Algae, Cyanobacteria:
• Microorganisms which have water-splitting capability

Biomass for Sustainable and High Quality Electricity Supply in Remote Area

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Annex 21/IEA-HIA
Regional Coordinator, EX OA
Chairman, Asia BioHyLink
Ultimate Goal of Technology

We are too much influenced by Industrial Revolution

Historical View for Technology Revolutions

Biomass of Use!

Entropy Engineering

Energy Engineering

Industrial Revolution

18c 20c Time
Brazilian Started Biomass-Hydrogen

Hydrogen Production

Alcohol Fermentation Waste

Hydrogen energy comes slow, but it is progressing certainly.

EVs vs Fuel Cell vs H₂ Cars
Regenerative Energies Substitute Oil?

NOT SIMPLE

But There is Hope

HOW?

Problem (1)
We Forgot the Cost of CO2 Recycle

\[
\Delta G = \Delta H - T\Delta S \quad \text{Gibbs}
\]

\[
\Delta F = \Delta U - T\Delta S \quad \text{Helmholtz}
\]

Oil is less harmful energy source than Nuclear power ????

CO2 is really giving troubles
1) Global Warming
2) Localized Torrential Downpour

Diffused Gas is no more possible to accumulate:
Heavy Cost is required (Entropy)
Problem (2)
Defects on Renewable Energy (a)

Wind and Solar are intermittent = fluctuating:
Could battery normalize the power?

Battery makes the cost effect

Environmental Effects through device production

Problem (3)
Defects on Renewable Energy (b)

Two difficulties
Accumulation of low-density energy
Normalization of the intermittent energy

It cost financially and energetically
Problem (4)
Solar Energy: Huge but Low in Density

Solar Radiation at the Earth Surface = 1.76x10^17 J/sec
Energy Consumption = 4.22x10^20 J/year = 1.34x10^13 J/sec
**Solar Energy: Huge but Low in Density**

Solar Radiation at the Earth Surface = $1.76 \times 10^{17}$ J/sec

Energy Density $\sim 1$ kW/m$^2$

Energy Consumption = $4.22 \times 10^{20}$ J/year = $1.34 \times 10^{13}$ J/sec

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**Energy Path for Reality**

- Cutting Peak power
- 5-15% Reduction in Total Power
- 50% Reduction in electric power peak demand
- 50% Reduction in infrastructure

---

**Biotechnology for Energy Substitution?**
Two difficulties
Accumulation of low-density energy
Normalization of the intermittent energy

It cost financially and energetically

We have not to forget
Biomass

1) Made by Automatic Process
2) For Automatic Storage

Good to Solve the Problems
Collection of Biomass: Simple and Economical Way

Soft Energy Path

Soft Energy Path, very simplified expression of low entropy system

50mx50m
- Agriculture
- Energy
- Resources

Emory B. Robins
Possible Applications

Classification of BioHydrogen Applications

1. Abundant Biomass (Large) → Ready to Go!
   Industrial Wastes as Ethanol Production in Brazil

2. Factory/Municipal Wastes (Middle) → Special Purpose
   Biomass/Population Ration is low
   Co-Generation, Supply to Waste-Water Treatment Facility

3. Country Side (Small) → Balanced (Smart) Grid
   High Quality Electric Power Supply
   Reduction of Infrastructure

4. Very Remote Area (Spot)
   Biomass Could be the Primal Energy Source

5. Mimetic Devices
Case 1. Abundant Biomass  Brazil Gasohol

Japanese Beer Brewer Ferments Brazil’s Biomass to Produce Hydrogen

Sapporo Breweries Ltd. plans to collaborate with Brazil’s state-owned oil company, Petrobras, to test a process for making hydrogen fuel from sugar cane dregs and other biomass.

Sapporo is testing a technology in Japan that generates hydrogen from the fermentation of bakery waste. Petrobras will use this technique to produce hydrogen fuel from the plentiful biomass available in Brazil.

Research plan to 2012, Commercialization before 2019, Petrobras USA$2.8B Total Budget of Biomass Fuel is up to 2013
**Sapporo/Ministry of Environment Project**

**Carbohydrate to H2 Conversion Efficiency 60-80%**

<table>
<thead>
<tr>
<th>Budget of the project</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007FY (from Nov.) 0.5-0.6M USD</td>
<td>Start to construct the pilot plant (H2-CH4)</td>
</tr>
<tr>
<td>2008FY (0.5-0.6M USD)</td>
<td>Working of the pilot plant using waste bread</td>
</tr>
<tr>
<td>2009FY (0.5-0.6M USD)</td>
<td>Long term stability and evaluation based on LCA</td>
</tr>
</tbody>
</table>

**Case 2. Factory Wastes**
Case 2.

NEDO-AIST-Kashima Project
A Test-Plant in Tsukuba (A NEDO Project)
Kitchen Waste 50kg +
Paper Waste 3-5kg/day

CH₄+H₂ Fermentations

Case 2.

Green Energy Development Center,
Feng Chia University

NEDO-AIST-Kashima Project
A Test-Plant in Tsukuba (A NEDO Project)
Kitchen Waste 50kg +
Paper Waste 3-5kg/day

CH₄+H₂ Fermentations

Green Energy Development Center,
Feng Chia University
Case 2. Factory Wastes  Wageningen U./AIST

Potato-Chip Factory Fluent: (Paring)
High Temperature (ca. 90°C), Conc. Carbohydrate

Waste water containing organic materials

Anaerobic reactor

Hydrogen Recovery

Photovoltaic synthetic reactor

Waste

PI*: Miyake, Jun
Wageningen University: Stams, Fon
Mie University: Goto, Kazuo

Pyrococcus furiosus anaerobic fermentation

Hydrogen fermentation by P. furiosus at 90°C in semi-large scale culture.

Gas evolution rate were 58 ml/h from 5 g starch in 1 liter
Selection of photosynthetic bacterial strains

Screening strain which have photo-synthetic hydrogen production ability

Hydrogen evolution by strain CST8 from acetate with 1% NaCl

Reactors

AIST/METI/NEDO Projects of BioHydrogen
AIST/METI (NEDO) Projects of BioHydrogen

Reactors

Department of International Affairs

Japan (JST)-China (NSFC) 7th Joint Workshop on
"Science and Technology for Environment Conservation and Construction of a Society with Less Environmental Burden"

Date : Aug. 30th and 31st, 2010
Venue : Jingui Hotel, Beijing, China
Coordinators : Professor TANG, DaWei
             Institute of Engineering Thermophysics, Chinese Academy of Sciences
             Professor HARAMURA, Yoshihiko
             Graduate School of Engineering, Kanagawa University
Sponsors : Japan Science and Technology Agency (JST)
           National Natural Science Foundation of China (NSFC)
Project (1) BioHydrogen Production with Consortia Engineering

Prof. XING, XinHui, Tsinghua University

Prof. Katsutoshi Hori, Nagoya University

Prof. Jun Miyake, Osaka University

2011-2015 ca. 1.5MUSD(1)+(2)

Project (2) Electricity Generation with Stirling Engine

Prof. Dawei Tang: Institute of Engineering Thermophysics, Chinese Academy of Sciences

Prof. Yoshihiko Hamamura
Kanagawa University
Case 3. Country Side

Infrastructure/Cost/Quality

Biomass

Fuel Cell

Electricity Supply by Existing Power Network

5% of the demand of the 20 Families (29 MWh/y (122 kWh X 20 y))

Social Science
How to realize Harmonized Developments

Methane/Hydrogen Complex Gas

Gas-Electricity Conversion Engine

ByProduct
Drugs
Supplements

Reactors design by LIPI (Indonesia)

Biomass

Biomass for Electricity Supply
Corn Wheat ~ 2 t/y or
Palm ~ 2 t/y or
Rice ~ 3 t/y or
Cow Dung ~ 10 t/y

Electricity Supply by Existing Power Network

5% of the demand of the 20 Families (29 MWh/y (122 kWh X 20 y))

Fuel Cell

Gas-Electricity Conversion Engine

ByProduct
Drugs
Supplements

Social Science
How to realize Harmonized Developments

Methane/Hydrogen Complex Gas

Gas-Electricity Conversion Engine

ByProduct
Drugs
Supplements

Reactors design by LIPI (Indonesia)
Case 4. Very Remote Area
LIPI's Research on Biomass Energy

Program IPTEKDA LIPI – Peternakan moderen

Sulawesi Selatan
3 Sapi berat rata-rata 350 kg

Digester
Ketuluan energi listrik & kompor masak

LIPI's Research on Biomass Energy

Digester
Keluaran energi listrik & kompor masak
Case 5. Mimetic Devices

PhotoElectric Device

Hydrogen evolution with Hydrogenase ($H_2$ase) catalysis

$H_2$ase from *Thiocapsa roseopersicina*

$H_2 \rightleftharpoons 2H^+ + 2e^-$

$H_2$ase (MW 91kD, pl 4.0, diameter 11 nm) is an enzyme to *catalyze* the reversible reduction of proton into $H_2$. 
Optimization of the photosynthesis module
- Development of artificial systems
- Technical system analysis and balancing of the various systems
- Optimization of the hydrogenase module

Electron transfer mediator for H$_2$ase

Electron transfer via methylviologen from ITO electrode to H$_2$ase active site
A supergrowth single-walled carbon nanotube “forest” (SWNT-F) was synthesized. Carbon nanotubes are considered to have excellent electrical conductivity. In the SWNT-F, densely packed carbon nanotubes were grown along one direction; the large surface area thus formed is useful for harboring molecules in the inner space between the carbon nanotubes. In this study, SWNT-F was first used as an electron transfer mediator for the H_2ase in order to develop the new H_2 evolution device.
The hydrogen evolution increased when bias potential was applied. A sharp response was found in switching on and off of hydrogen evolution.

The hydrogen evolution was found to depend closely on the bias applied. Otherwise, a very weak signal was detected.

The CNT forest covered by a membrane of Seamless Cellulose Tubing could mediate the electron transfer from electrode to hydrogenase.
Renewable Energy

1. Combination of Various Kinds
2. To Cancel/Compensate the Defects
3. Biomass as a Storage and Balancing Member

Ultimate Goal of Technology

1. Live in the flow of natural energy
2. Energy accumulation with high efficiency
3. Low-Entropy emitting system in IN/OUT

System Design and Applications
BioHydrogen In the World

Partners in HYVOLUTION

Aim
Blue print for a bioprocess for decentralized hydrogen production from biomass

22 partners
13 countries (7 Task 21)
Jan 2006 – Dec 2010
14 M€ budget
10 M€ EC grant
www.hyvolution.nl
Rapidly Growing Activity in Asia
(No. Researchers, Papers)

KIEL, Daejon Korea 2007

Asia BioHyLinks
China, Indonesia, Japan, Korea, Malaysia, Singapore, Thailand, Taiwan, Vietnam,

1. 2006 Singapore Preparative Meeting
2. 2006 Taichung, Taiwan
3. 2007 Daejon, Korea
4. 2008 Harbin, China
5. 2009 KongKeh,n Thailand
6. 2010 Taichung, Taiwan
7. 2011 Bogor, Indonesia
8. 2012 ChonChen, China

As a Network Node in Asia

The first Asian organization of researchers of this field. The activity corresponds to COST 841 in EU.