

POME to Energy Workshop

Enhanced Energy Recovery from Wastewater through Sequential bioH_2 and CH_4 Fermentation

Prof Dr. Shu-Yii Wu

Chair Holder
UKM-YSD, Malaysia
2016 April 5-6



Source: en.trend.az, inweh.unu.edu, www.readit.com.cn, www.glogster.com, www.tripadvisor.com, twitter.com

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Introduction

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Renewable Energy






Source: http://zh.wikipedia.org/wiki/File:Dreischluchtendamm_hauptwall_2006.jpg, http://www.tuvnord.com.tw, http://zh.wikipedia.org/wiki/File:NesjavellirPowerPlant_edit2.jpg, http://asiabiodiesel.com/biodiesel_c.html

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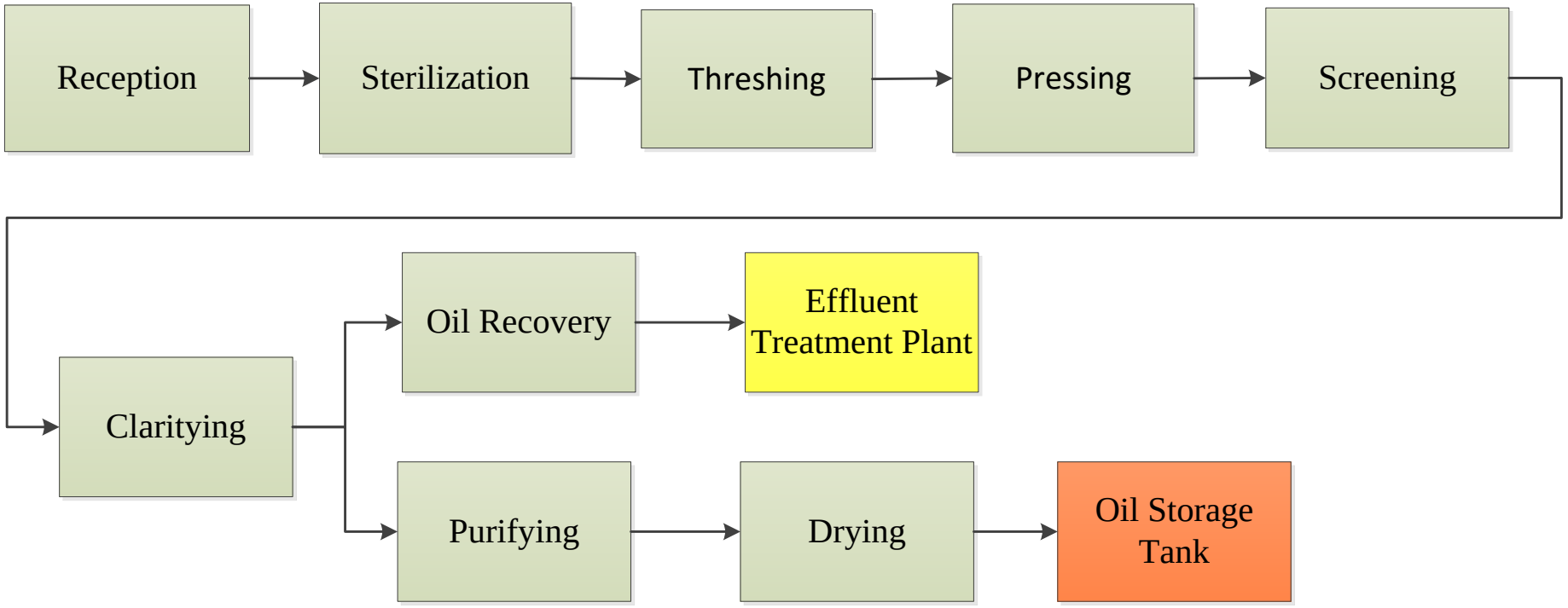
Effluent from POME (1/2)



Source: http://www.palmoilworld.org/about_palmoil.html

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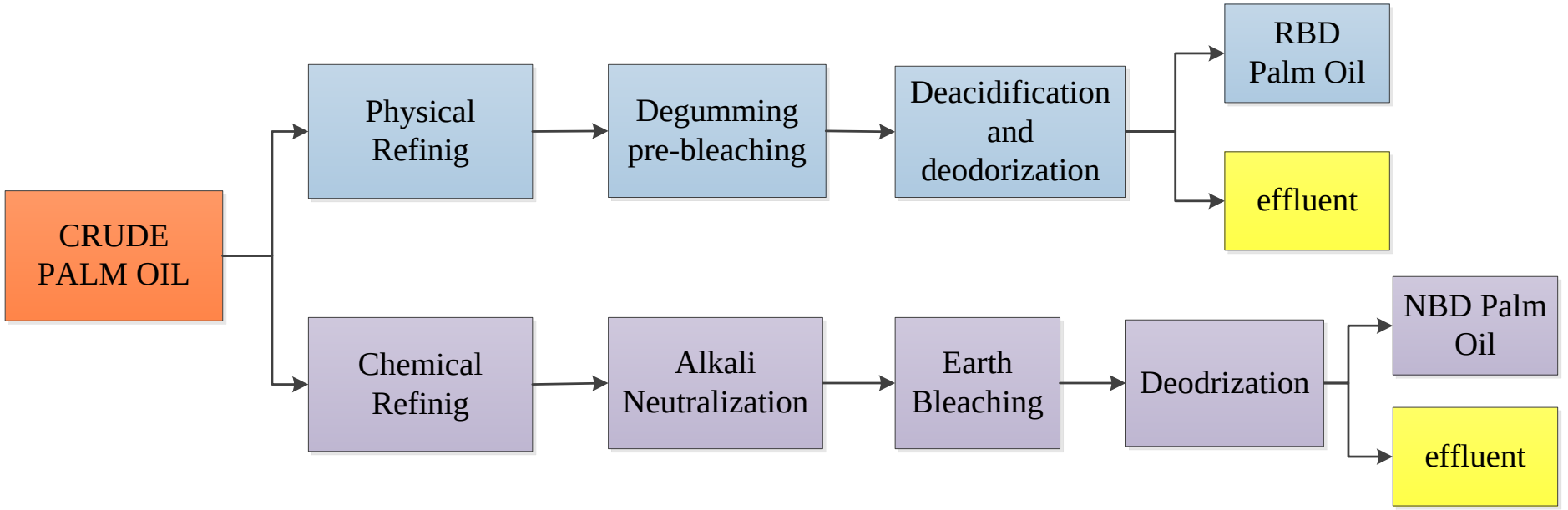
Effluent from POME (2/2)



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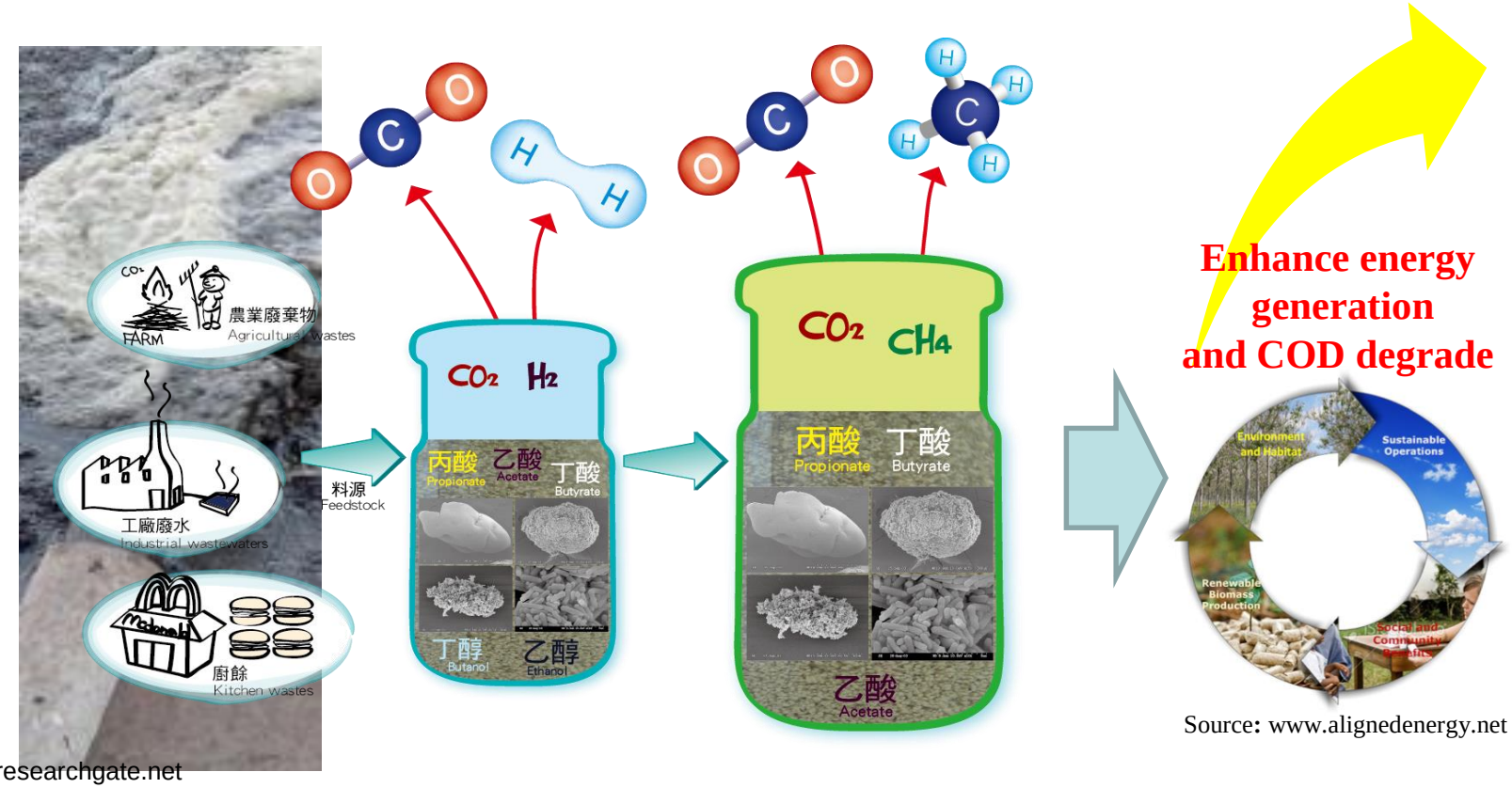
Two-stage of hydrogen and methane production



Source: www.researchgate.net

Source: www.alignedenergy.net

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Two-stage of hydrogen and methane production

(1) N or (6)
pH (10)
Mixing tank (11) CH_4 reactor

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Single stage for bioH_2 production at different HRT

- Temperature：37˚C
- Substrate conc.20 g/L
- HRT：2 h
  - H_2 conc.：40.55 ± 1.44%
  - HPR：42.02 ± 1.68 L/L/d
  - Yield：1.21 ± 0.05 mol H_2/mol hexose
  - Utilization：94.15 ± 1.95%
- HRT：4 h
  - H_2 conc.：41.15 ± 2.97%
  - HPR：19.58 ± 1.05 L/L/d
  - Yield：1.07 ± 0.10 mol H_2/mol hexose
  - Utilization：88.97 ± 7.85%
- HRT：8 h
  - H_2 conc.：40.34 ± 1.69%
  - HPR：9.70 ± 0.95 L/L/d
  - Yield：0.97 ± 0.14 mol H_2/mol hexose
  - Utilization：94.17 ± 0.14%

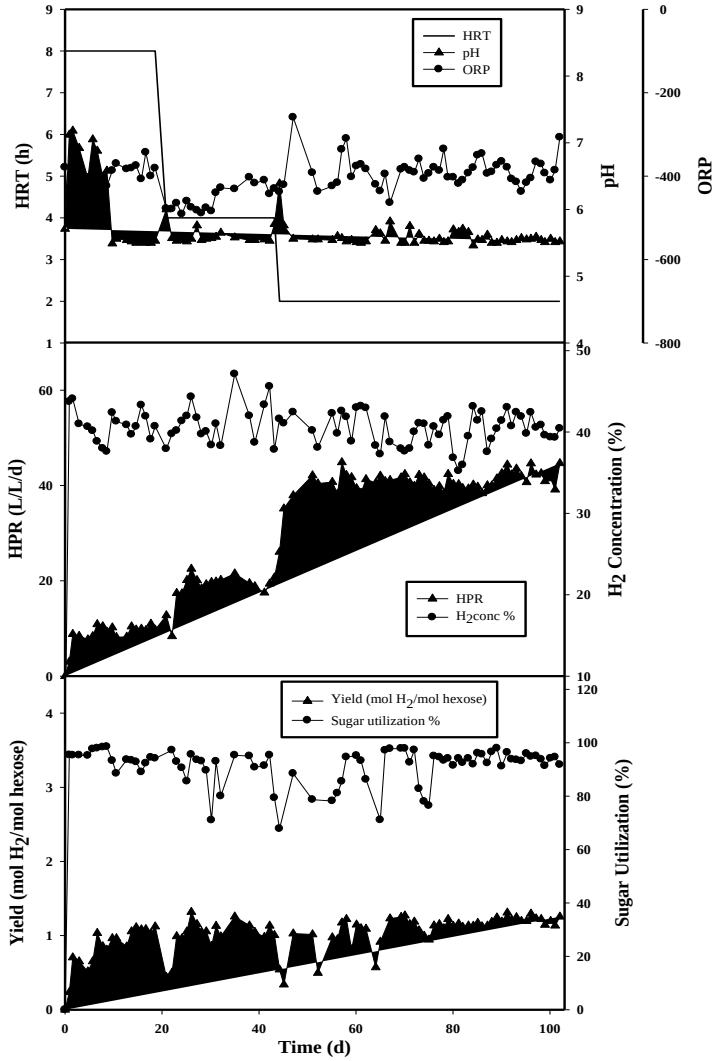

Fig. 1 A continuous biohydrogen production performance at different HRT. (The operation pH was maintained at 5.5 ± 0.1; temperature controlled at 37℃ and gas production was monitored using a wet gas meter.)

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Single stage for bioCH_4 production at different HRT

- Temperature：45˚C
- At First-stage HRT_{H_2} 2 h

- HRT_{CH_4}：24 h (Reactor type：CSABR)
  - Substrate conc.： 25.65 ± 0.95 g COD/L
  - CH4 conc.：80.55 ± 3.35%
  - MPR：3.13 ± 0.20 L/L/d
  - COD removal：65.58 ± 3.77%

- HRT_{CH_4}：48 h (Reactor type：CSABR)
  - Substrate conc.： 25.65 ± 0.95 g COD/L
  - CH_4 conc.：77.89 ± 2.81%
  - MPR：1.11 ± 0.09 L/L/d
  - COD removal：78.46 ± 1.90%

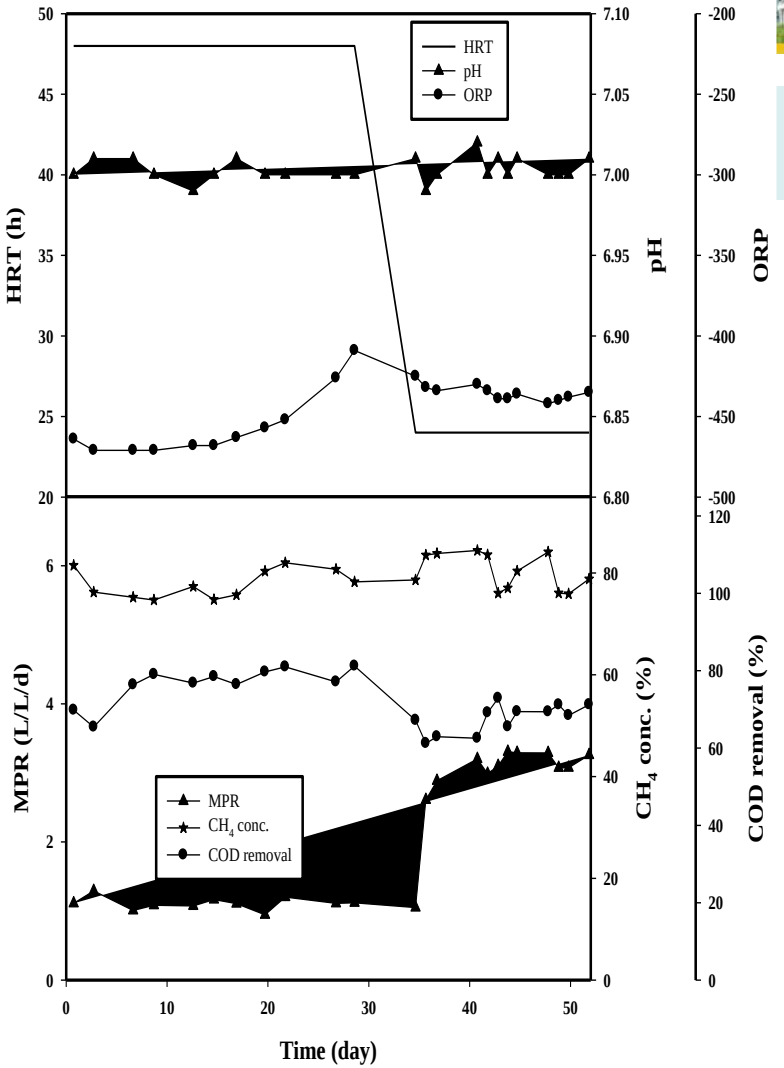

Fig. 2 The continuous biomethane production performance at different HRT. (The operation pH was maintained at 7.0 ± 0.1; temperature controlled at 45℃; gas production was monitored using a wet gas meter.)

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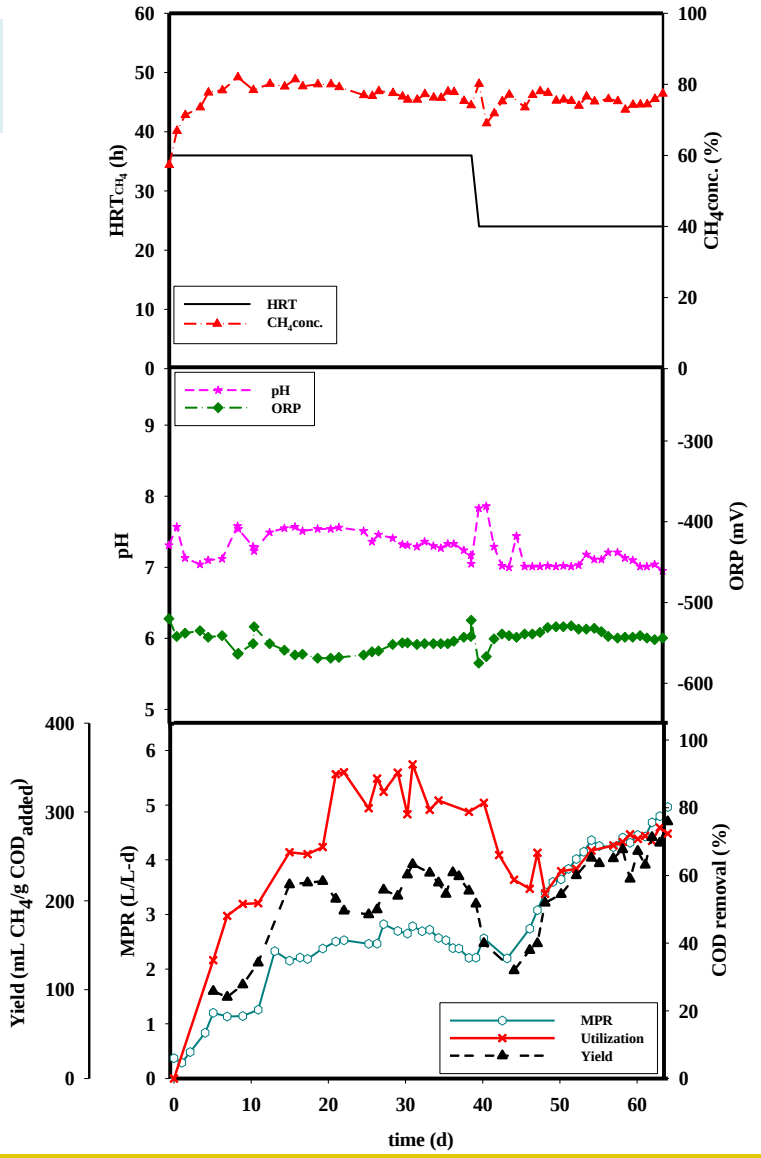
Two-stage for bioH_2 and CH_4 production at different HRT

- Temperature：45˚C
- At First-stage HRT_{H_2} 2 h
- HRT_{CH_4}：24 h (Reactor type：CSABR)
  - Substrate conc.： 17.58 ± 0.53 g COD/L
  - CH_4 conc.：75.78 ± 1.78%
  - MPR：4.28 ± 0.48 L/L/d
  - Yield：248.32 ± 28.67 mL CH_4/g COD_{added}
  - COD removal：74.56 ± 5.17%
  - Energy recovery：1.77 ± 0.20 W/L
- HRT_{CH_4}：36 h (Reactor type：CSABR)
  - Substrate conc.： 18.02 ± 2.06 g COD/L
  - CH_4 conc.：77.60 ± 1.44%
  - MPR：2.50 ± 0.22 L/L/d
  - Yield：210.36 ± 18.02 mL CH_4/g COD_{added}
  - COD removal：84.71 ± 5.40%
  - Energy recovery：1.05 ± 0.07 W/L



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Effect of bioCH_4 production with different reactor type and HRT

H_2 reactor HRT (h)	2	2	2	2	4	4
CH_4 reactor HRT (h)	24	48	24	36	24	36
Reactor type	CSTR	CSTR	CSABR	CSABR	CSTR	CSABR
MPR (L/L/d)	3.13 ± 0.20	1.11 ± 0.09	4.28 ± 0.48	2.50 ± 0.22	3.63 ± 0.26	3.01 ± 0.34
COD removal (%)	65.58 ± 3.77	78.46 ± 1.90	74.56 ± 5.17	84.71 ± 5.40	73.99 ± 5.31	88.55 ± 7.51

Chun-Min Liu, Shu-Yii Wu. From biomass waste to biofuels and biomaterial building blocks. Renewable Energy, In Press.

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Remarks

Single stage of biohydrogen production

HRT_{H_2} 2 h：HPR = 44.06 ± 4.11 L/L/d；COD removal = 10%~20%

Energy recovery ： 5.63 ± 0.53 W/L

Single stage of biomethane production

HRT_{CH_4} 24 h：MPR = 6.38 ± 0.38 L/L/d；COD removal = 74.56 ± 5.17 %

Energy recovery ： 2.64 ± 0.16 W/L

Two-stage of biohydrogen and biomethane production

HRT_{H_2} 2 h + HRT_{CH_4} 24 h：HPR = 44.06 ± 4.11 L/L/d + MPR = 4.28 ± 0.48 L/L/d

Total COD removal = 81.68 ± 11.12%；Energy recovery ： 7.40 ± 0.73W/L

HRT_{H_2} 4 h + HRT_{CH_4} 36 h：HPR = 20.80 ± 1.61L/L/d + MPR = 3.01 ± 0.34 L/L/d

Total COD removal = 94.60 ± 5.00%；Energy recovery ： 3.83 ± 0.35W/L

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Technology Analysis

Types	MBR	Activated Sludge	MBBR	UASB	HyMeTek
Sludge Yield (Kg SS/Kg COD)	0.2	0.3-0.5	0.3	< 0.2	< 0.2
Wastewater treatment limit (COD mg /L)	≒10000	< 3000	≒10000	3000~50000	3000~50000
COD removal (%)	90	90	90	>90	>90
Setting mode	Easy setup, small space	Difficult set up	Easy setup	Customized, on-site construction	Modular, Easy construction
Maintenance costs	high film maintenance costs	Much sludge	Long recovery time of film maintenance and high cost	High equipment prices, maintenance difficulties	Cheap, easy and low costs of maintenance
Energy Recovery	N/A	N/A	N/A	Methane recovery, less sludge	1. COD degradation time fast 2. High energy recovery efficiency. (25% higher than methane equipment) 3. produce less sludge
Reliability	Medium	Medium	Medium	High	High
Stability	Medium	High	Medium	High	High

Operational processes of the real case (1/2)

6 浓缩物装载系统

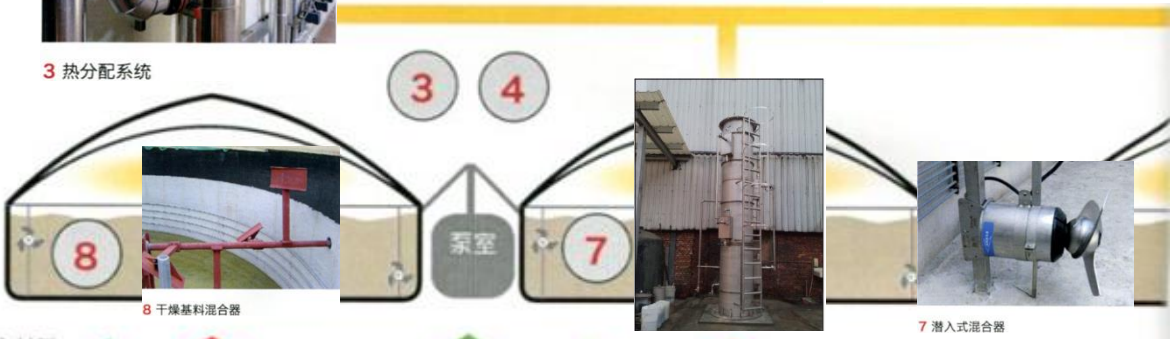
3 热分配系统

4 泵送系统

BioHydrogen

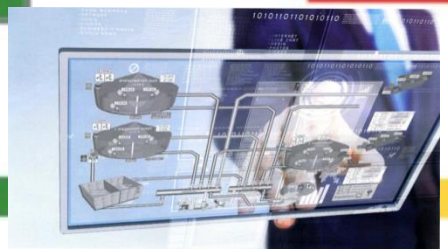
2 混凝土装载区供料

1 箱式混合器供料



8 干燥基料混合器

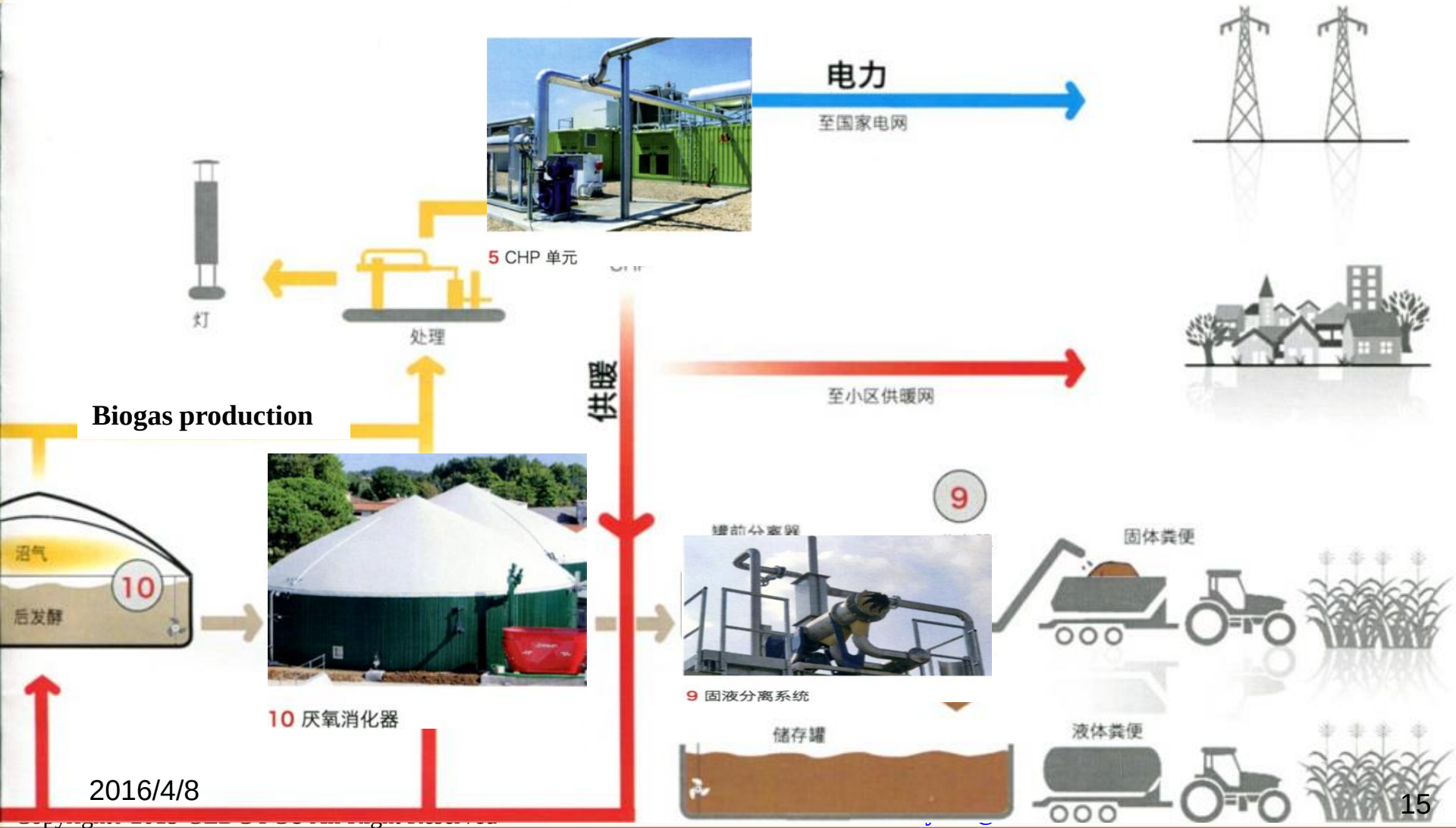
7 潜入式混合器



HyMeTek Monitoring System

Hydrogen and methane production

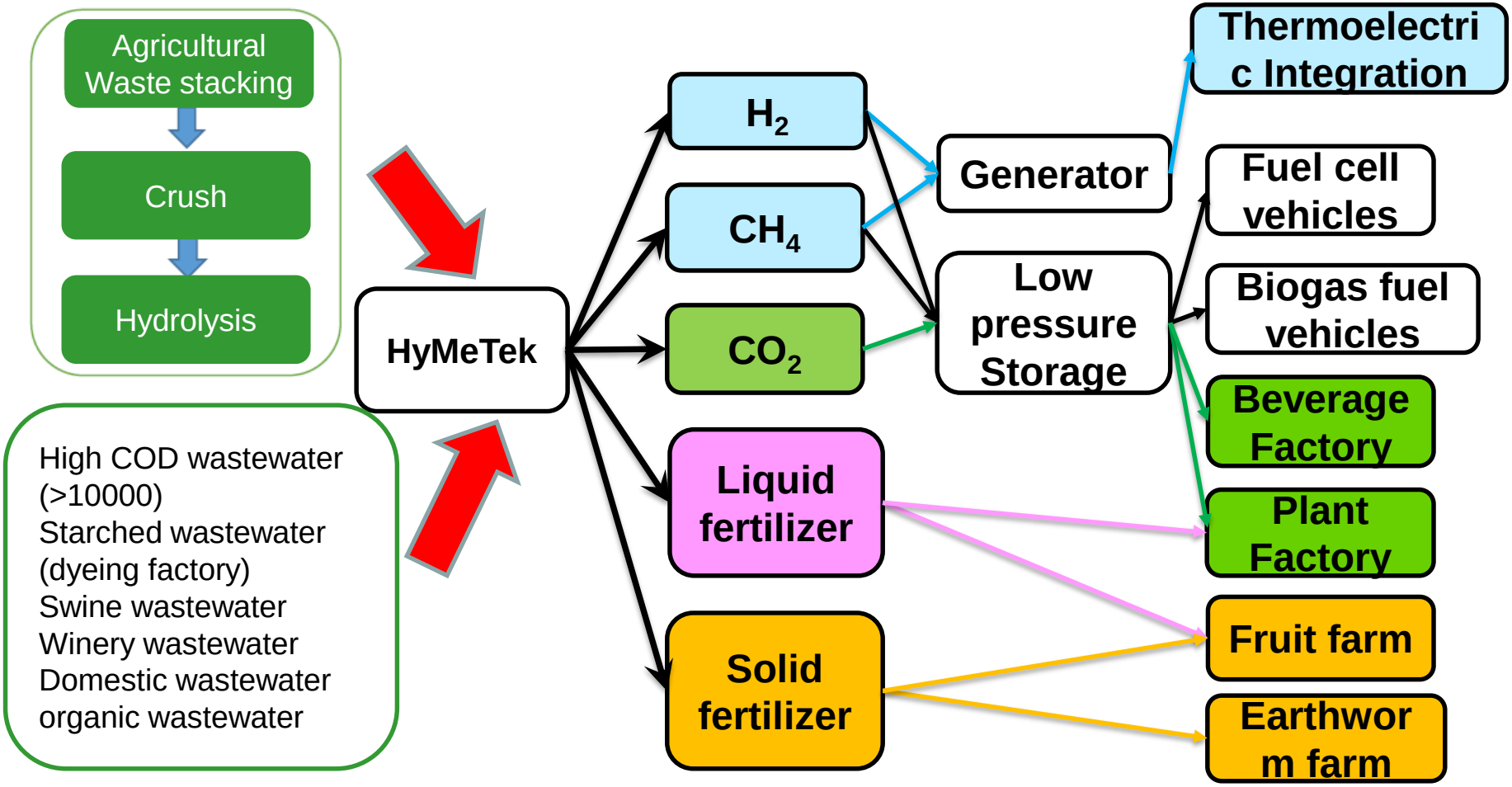
Operational processes of the real case (2/2)



Payback Estimated of Capital Cost
(Based on biomass feedstock of 150 tons/day)

Item		Unit	Sell For electricity	Sell For CNG	Model 1/2	Model 3
COD	50	Ton CODre/day			50	50
Bio-H_2, CH_4	13,200	m^3/day		13,200	13,200	13,200
Electricity generation	34,032	kWh/day	34,032		34,032	34,032
Heating generation	37,732	kWh/day	37,732		37,732	37,732
Compost	50	ton/day			50	50
CNG generation	9,240	m^3/day		9,240	9,240	9,240
Income		RMB/yr	8,513,891	12,196,800	27,763,891	40,471,200
Waste water treatment cost	600	RMB/ton CODre	0	0	10,500,000	10,500,000
Electricity selling price	0.65	RMB/kWh	8,513,891	0	8,513,891	0
CNG selling price	4	RMB/m^3	0	12,196,800	0	8,131,200
Compost selling price	500	RMB/ton	0	0	8,750,000	8,750,000
H_2 selling price	11	RMB/m^3	0	0	0	8,470,000
CO_2 selling price	6	RMB/m^3	0	0	0	4,620,000
Equipment costs		RMB	38,997,348	38,938,056	58,407,084	77,876,112
Payback period		Year	6.1	3.2	2.1	1.9

Long-term plans for agriculture and high organic wastes



Scenario for promoting community empowerment in APEC's rural area by using agro-wastes recycling biotechnologies and GIS assistance-- cycled infrastructure



24 hours to enjoy the new life (bio-H_2/CH_4)
Thank you for your attention

2016/4/8



APEC Workshop on Promoting Community Empowerment in APEC's Rural Area

Agenda

(Tentative) APEC Workshop on Promoting Community Empowerment in APEC's Rural Area Venue: Feng Chia University, Taichung, Taiwan Date: July 13-15, 2016	
Date	**Wednesday, July 13, 2016**
17:00-18:30	Early Registration
18:30-21:00	Welcome party
Date	**Thursday, July 14, 2016**
9:00-12:00 30 min/person (including 10 mins discussion)	(TBC) Session 1 Promoting green growth of aboriginal/remote agricultural area through social entrepreneurship for motivating inclusive economy Keynote speaker 1-4
11:30-13:30	Lunch
13:30-15:30	(TBC) Session 2 HRD strategy in platform/CRP(O2O frame) driven through agro-wastes recycling via biotechnologies and GIS assistance Keynote speaker 5-8
15:30-16:00	Break
16:00-18:00	(TBC) Session 3 Technologic-entrepreneurial network of cooperation across economies by running an internet of thing (IoT), including fair-trade… Keynote speaker 9-12
18:00-20:30	Banquet
Date	**Friday, July 15, 2016**
9:00~12:00	(TBC) Session 4: Policy Recommendation on Promoting Community Empowerment in Rural Area based on technical-entrepreneurial HRD Keynote speaker 13-16
12:00-14:00	Lunch
14:00-17:00	Tour (Taichung)
17:00-	Dinner (Feng chia night market)