Renewable Energy through Biological Processes

Tjandra Setiadi, Ph.D., Prof.
Centre of Resource Efficient and Cleaner Production Indonesia (CRECPI)
Institut Teknologi Bandung (ITB)
tjandra@che.itb.ac.id

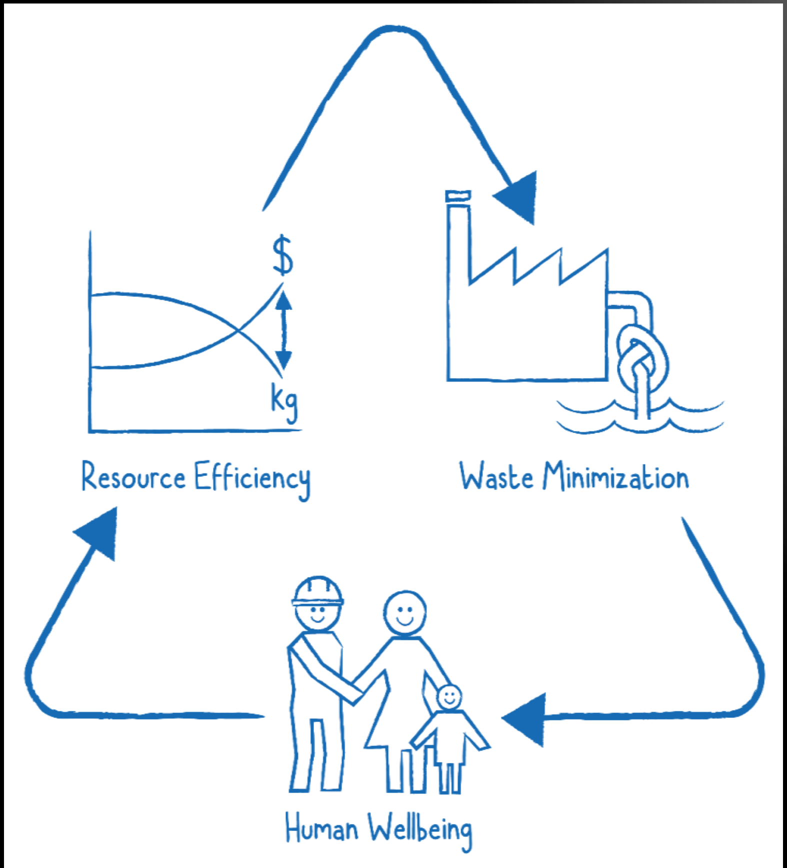
Outline of Presentation

- Centre of Resource Efficient and Cleaner Production Indonesia (CRECPI)
- Current Energy Situation in Indonesia
- Projection of Energy Supply in Indonesia
- Renewable Energy
- Examples of Renewable Energy through Biological Processes
  - Anaerobic Treatment of Wastewater from different Industries
  - Microbial Fuel Cells
  - Hydrogen Production
- Challenges in the Future

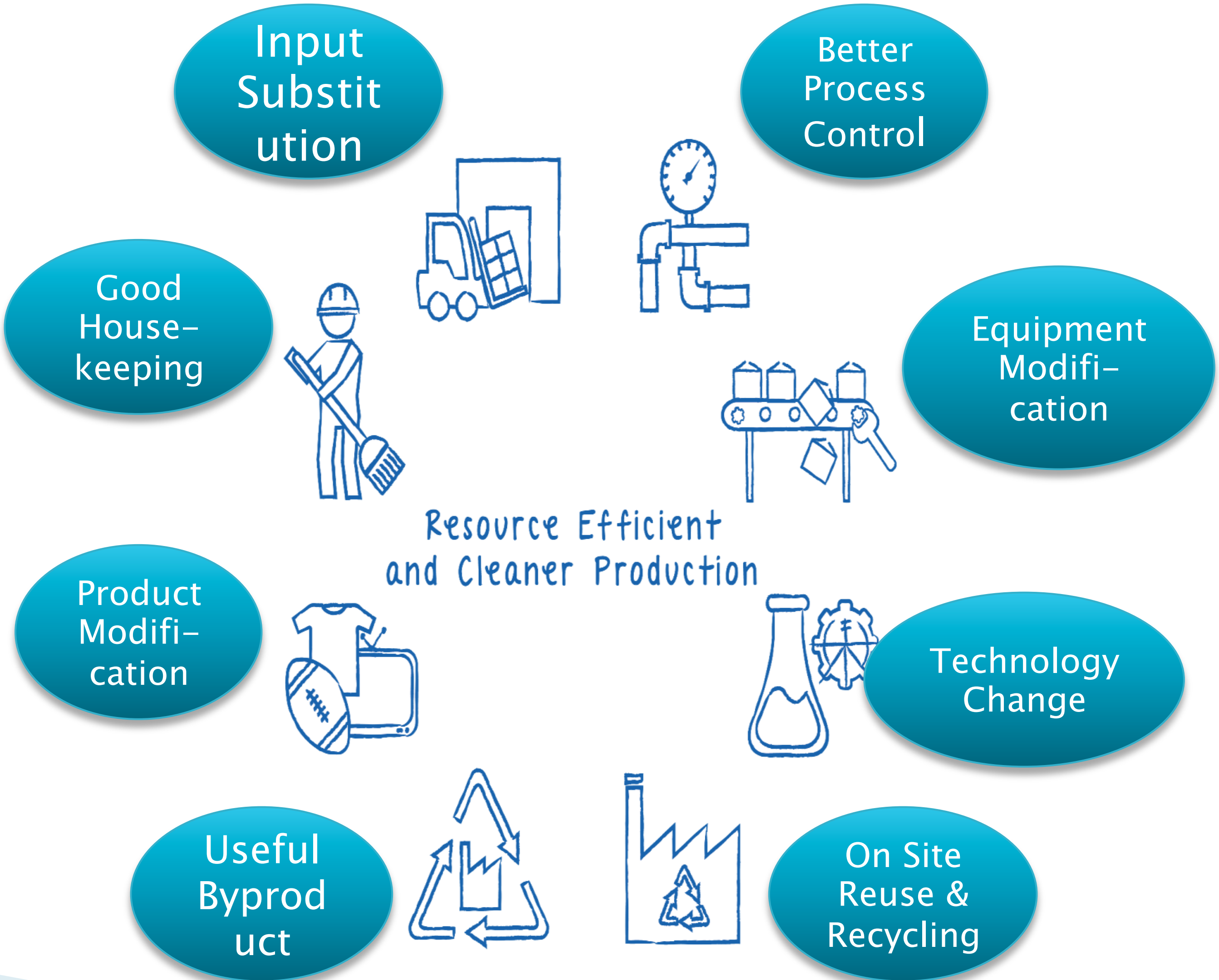
Centre for Resource Efficient and Cleaner Production Indonesia (CRECPI)

- Established in 2014 by the Institute of Technology Bandung (ITB) to **foster application of Resource Efficient and Cleaner Production in Indonesia**
  - Through (applied) research and education
  - Co-implementation of the Swiss funded Resource Efficient and Cleaner Production Programme of the United Nations Industrial Development Organization (UNIDO)

Resource Efficient and Cleaner Production



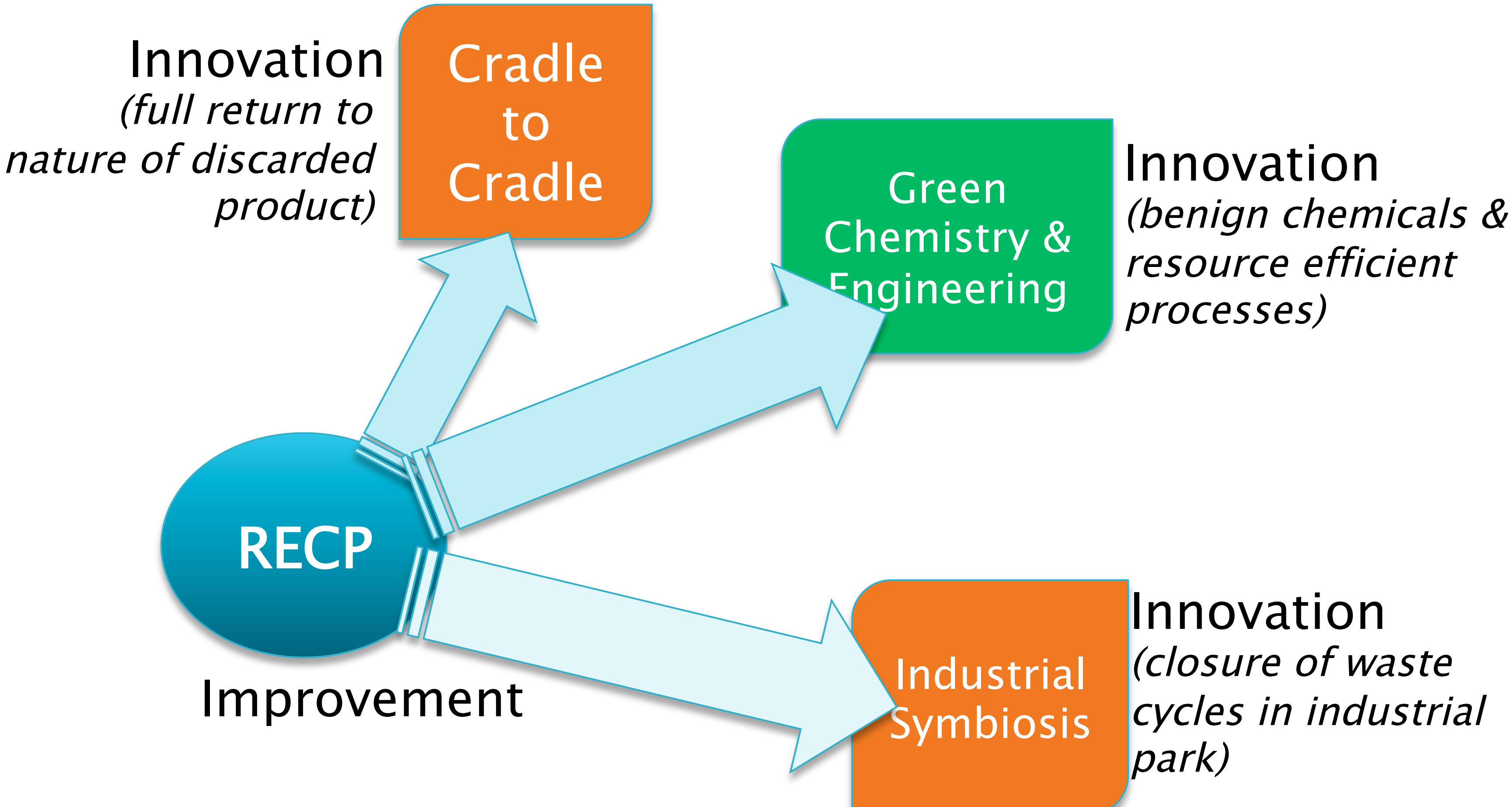
- *Integrated* and *continued* application of *preventive environmental* practices and *total productivity* techniques to processes, products and services to *increase efficiency* and *reduce risks* to humans and environment


Input Substitution
Better Process Control
Good House-keeping
Equipment Modifi-cation
Resource Efficient and Cleaner Production
Product Modifi-cation
Technology Change
Useful Byproduct
On Site Reuse & Recycling

Business Case

- Cost savings
- Productivity enhancements
- Quality improvements
- Organizational efficiency
- License-to-operate

RECP: stepping stone towards sustainable innovation



Indonesia RECP Programme

- Networked initiative to foster RECP implementation *at scale* and *at speed* in Indonesia

Sectors (food, textile, metal & chemical)

Industrial Zones (Makassar, Batam & Surabaya)

Micro-Industries (palm sugar, coffee)

Tourism Destinations (Sleman/ Magelang & Bintan)

1. RECP Capacity & Network
2. RECP Implementation & Replication
3. RECP Policy & Strategy
4. RECP Technology & Innovation
5. RECP Finance & Investment

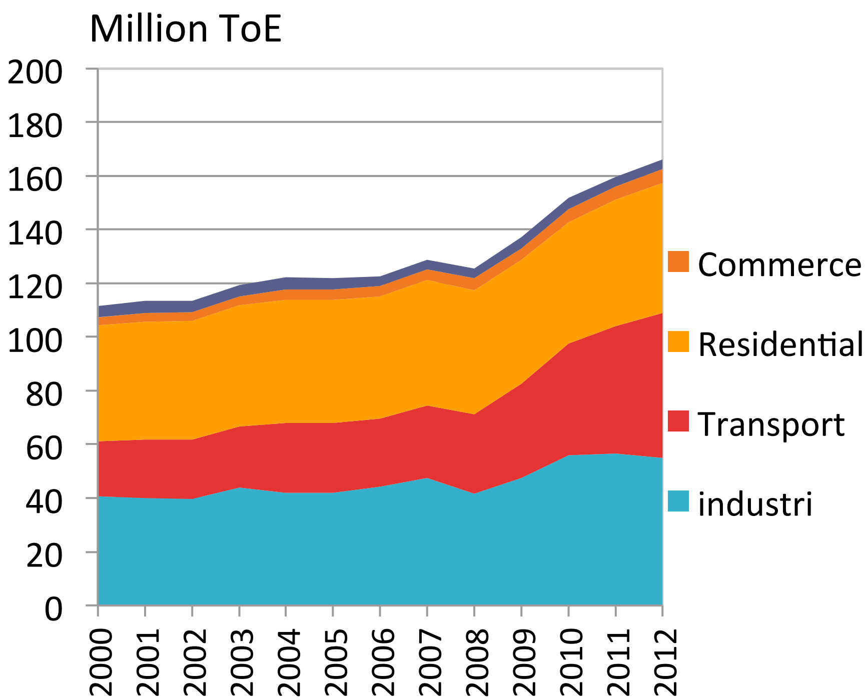
Swiss Confederation

UNIDO

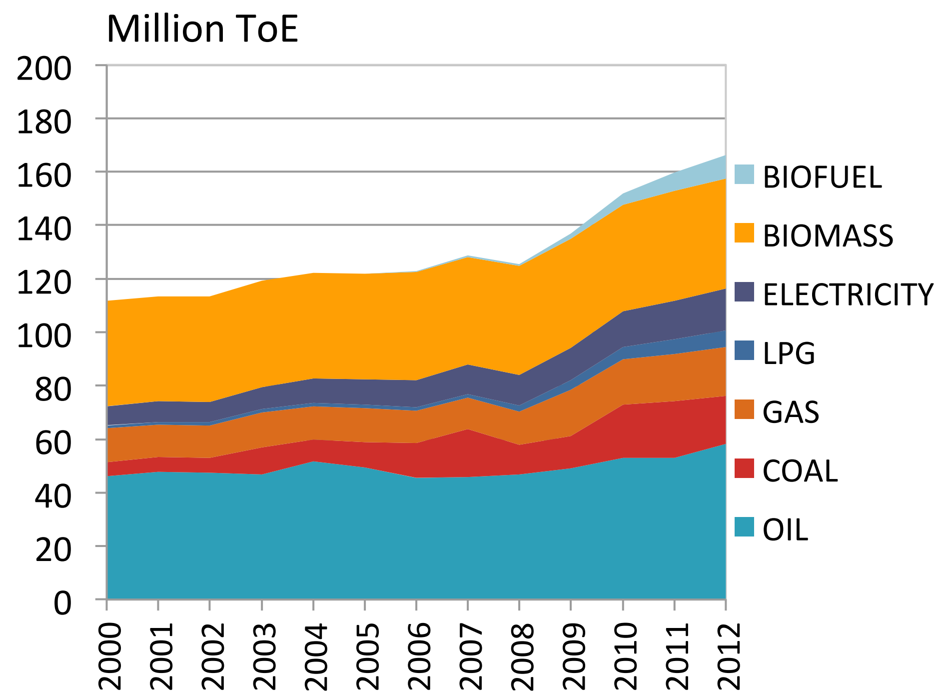
CURRENT ENERGY SITUATION IN INDONESIA

Current Energy Demand Development

Final ENERGY DEMAND By Sector



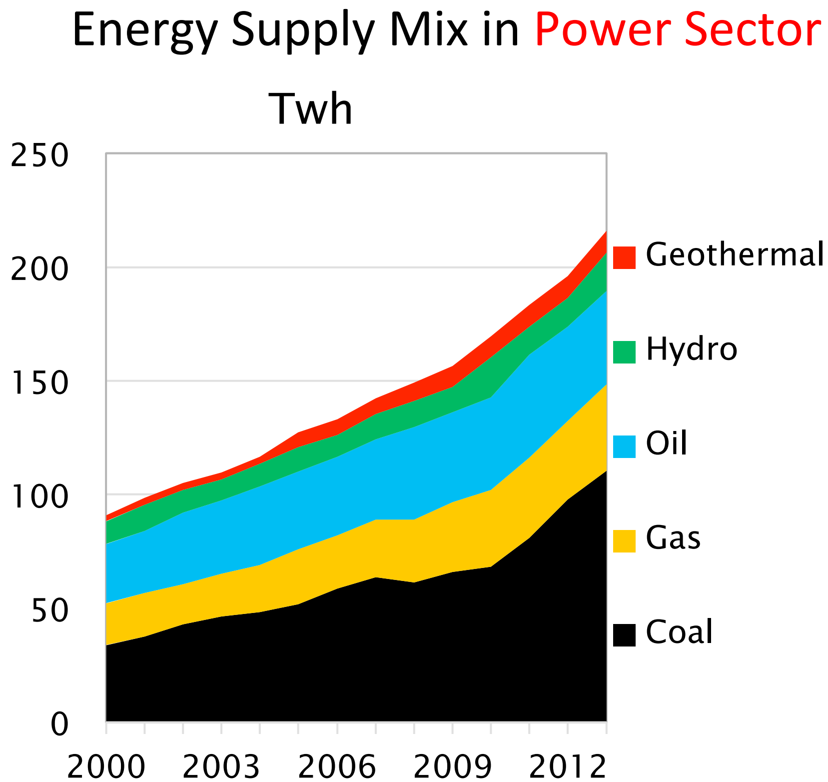
FINAL ENERGY DEMAND By Type of Fuel



source: Pusdatin—MEMR

- **By sector**, demand is dominated by demand from **industry, transport**, and **residential**. Commercial sector demand is relatively small (4%)
- **By type of fuels**, demand is dominated by **oil**, Biomass is used primarily used in **rural residential**, Biofuel growth is significant in the past five years

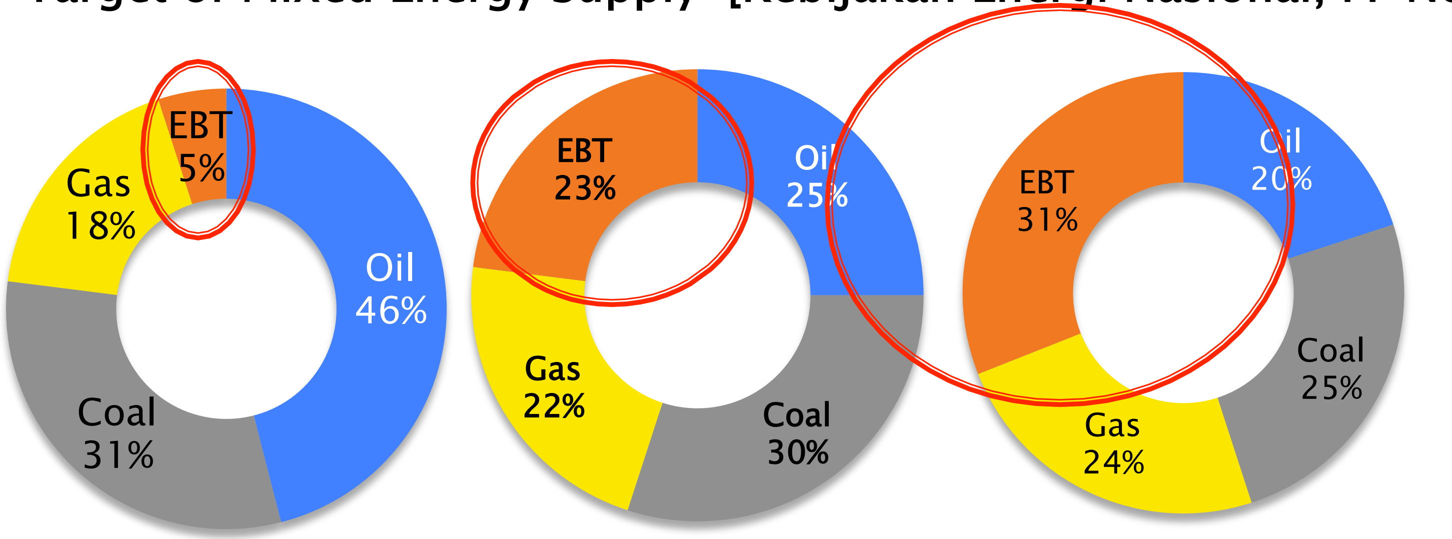
Current Energy Supply Development



- Dominated by coal which grew steadily since 2000
- Oil is used in distributed diesel generators in remote areas. Installed in 80s and 90s for boosting electrification
- Renewable share is still low.

source: Pusdatin—MEMR

Target of Mixed Energy Supply [Kebijakan Energi Nasional, PP No.79/2014]



194 MToe (2013) 400 MToe (2025) 1000 MToe (2050)

EBT – New & Renewable Energy will be increased to 23% in 2025 (from 5% in 2013)

TARGET	Unit	2013	2020	2025	2050
Primary energy supply	MToe	194	290	400	1.000
Primary energy/capita	Toe	0,8	1,1	1,4	3,2
Power Plant Capacity	GW	51	79	115	430
Electricity per capita	KWh	776	1308	2.500	7.000

Average growth till 2025:
Energy supply 6.2% per year; Power Plant 7% per year;

Renewable Energy

Wind

Biomass

Solar

Hydro

Waste water

Geothermal

Courtesy of Prof[illegible] M. Whang

Examples of Renewable Energy through Biological Processes
(carried out in our Laboratory at ITB)

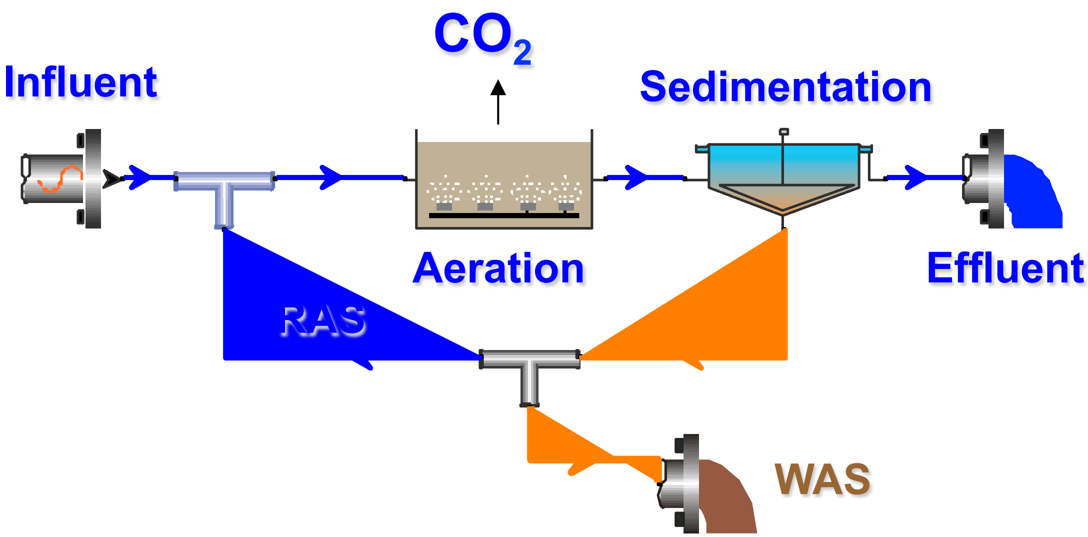
- Anaerobic Treatment of Wastewater from different Industries
- Microbial Fuel Cells
- Hydrogen Production

Anaerobic Treatment of Wastewater from different Industries

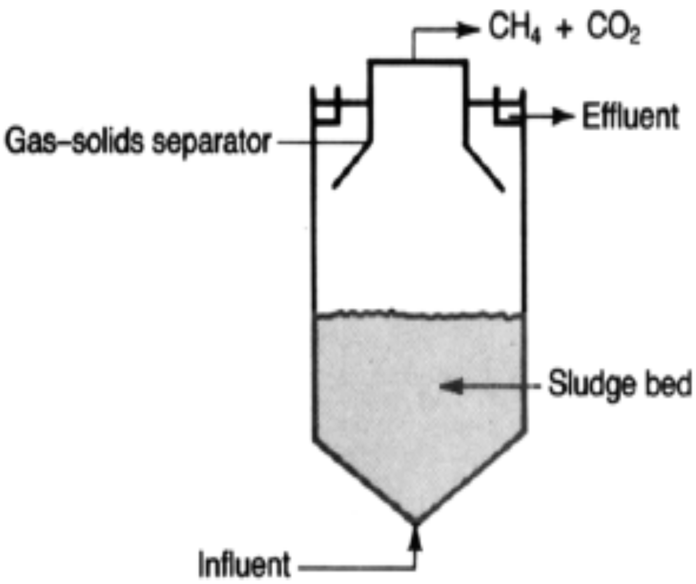
Biological Treatment of Organic Wastes

Aerobic vs Anaerobic Treatment

Aerobic Processes



Anaerobic Processes

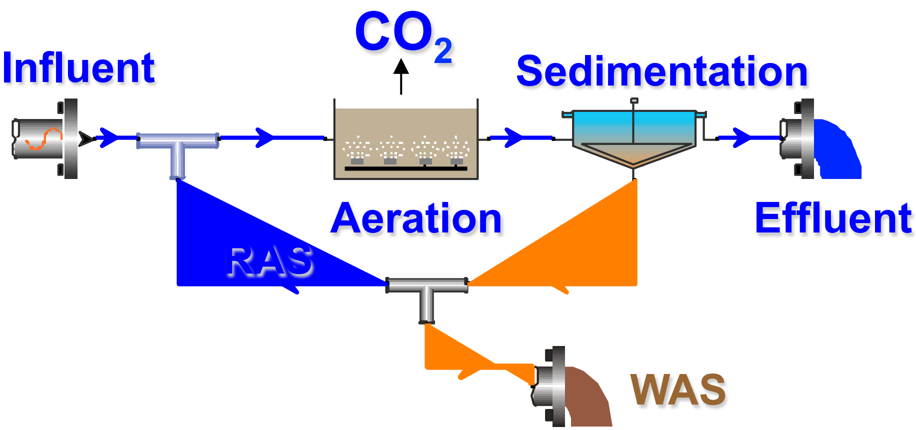


Upflow anaerobic sludge blanket

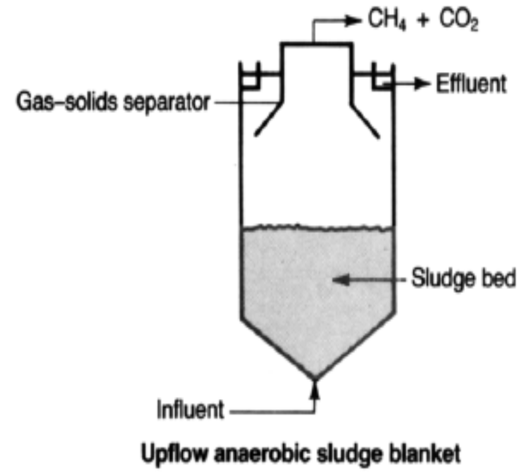
Courtesy of Prof. L.M. Whang

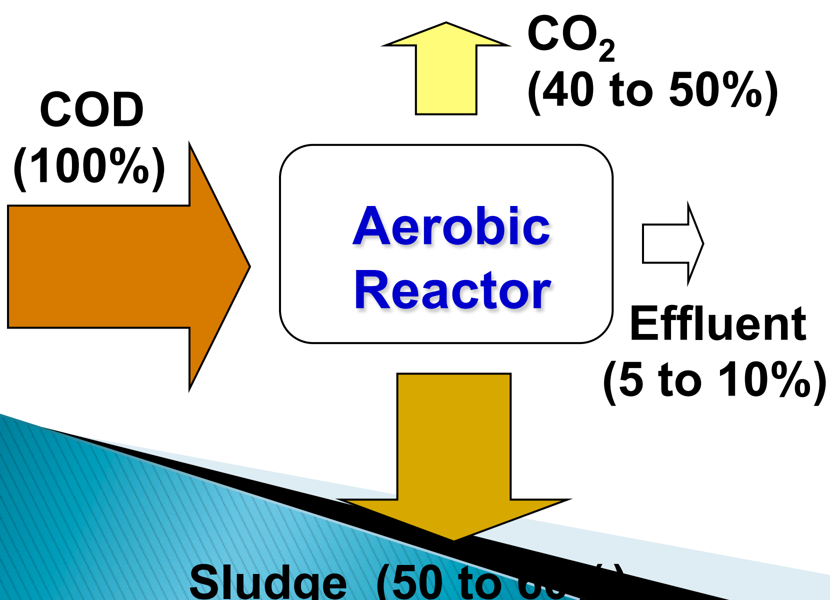
Biological Conversion of Organic Wastes in Aerobic and Anaerobic Systems

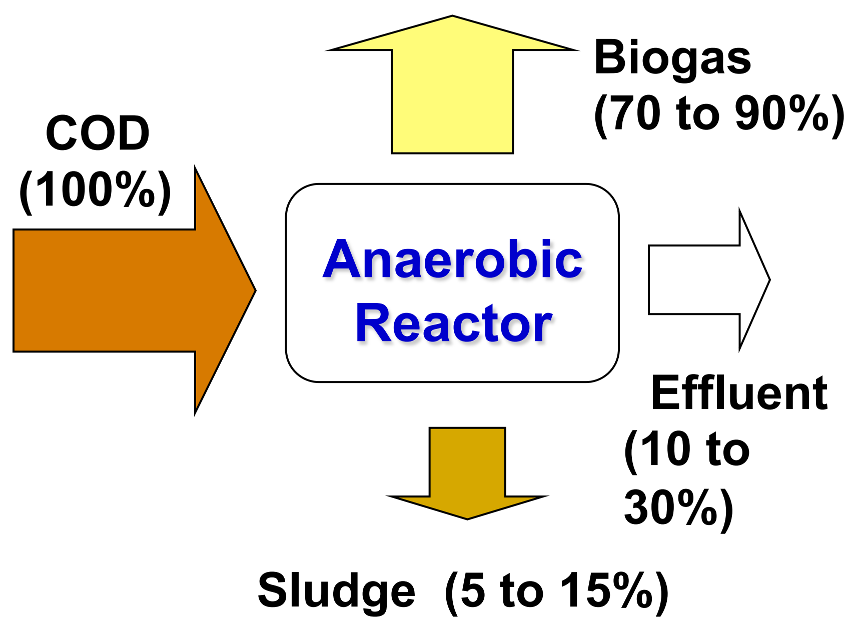
Aerobic Processes



Anaerobic Processes







Wastewater Treatment (Aerobic vs. Anaerobic)

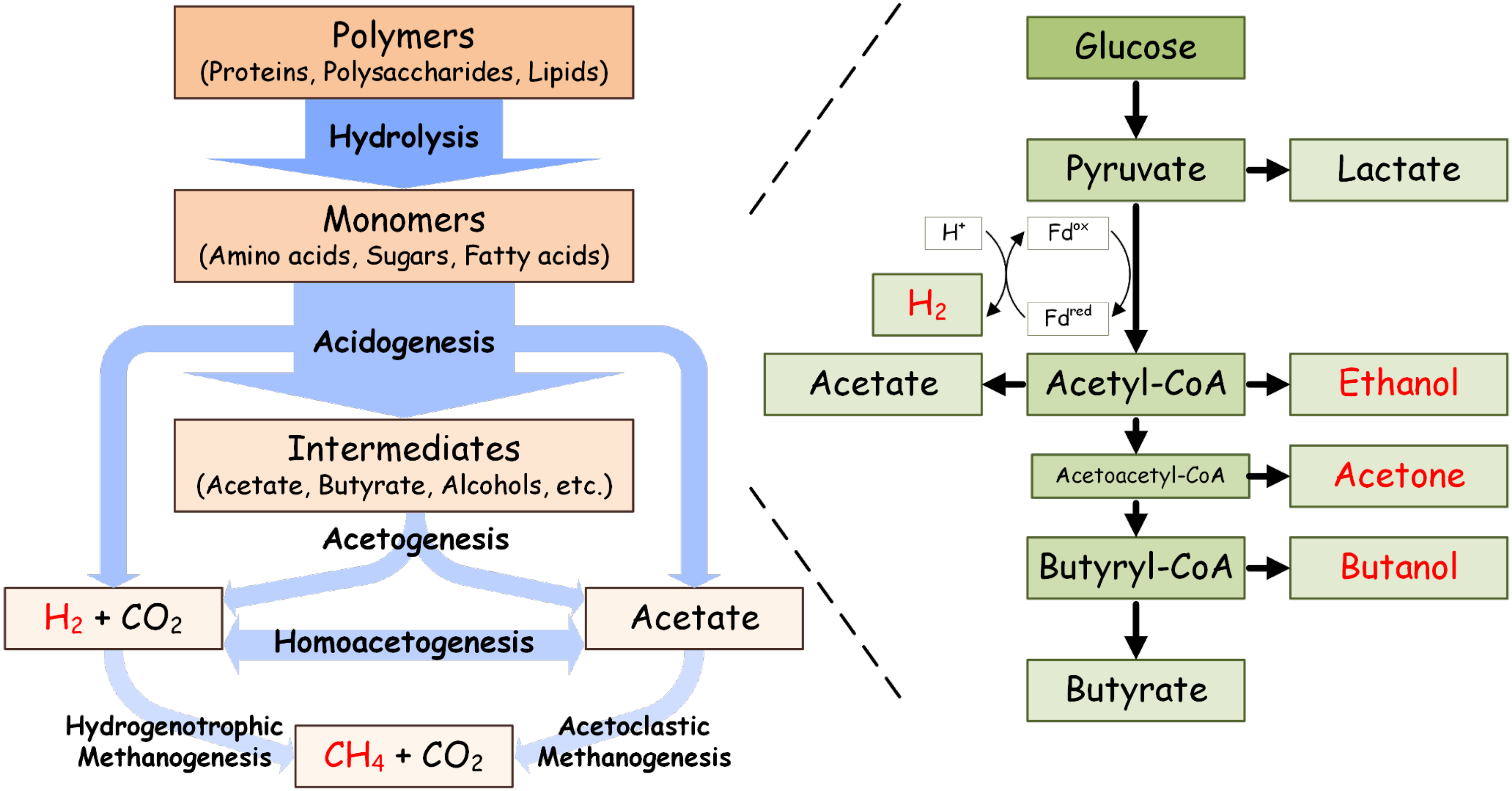
Aspects	Anaerobic	Aerobic
Energy requirements	Low	Much higher
Electron acceptor	Organic Carbon	O_2 (D.O.)
Degree of treatment	High (90%)	Very High (>95%)
Sludge production	Very low	Much higher
Nutrient requirements	Less than 1/5 of aerobic	Higher
Energy production	Yes (H_2, CH_4)	No
Effluent quality	Moderate to poor (Higher SS and NH_4^+-N)	Excellent (Relatively stable)

Anaerobic wastewater treatment

Solution to wastewater treatment and energy recovery

Courtesy of Prof. L.M. Whang

Anaerobic Digestion



Biofuels can be produced during anaerobic process:

H_2, acetone, ethanol, butanol, CH_4

◦ Case study in Oleochemical Industry

Laboratory
Scale

200 L
Pilot Scale

700 and 1,500 m3
industrial scale

Case study in energy-drink industry

Original condition :
wastewater was treated aerobically

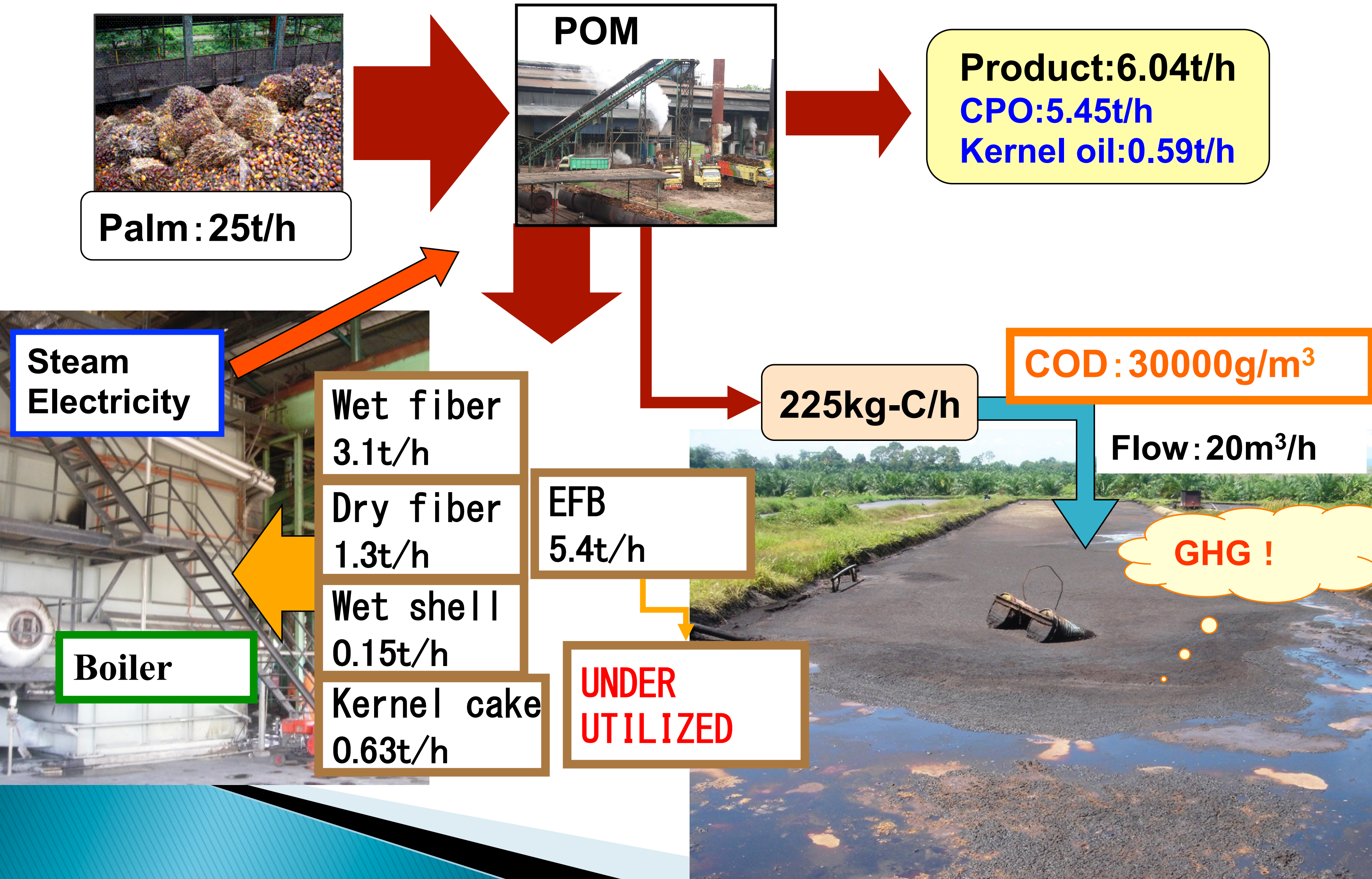
Current condition :
- increase in capacity (Three times),
- wastewater is treated anaerobically and aerobically

THE CHALLENGES

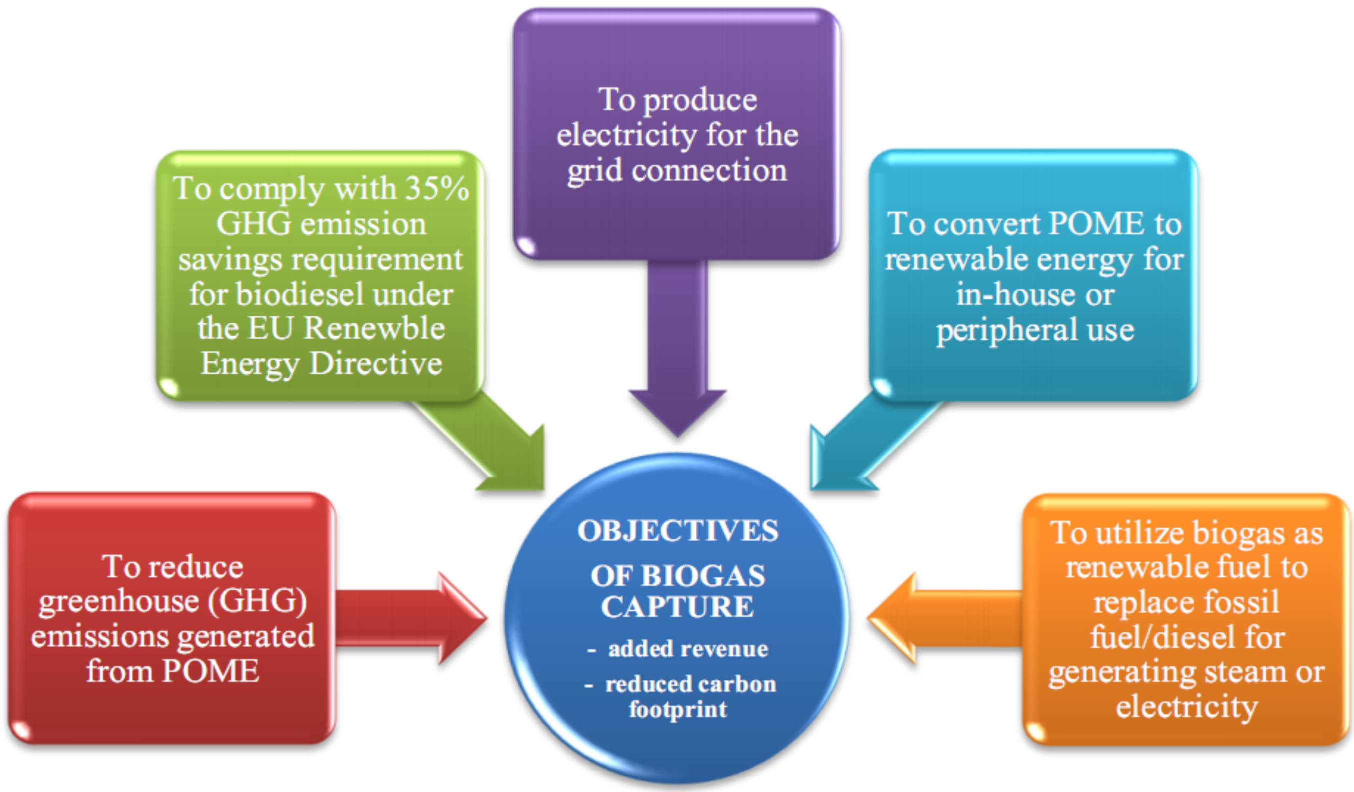
- Although the application of anaerobic processes are common in certain applications (industries), however this process is still applied rather 'primitively'. such as in the agroindustries throughout Indonesia.

- The application of anaerobic and aerobic processes as energy generators.

Material flow in Palm Oil Mill

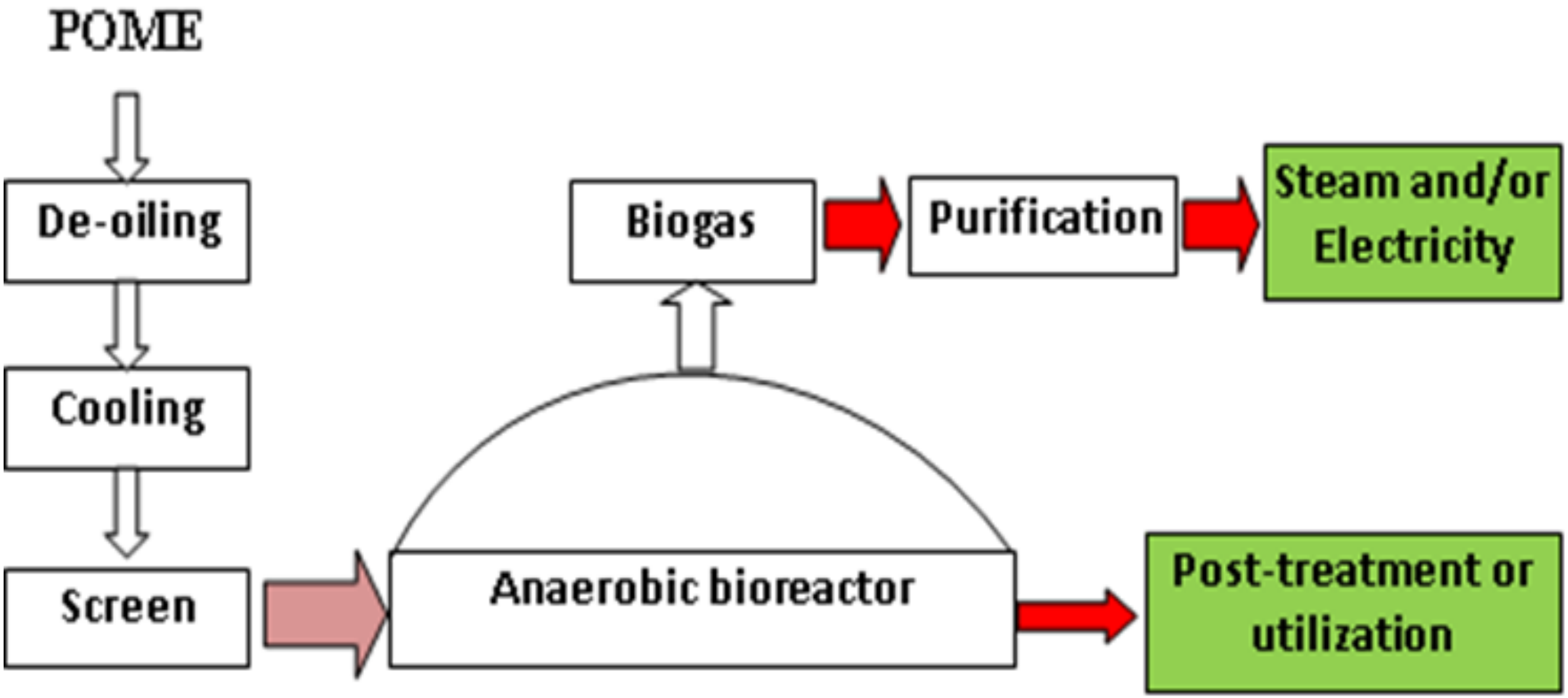


Benefits of methane capture from POME and their impact on reducing global and local environmental burden



Udin Hasanudin and Tjandra Setiadi (2016), 'Sustainable Wastewater Management in Palm Oil Mills'. Chapter 27 in 'Green Technologies for Sustainable Water Management', Editor: Ngo et al (2016), ASCE

Process design for the anaerobic treatment and utilization of POME



Potential electricity production and CO_2e emission reduction from POME at a palm oil mill with a capacity of 45 ton FFB/hour

INPUT

Capacity	45	Ton FFB/h
	900	Ton FFB/day
COD Influent	45000	mg/l
Flow rate	630	m3/day
COD load	28350	kg COD/day

BIOGAS PLANT

OUTPUT

COD Effluent	4500	mg/l
COD removal	90	%
Flow rate	630	m3/day
kg DOD rem	25515	kg CODr/day

BIOGAS Production

CH4 Production	8930.25	m3/day
CH4 Concentration	65	%
Biogas Production	13739	m3/day
	572	m3/h
LHV	23	MJ/m3
Potential electricity production	3.66	MW
Eff. Conversion	35	%
Electricity production	1.28	MW
CO_2e Emission Reduction	133.95	tons CO2/day

Udin Hasanudin and Tjandra Setiadi (2016), 'Sustainable Wastewater Management in Palm Oil Mills'. Chapter 27 in 'Green Technologies for Sustainable Water Management', Editor: Ngo et al (2016), ASCE

The next challenge >> MICROBIAL FUEL CELLS

- Novel biotechnology for energy generation

- Microbial fuel cells (MFCs) provide new opportunities for the sustainable production of energy from biodegradable, reduced compounds. MFCs function on different carbohydrates but also on complex substrates present in wastewaters.

Microbial Fuel Cell (MFC)

Organic Matters → Microorganism → Electricity

- Occuring in anaerobic condition
- As a wastewater treatment
- Produce sustainable clean energy
- Can use wide range organic compounds as fuels
- Cost effective

R.M Rachma, V. Reinaldo, A. Muhyinsyah and **T. Setiadi**. 'Electricity generation from Tapioca wastewater using a Microbial Fuel Cell (MFC)'. Southeast Asian Water Environment 4. IWA Publishing, London, 2010. pp. 115-120

MFC Principles

Anode

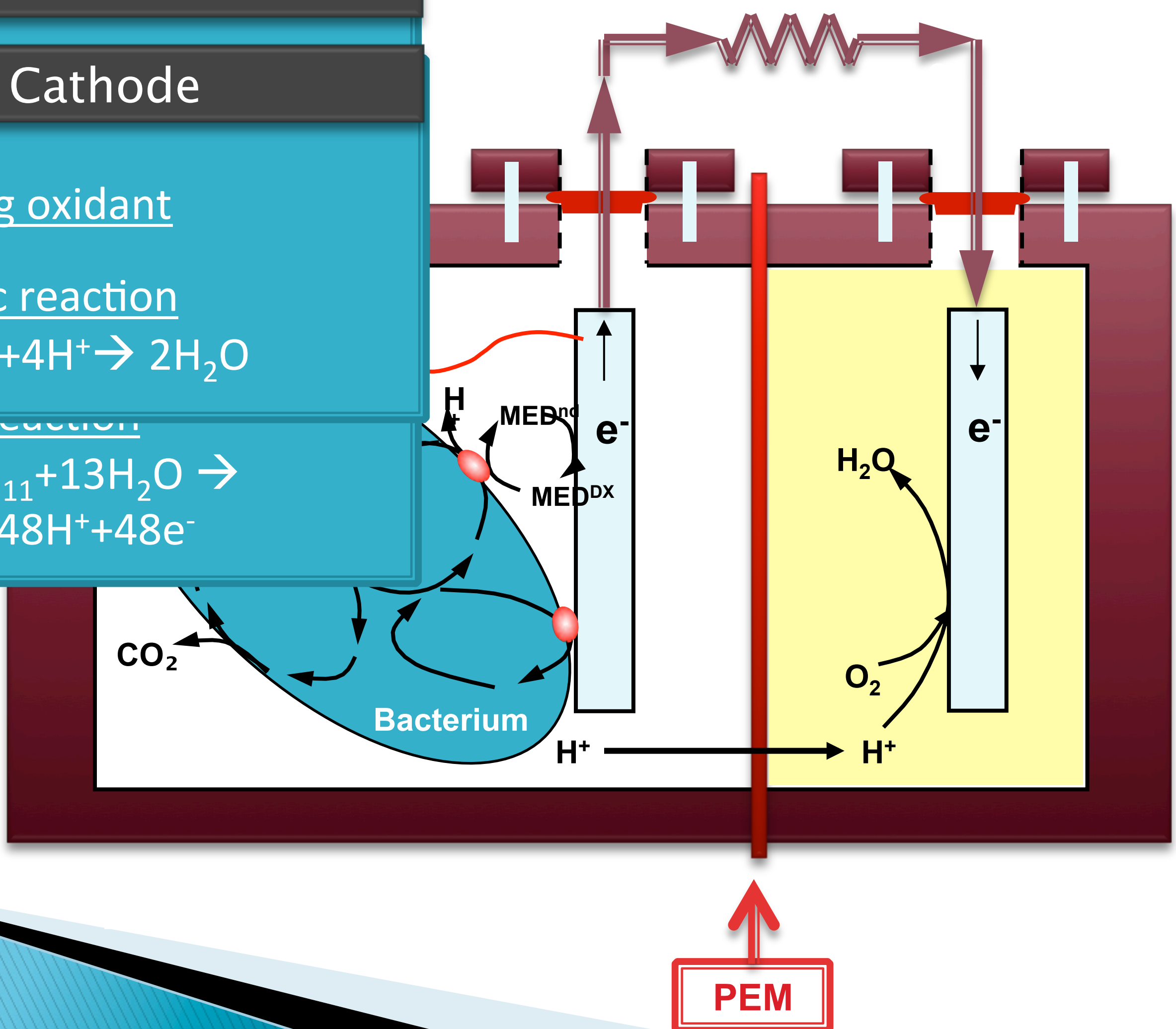
Cathode

- Reducing oxidant
- Cathodic reaction

  $O_2 + 4e^- + 4H^+ \rightarrow 2H_2O$

Anodic reaction

$C_{12}H_{22}O_{11} + 13H_2O \rightarrow$
$12CO_2 + 48H^+ + 48e^-$



Tapioca Wastewater in Indonesia

15 million tons/year

Characteristic of Tapioca Wastewater

high organic content

Parameter	Area			
	Padalarang		Sumedang	
	Range	Avg	Range	Avg
COD (mg/L)	6000 – 8000	7000	6000 – 12000	9000
NTK (mg/L)	300 – 670	485	50 – 62	56
PO_4^{3-} (mg/L)	4000 – 12000	4000	5000 – 5500	5400
Volatile Fatty Acid (mg/L acetate acid)	30 – 60	45	30 – 100	65,36
pH	3,6 – 4,4	4	3,6 – 4,4	4

Hydrogen Production

Introduction

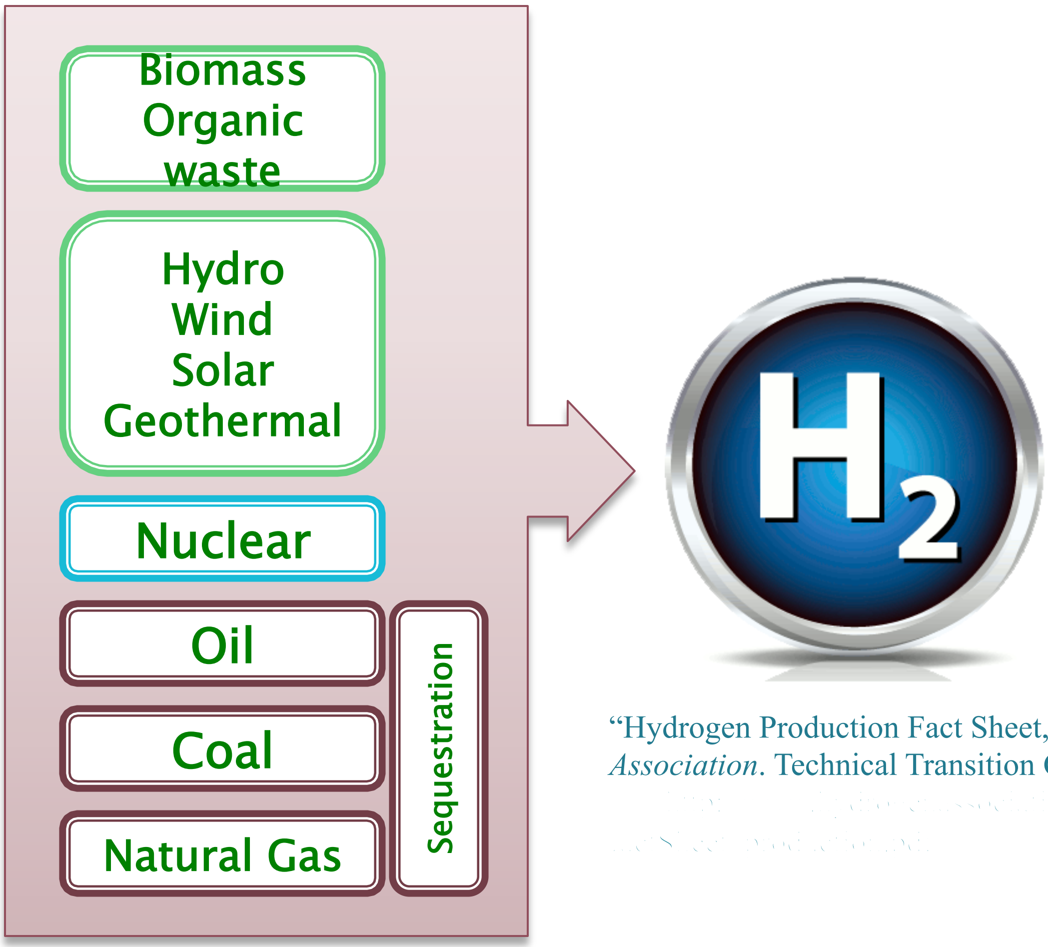
Todays, the primary energy for industries and other human activities are based on fossil fuels.

For the next decade, there will be a dramatic changing on primary energy utilization on industrial countries, changing into alternative fuel

One of the alternative fuel is **Hydrogen**

Billy Andreas, Ilona S. Horvath, Khamdan Cahyari, **Tjandra Setiadi**. (2011). Effects of Acid-Pretreatment of Inoculums and Substrate Concentration for Batch Thermophilic Biohydrogen Production from Starch-Rich Synthetic Wastewater. Proceeding of The 9th International Symposium on Southeast Asian Water Environment. Bangkok, 1-3 Dec. 2011

Bio-Hydrogen



"Hydrogen Production Fact Sheet," *The National Hydrogen Association*. Technical Transition Cooperation, (2005)

Methods	Process	Resources	Energy needs	Emission
Thermal	Steam reforming	Natural gas	High temperature vapor	+
	Gasification	Coal, Biomass	High temperature and pressure of vapor and oxygen	+
	Pyrolysis	Biomass	Relative high temperature vapor	+
Electro chemistry	Electrolysis	Water	Electricity from wind power, water and nuclear reaction	+
	Photo electrochemistry	Water	Sun light	–
Biology	Photo biology	Water and algae	Sun light	–
	Anaerobic Digestion	Biomass		–
	Fermentative Microorganism	Biomass		–

"Hydrogen Production Fact Sheet," *The National Hydrogen Association*. Technical Transition Cooperation, (2005)

Metabolism	Organism	Enzyme	Light need	e⁻ source	Product
Bio photolysis	Green algae	Hydrogenase	Yes	H_2O	H_2 and O_2
Photo fermentation	Phototropic bacteria	Nitrogenase Hydrogenase	Yes	Organic compound	H_2 and CO_2
Water-Gas Shift	Phototropic bacteria	Hydrogenase	No	CO	H_2 and CO_2
Dark Fermentation	**Fermentation** bacteria	**Nitrogenase Hydrogenase**	**No**	**Organic compound**	**H_2, CO_2, and organic acid**

"Hydrogen Production Fact Sheet," *The National Hydrogen Association*. Technical Transition Cooperation, (2005)

Dark Fermentation

- Dark fermentation has some advantages:
  - Simple technology
  - Best choice for organic waste conversion

Dark fermentation reactions:

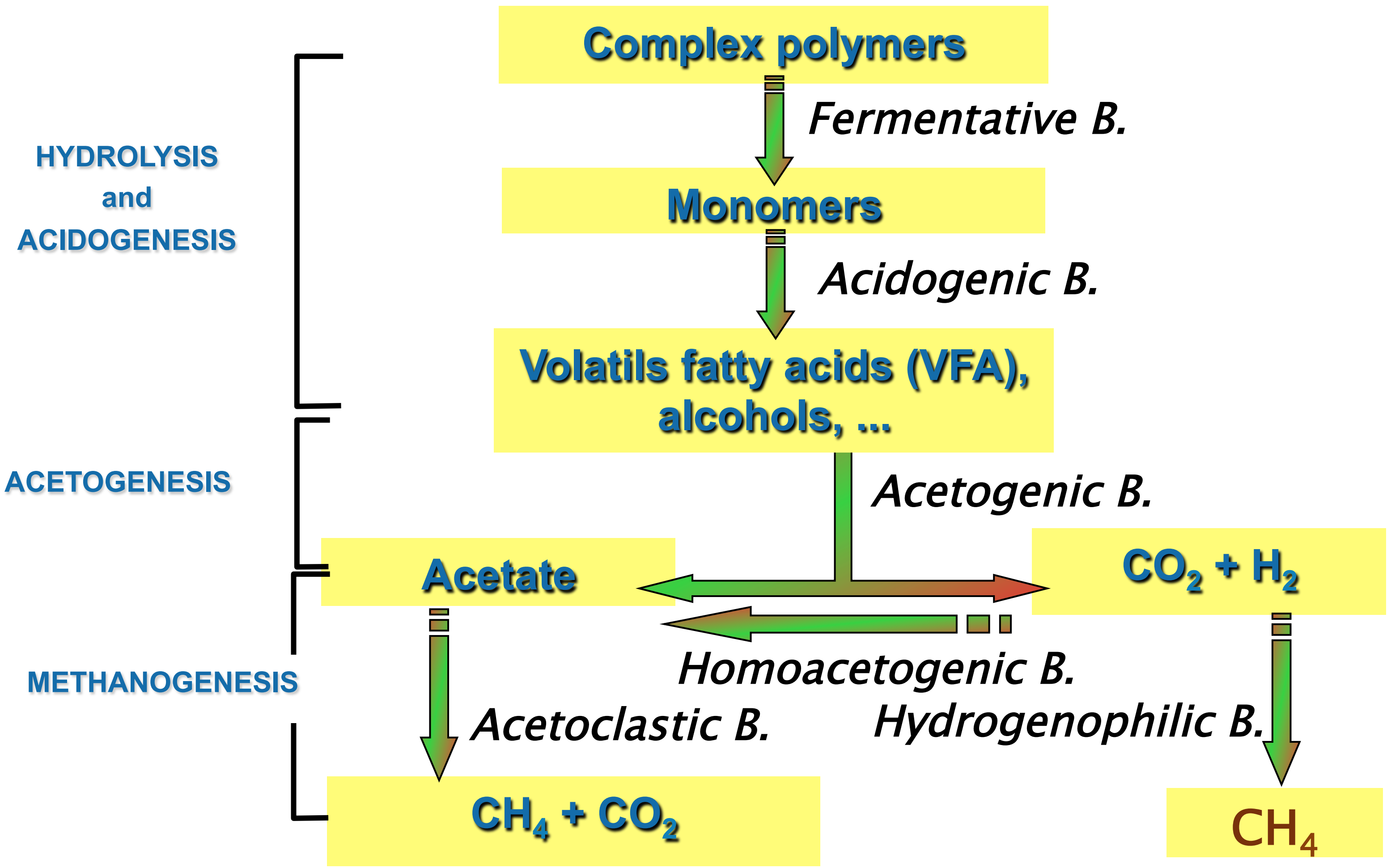
$$C_6H_{12}O_6 + H_2O \rightarrow 2CH_3COOH + 2CO_2 + 4H_2$$

$$C_6H_{12}O_6 + 2H_2O \rightarrow 2C_3H_7COOH + 2HCO_2 + 2H_2$$

$$4C_6H_{12}O_6 + 2H_2O \rightarrow 2CH_3COOH + 2C_3H_7COOH + 8CO_2 + 10H_2$$ *

* Benemann JR. Biological Production Of Hydrogen-Methane Mixtures For Clean Electricity Production. In: Fifteenth Hydrogen Energy Conference; 2004. Japan.

Anaerobic digestion



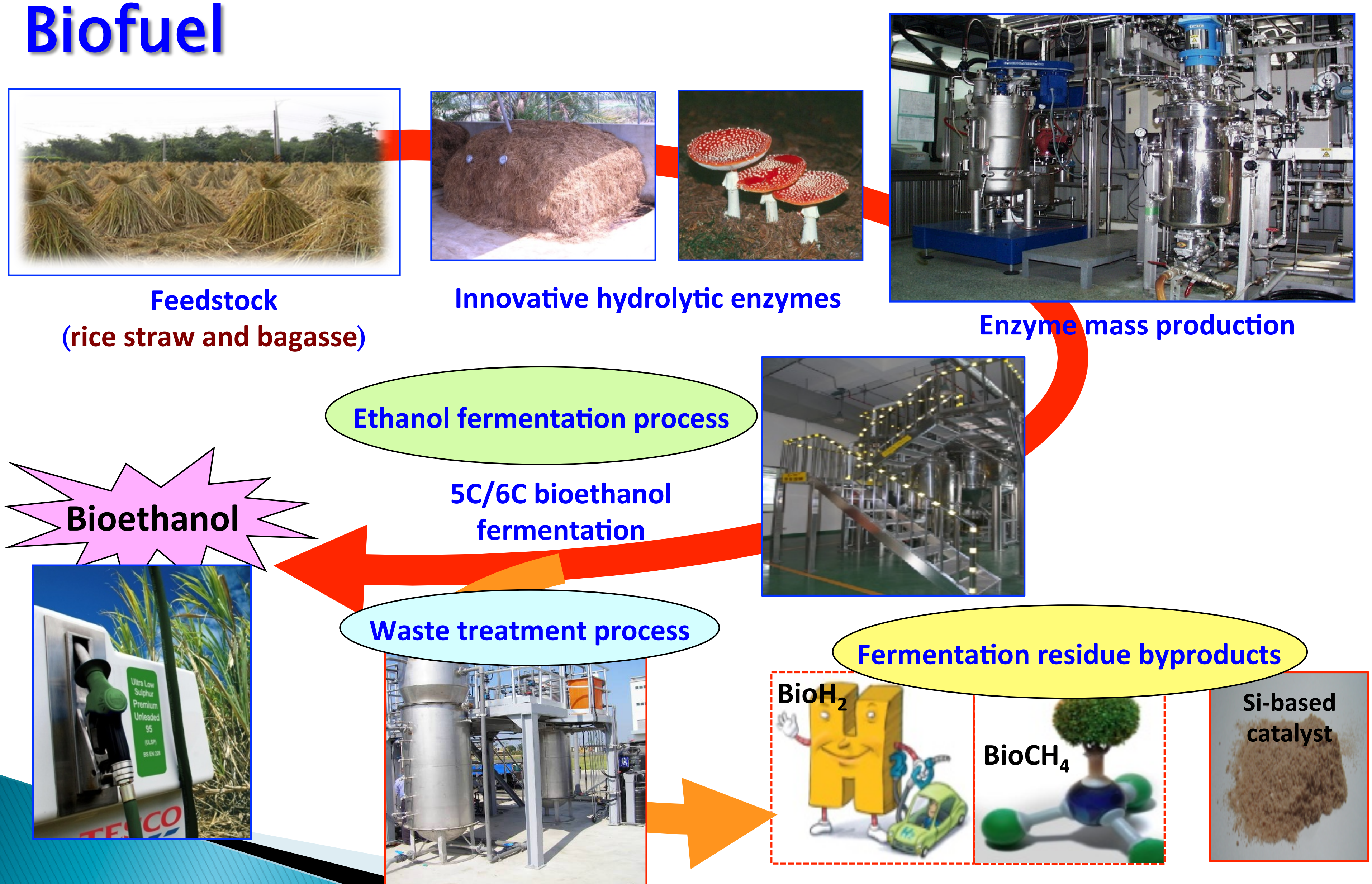
Organism	Substrate	Operation mode	pH/ temperature	Nutrition	Yield	References
C. acetobutylicum X9 + E. harbinese B49	Micro – crystalline	Batch	–/37^0C	+	1,8 L H_2/ L-POME	Wang et all(2008)
Thermoanaerobacterium-rich sludge	POME	Batch	5,5/60^0C	+	6,33 L H_2/ L-POME	Thong et all (2007)
C.saccharoperbutylacetonicum ATCC27021	Cheese whey (49,2g laktosa/L)	Batch	6/30^0C	–	2,7 mol H_2/mol lactose	Ferchichi et all (2005)
T. maritime DSM3109	Glucose (7,5 g/L)	Batch	6,5/65^0C	+	1,67 mol H_2/mol glucose	Nguyen et all (2008)
C. beijerinckii L9	Glucose (3g/ L)	Batch	7,2/35^0C	+	2,81 mol H_2/mol glucose	Lindkk., (2007)
Mixed culture	Potato processing wastewater	Batch	6,0/–	+	0,1 L H_2/g COD	Van Ginkel et all (2005)
Mixed culture	Rice Slurry (5 -CHO/L)	Batch	4,5/37^0C	–	346 mL H_2/g-carbohydrate	Fang et all (2006)
Mixed culture	POME	Repeated Batch	5,5/60^0C	–	2,3 L H_2/ L-POME	Atif et all (2005)
Mixed culture	Food waste	Continue	6,5/35^0C	–	0,39 L H_2/ g COD	Han et all (2004)

Materials

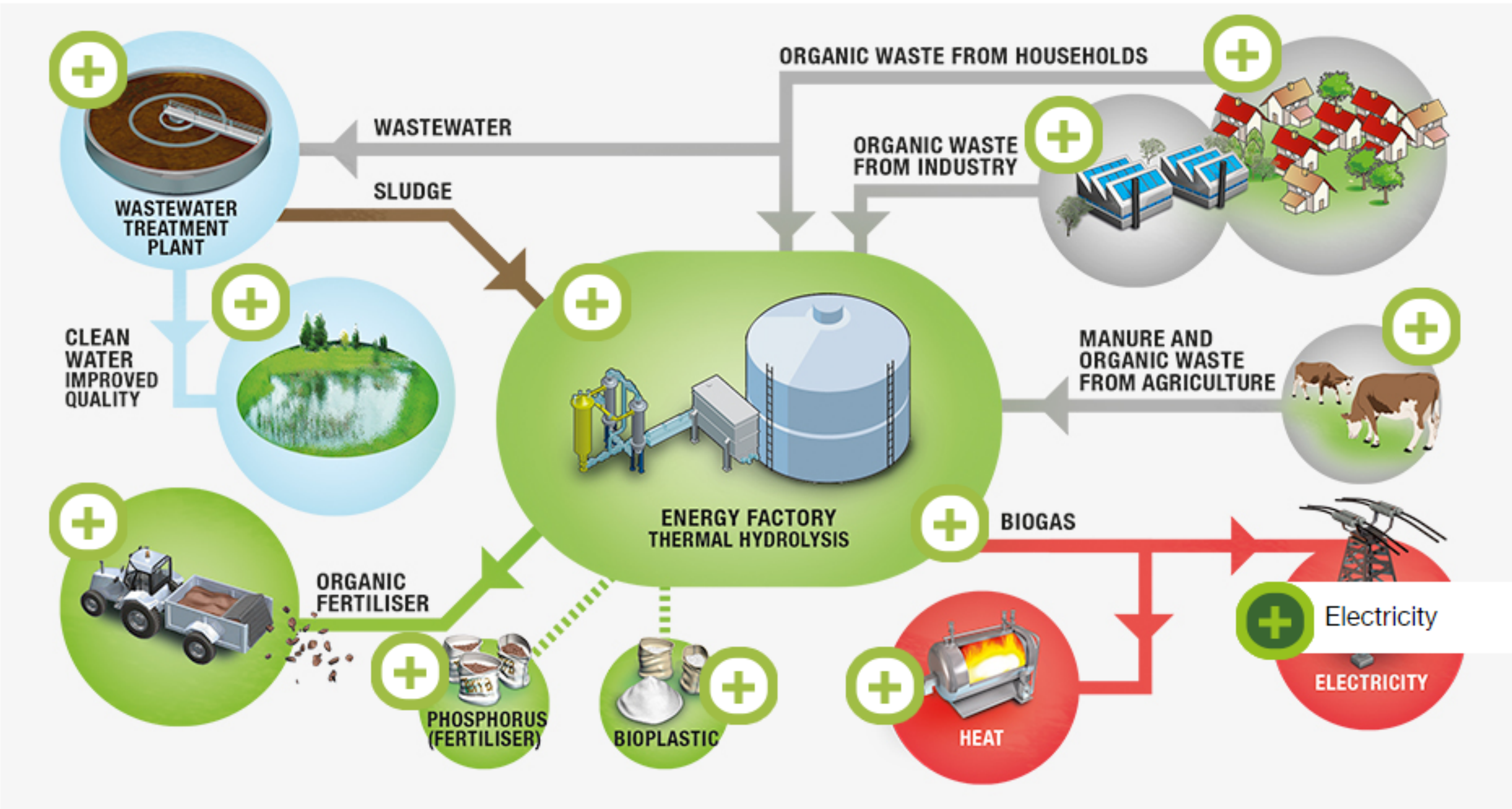
One kilogram of cassava yields 700 g starch and about 10 L of wastewater and as a carbohydrate-rich wastewater

The Future Research on Renewable Energy through Biological Processes

New Generation of Cellulosic Biofuel



Courtesy of Prof. L.M. W

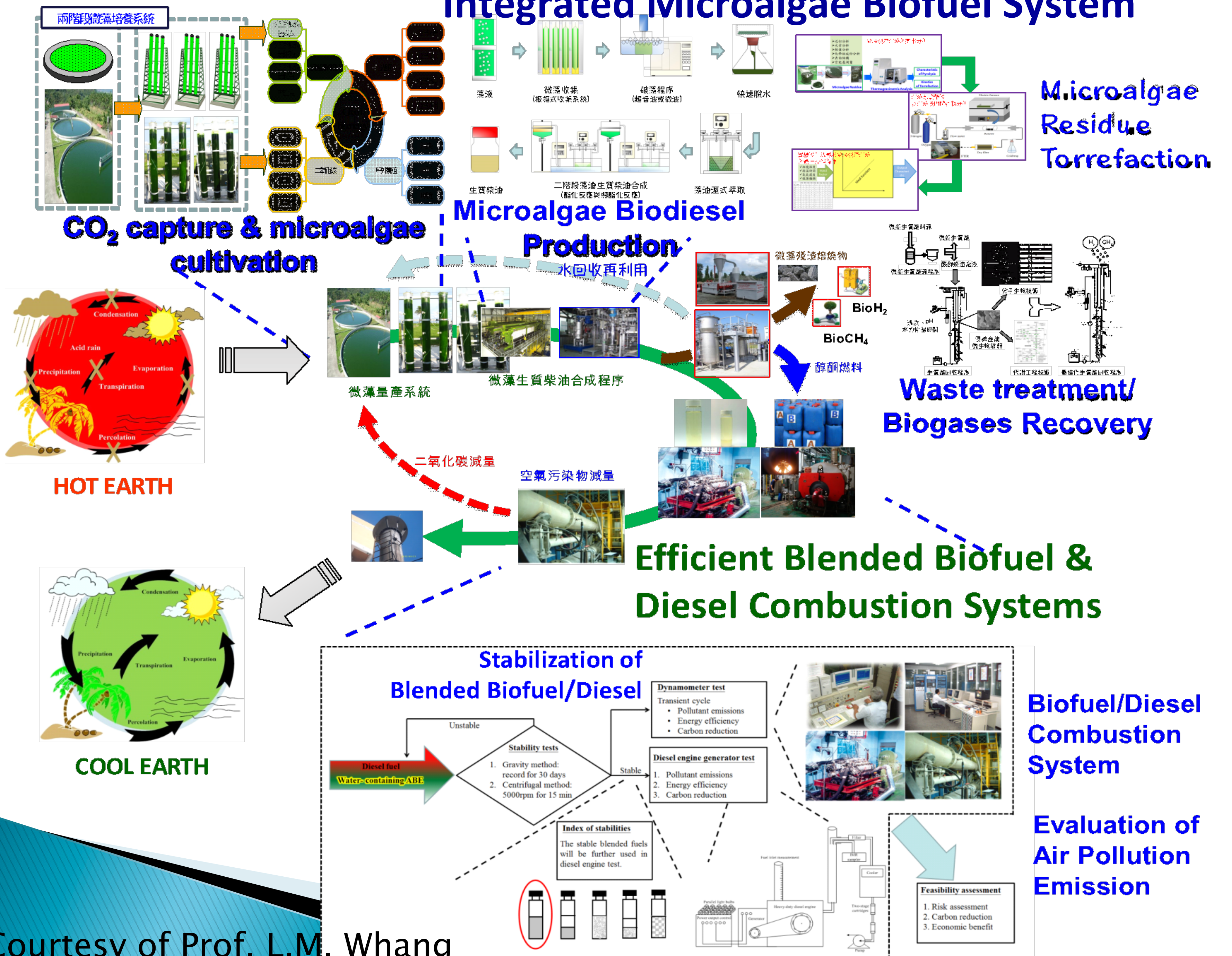


Billund BioRefinery - Resource Recovery for the Future

Waste and wastewater are not problems

Courtesy of Prof. Willy Vestraete

Integrated Microalgae Biofuel System



Courtesy of Prof. L.M. Whang

West Hall

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Thank You.....