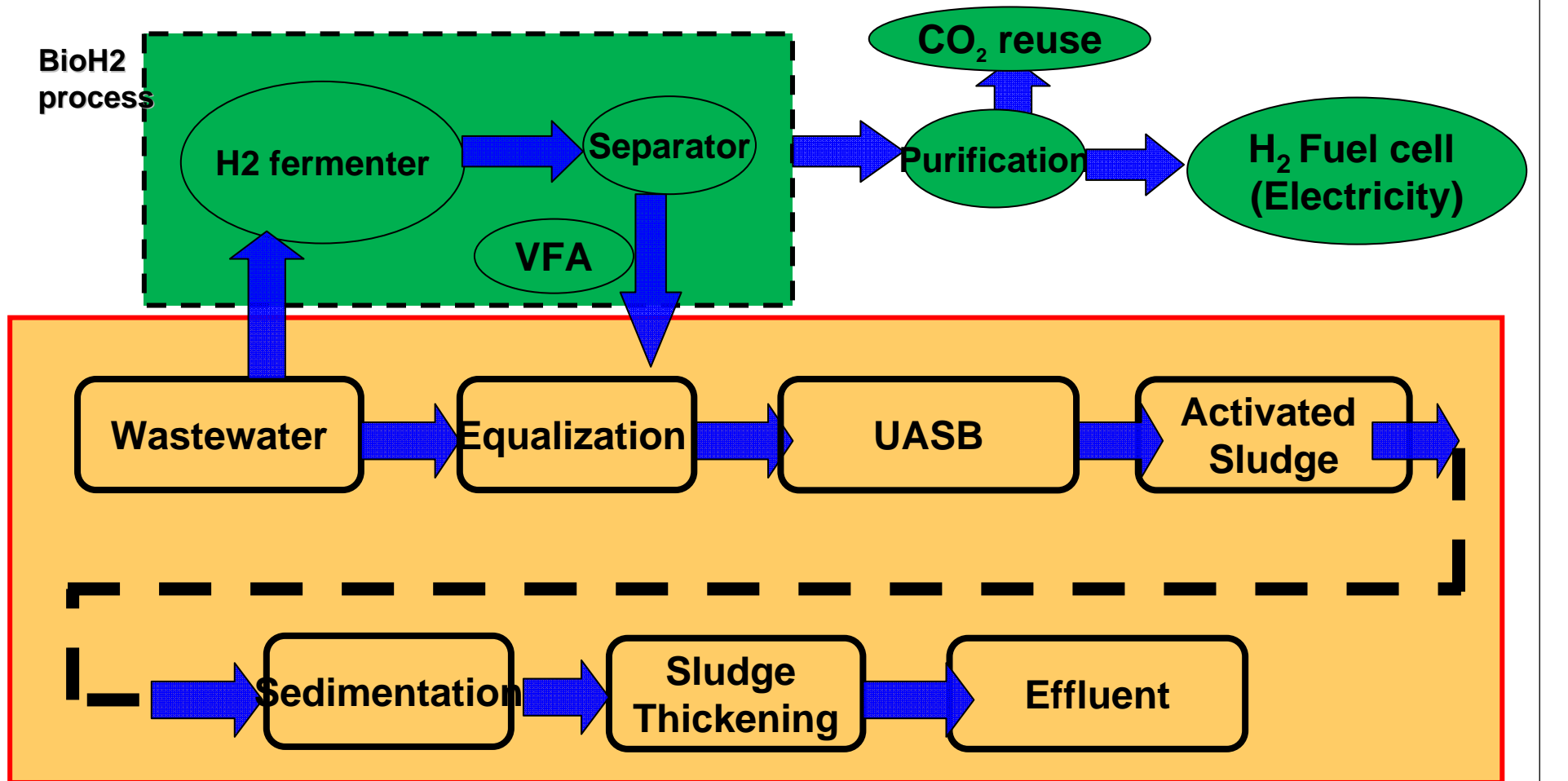


Lab visiting and operation

# Applications



# BioH<sub>2</sub> Process in the Conventional Wastewater Treatment Process

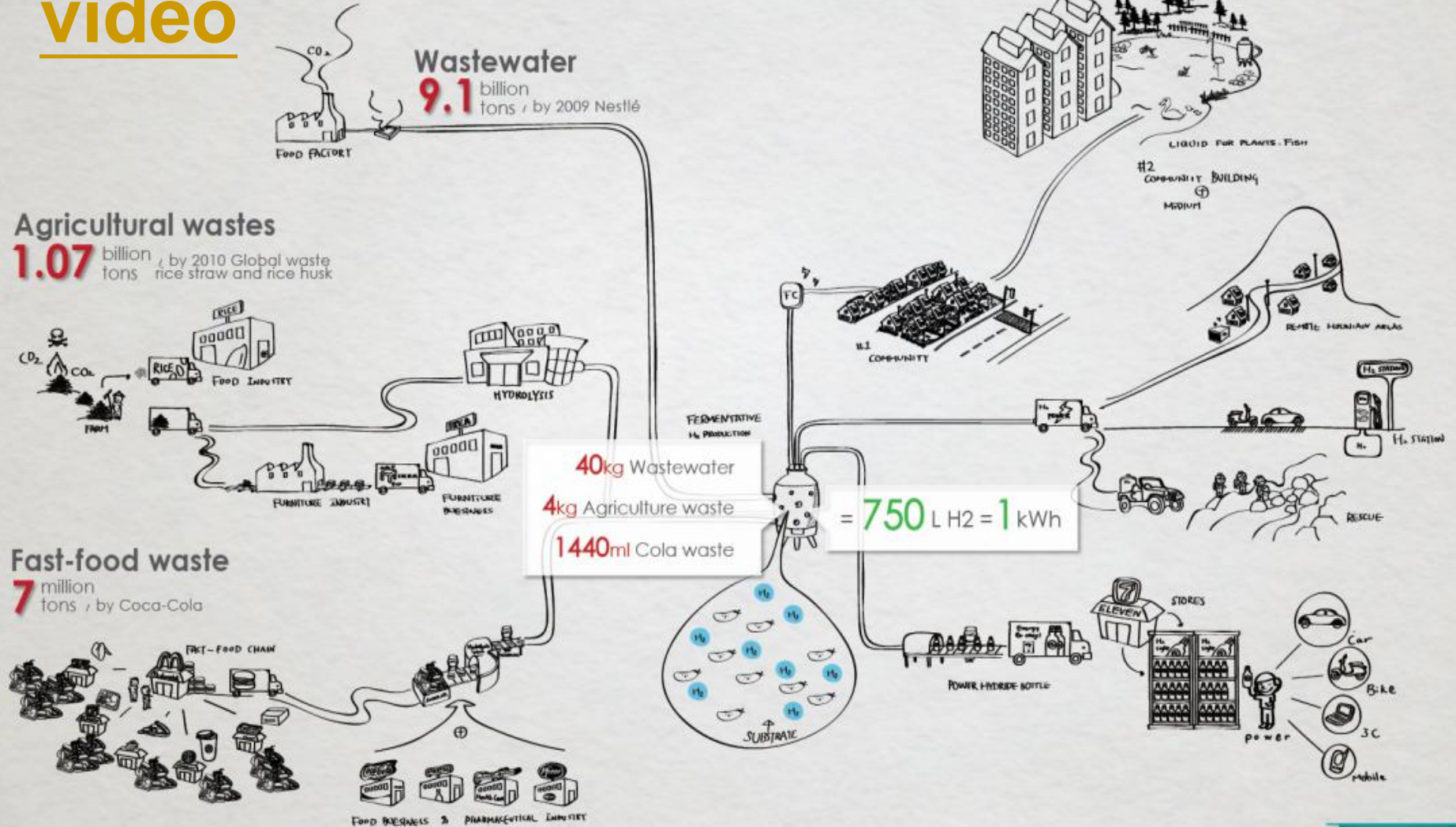


Conventional wastewater treatment process





**video**





# Network with Asia BioHyLinks (ABHL)



## Members

- China
- India
- Indonesia
- Japan
- Korea
- Malaysia
- Russia
- Singapore
- Chinese Taipei
- Thailand
- VietNam

## Aims

- Annual Meeting
- Publication (IJHE or others)
- Technical Exchange of Researchers

# 2011 ICCE Conference in FCU

## 11<sup>th</sup> International Conference on Clean Energy (ICCE-2011)

- **Date:** November 2 - 5, 2011
- **Venue:** Feng Chia University, Taichung, Taiwan
- **Information Website:** [www.icce2011.org.tw](http://www.icce2011.org.tw)
- **Topics of interest include, but are not limited to:**

- Hydrogen economy
- Solar energy
- Wind energy
- Hydrogen and fuel cell
- Geothermal energy
- Hydropower
- Ocean/tidal/wave energy
- Biomass and biofuels

- Waste-to-energy
- Nuclear energy
- Clean coal
- Clean fossil fuels
- Environmental remediation
- Energy management
- Energy policy

- Energy awareness
- Risk analysis
- Economical appraisal
- Energy conservation
- Energy storage
- Intelligent grids
- Intelligent buildings

High quality papers will be selected and published in special issues of *the International Journal of Hydrogen Energy* and *Applied Energy Journal* and in other prestigious journals.

## 2011 ABBS in LIPI

# The 2011 Asian Bio-Hydrogen and Biorefinery Symposium (2011ABBS)

- **Date:** Oct. 14-16, 2011
- **Place:** Bogor, Indonesia
- **Information Website:** <http://www.asia-biohylinks.org>
- **Topics of interest include, but are not limited to:**
  - Biomass to hydrogen and biochemicals
  - Molecular biology approaches
  - Biohydrogen by dark/photo fermentation
  - Bioreactor design
  - Biohydrogen applications
  - Biorefineries and its applications

High quality papers will be selected and published in special issue of *the International Journal of Hydrogen Energy*.

## BioH2 Pilot Plant (400 L) in Feng Chia University Campus

