Demonstration of Biofuel Production Technology from Non-Edible Biomass Resources at AIST for Sustainable Biomass-Asia Strategy

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"Green Biomass for Blue Earth"

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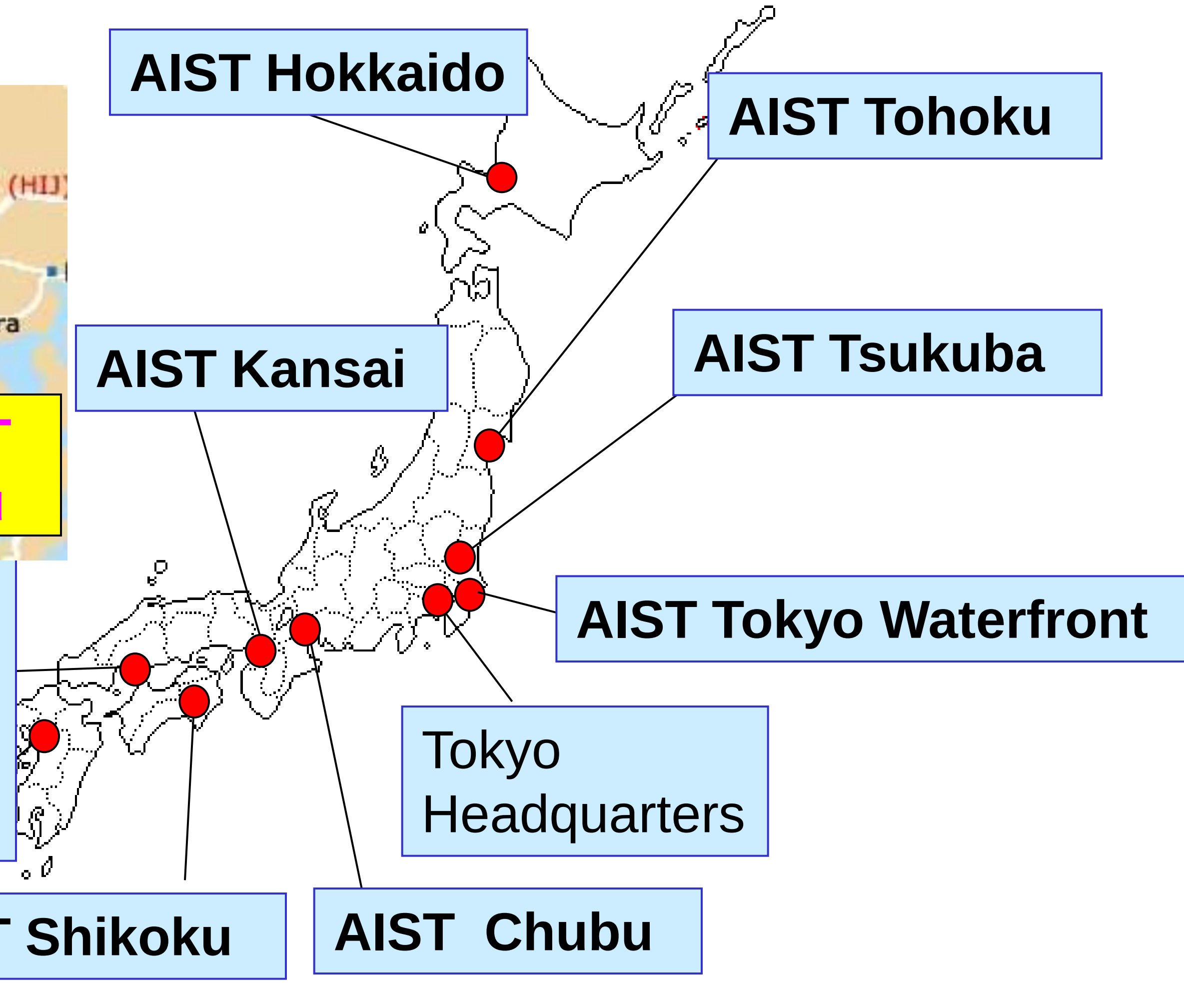
Research Bases of AIST

AIST Chugoku(Biomass Technology Research Center, 1/10/2005 started, and relocated to Higashi-Hiroshima in 1/4/2010)



Challenges in the 21st century

1) **Energy**
2) **Environment**
3) **Food**

Trilemma !

Collaborations (Agriculture & Engineering etc.) in the Asian Countries

keyword: **Biomass**

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Political and Social Needs

Political Need;

- Biomass Nippon Strategy（2002 & 2006 renewed）
- EPA：Japan-Malaysia(2006), -Thailand(2007), -Indonesia(2008)
- Japan-China-Korea Science&Technology Collaboration Ministry Meeting (2007)
- East Asia(ASEAN+E3) Summit：Cebu Island Declaration(2007)
- **Toya Lake Summit (2008) , COP15 (2009) =>=> 2020, 2050**

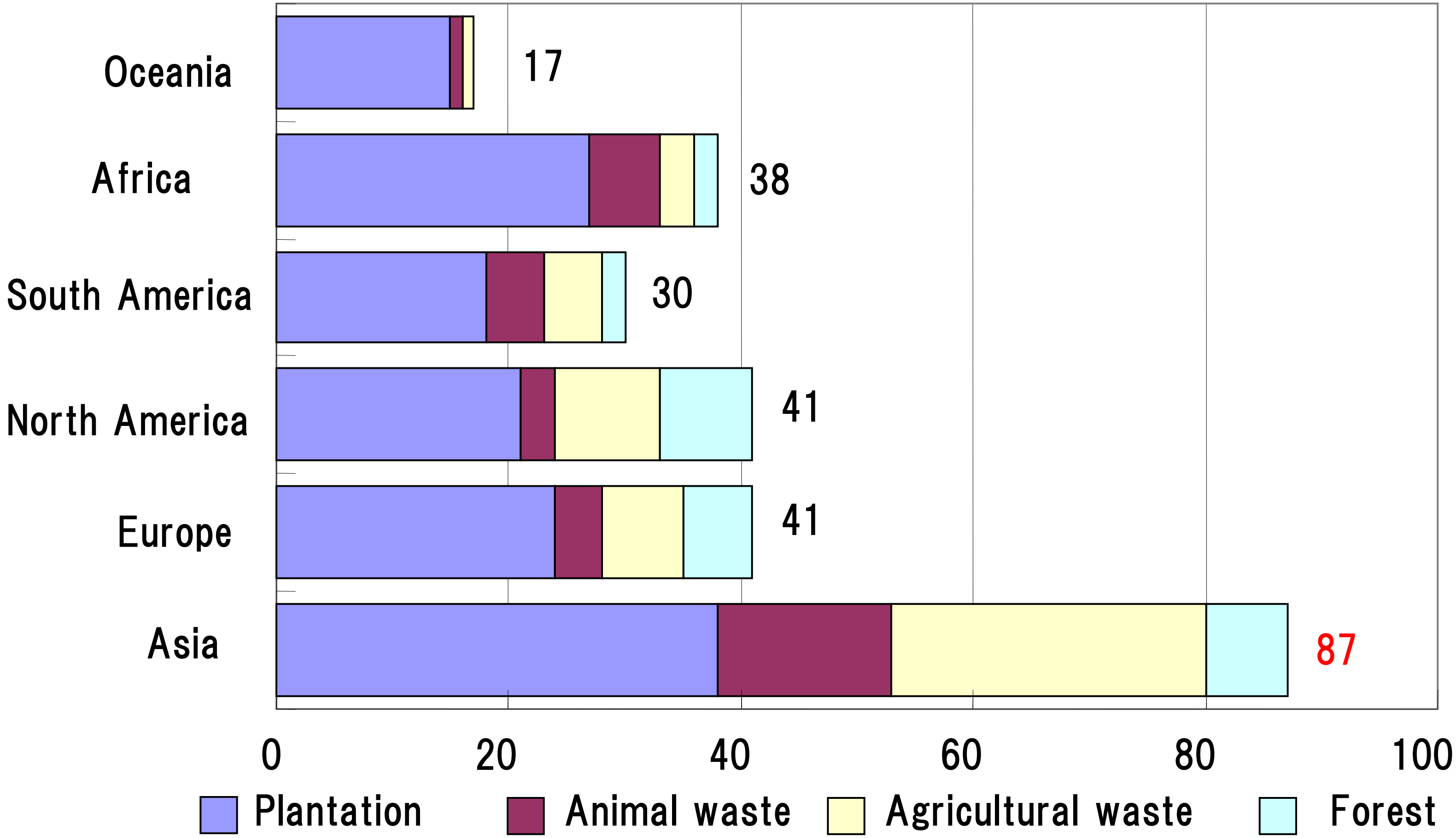
Social Need and Impact;

- Mitigation of Global Warming
- Substitution of Fossil Fuels
- Activation of Agriculture
- Suppression of Desertification
- Demonstration of Sustainable Development Scenario

Potential of Biomass Energy in the World

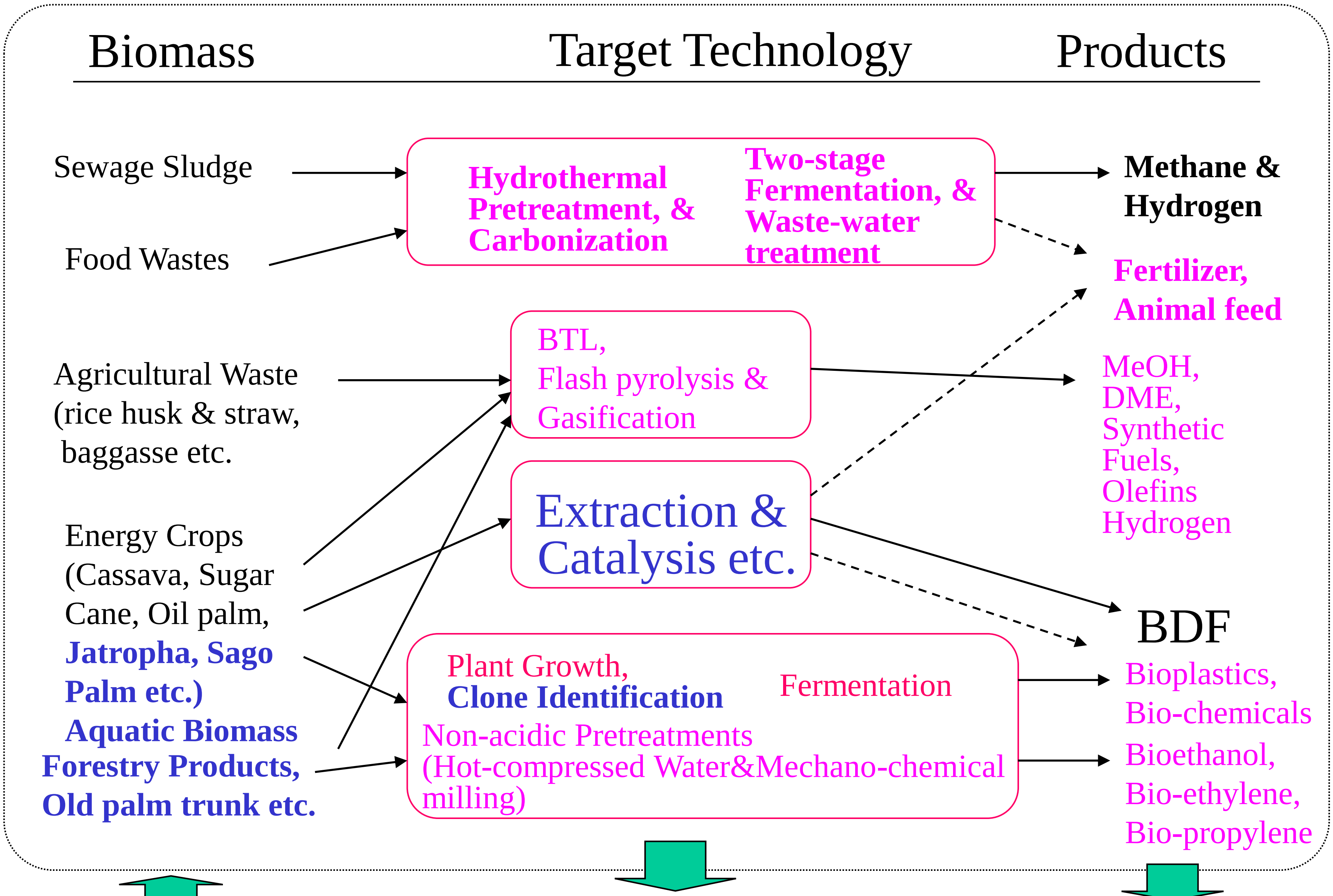
Asian region has abundant biomass resources.
(87EJ corresponds to 2.3 billion kl-petroleum)

Unit: EJ ※1EJ=2.6×10^7kl-petroleum



Ref. "Study on energy conversion technology for Biomass" (RITE、1998～2000)

Potential Collaboration Projects on Utilization of Non-Edible Biomass

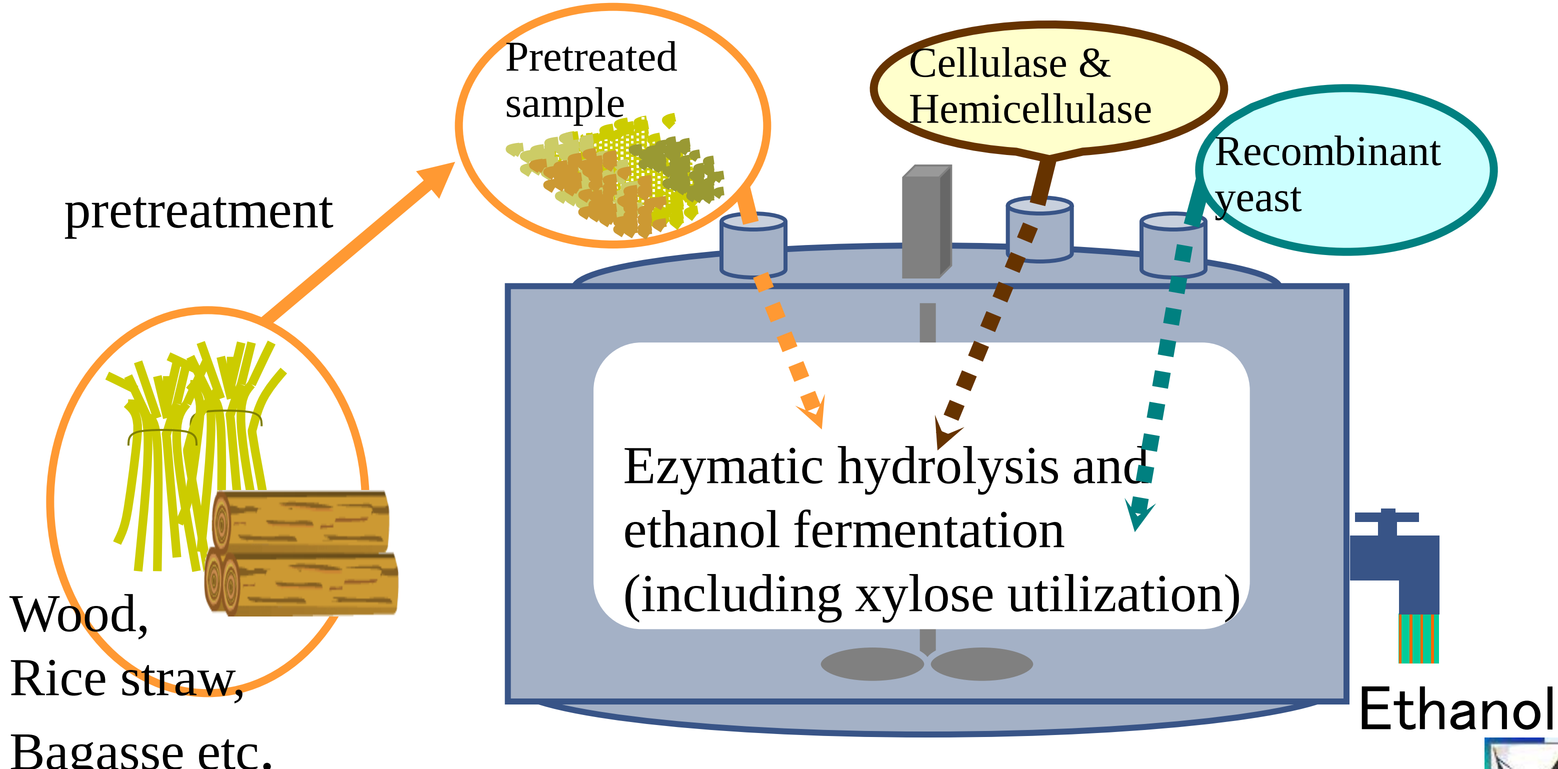


Biomass LCA, New CDM

Technical and Post Doctoral Training (JICA/JST, NEF, AIST fellowship etc.)

Standardization in Asia & JIS, and ISO

BTRC ethanol production process (One-batch concept)



→ Requirement of pretreatment without separation of cellulose and hemicellulose fraction

→ Requirement of cellulase and hemicellulase to hydrolyze both components

→ Requirement of glucose- and xylose-fermenable recombinant yeast

Mini plant(0.2 t/batch)
(pretreatment process)

① Coarse pulverizing processes:
Raw materials (wood chips or straw) are crushed and milled to under several mm.

Coarse grinder (<3 mm)

Wet cutter-milling

Milled sample(<0.8 mm)

Small pilot plant (pretreatment 2)

② Hydrothermal process：
The milled materials are softened by hot-compressed water.

Pressure cooker
(Max temp. 180˚C,
Max press. 1.0 Mpa)

Wet disc-milling

Disc-milled sample
(5-7%w/v)

③ Fine pulverizing processes：
The softened materials are finely fibrillated to several microns by wet disc-milling. The milled sample (5-7%w/v) are centrifuged to make a dewatered cake (20% w/v) .

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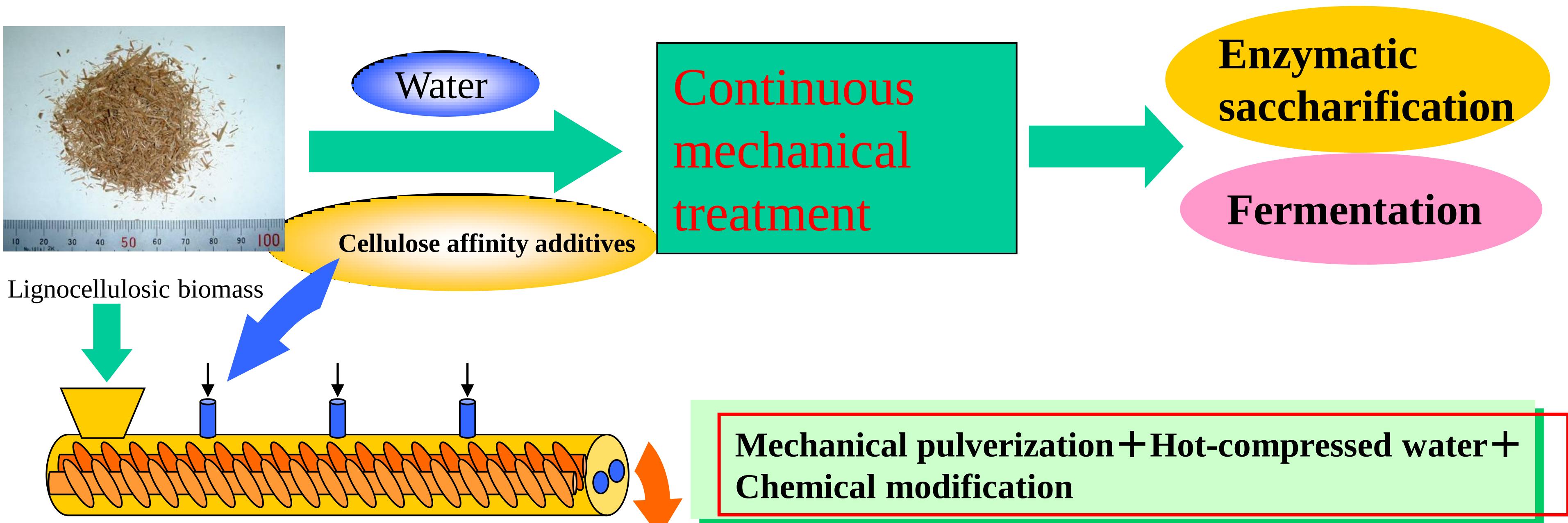
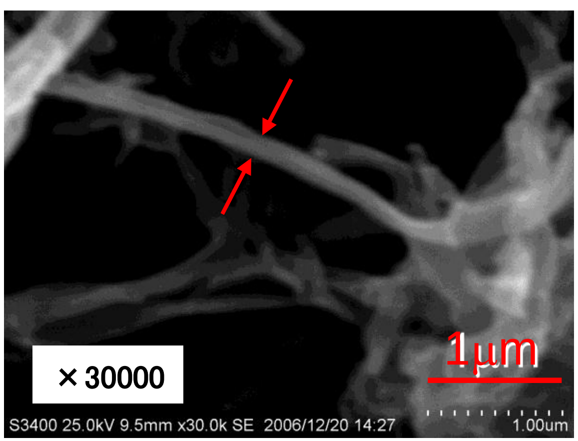
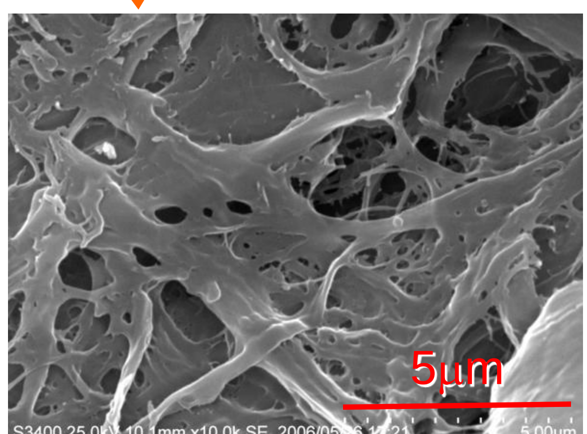
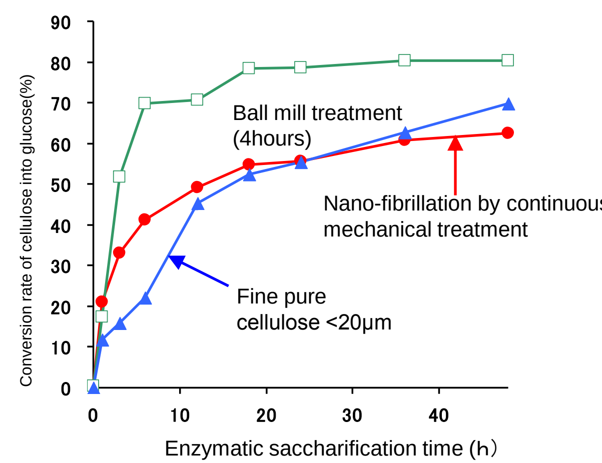
Current approaches for cost effective nano-fibrilation

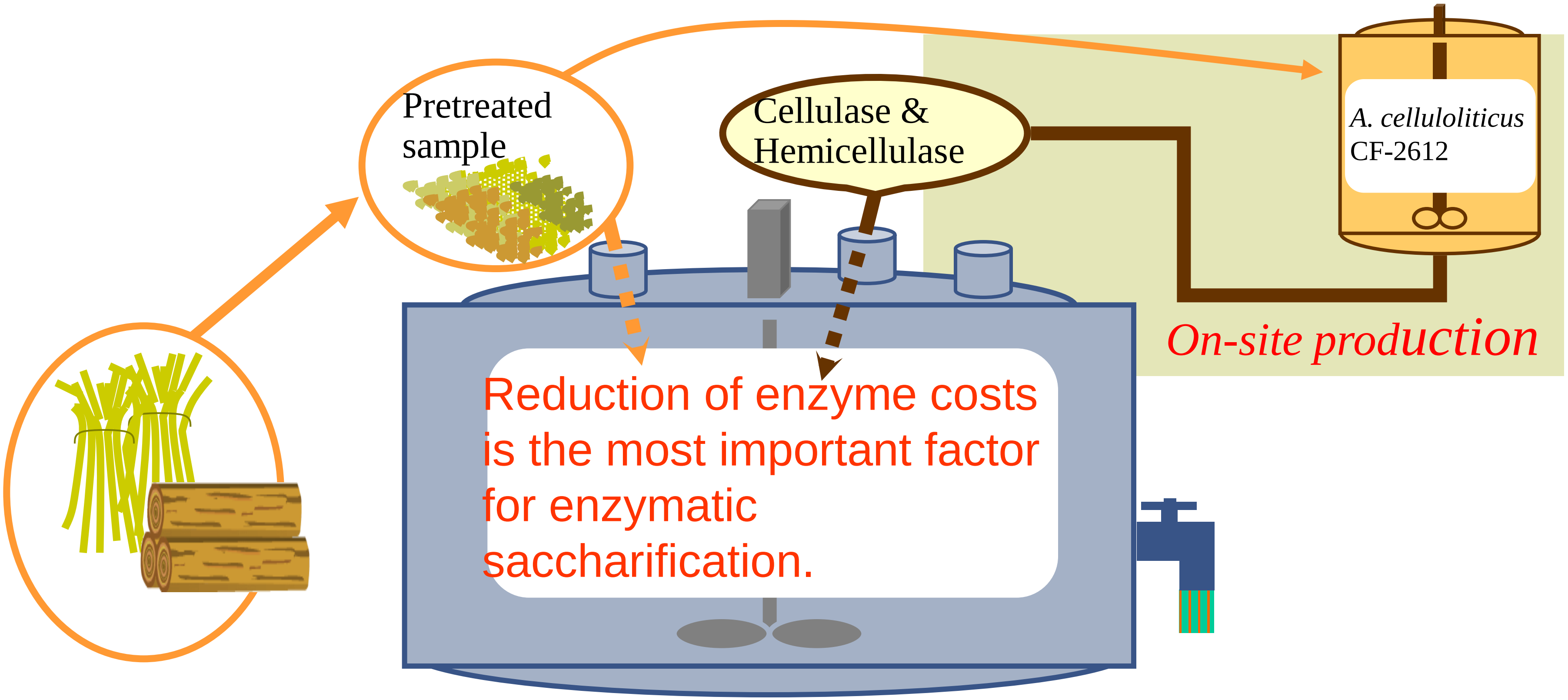








BTRC ethanol production process: Enzymatic hydrolysis process



☆ Development of cellulase-producing fungus, *Acremonium cellulolyticus*

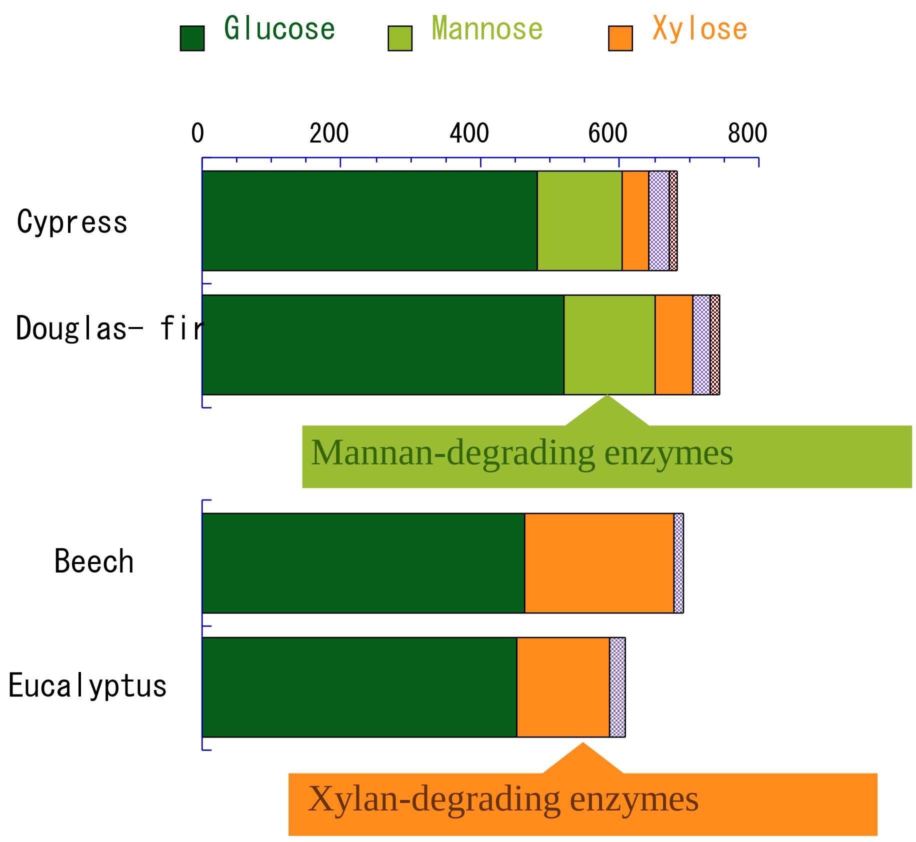
→ Analysis of cellulase and hemicellulase components

→ Heterologous expression of hemicellulase in *A. cellulolyticus*

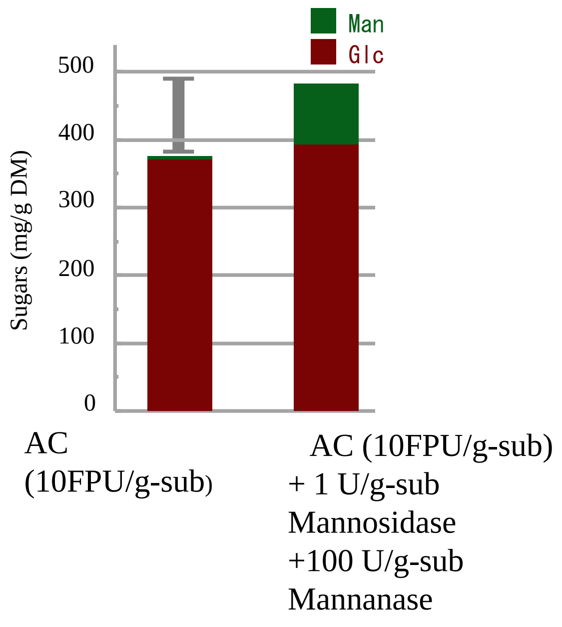
☆ Development of hemicellulase-producing fungi to combine with *A. cellulolyticus*

☆ On-site production of cellulase and hemicellulase using pretreated biomass

Necessity of hemicellulase supplements



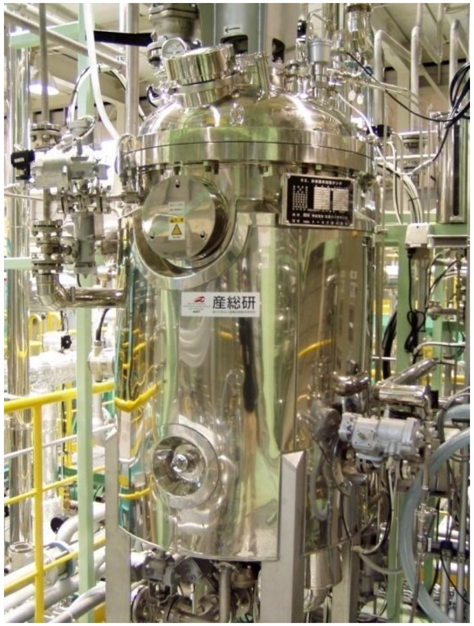
Supplemental hemicellulase enzymes to Acremonium cellulase are required for higher sugar recoveries from hemicellulose.



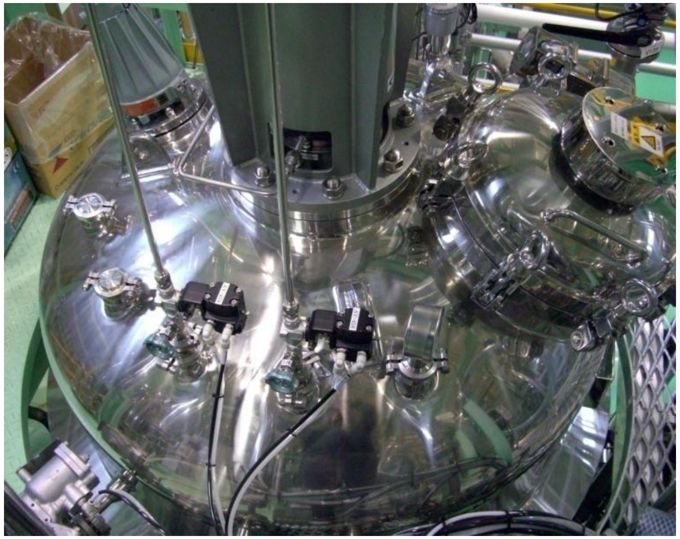
Enzymatic hydrolysis of ball-milled Douglas-fir

Small pilot plant
(Saccharification & Fermentation)

④ Saccharification and fermentation processes :
The pretreated materials are hydrolyzed (48-72 h) and then fermented (24 h) by fungal enzymes and yeast cells, respectively. The enzymes and yeast cells are produced on-site.



Enzyme production (400 L)



Saccharification& fermentation (2,000 L)

Yeast production (200 L)

Small pilot plant (Distillation)

⑤ Distillation and dehydration processes：

The fermentation liquor is directly distilled without separation of the residue.
Pure ethanol (99.5%v/v) is obtained by 2-nd distillation and dehydration processes.

First distillation (20-30%v/v)

Second distillation (90%v/v) & dehydration (99.5%v/v)

Ethanol

Future Needs for Alternative Transportation Fuel

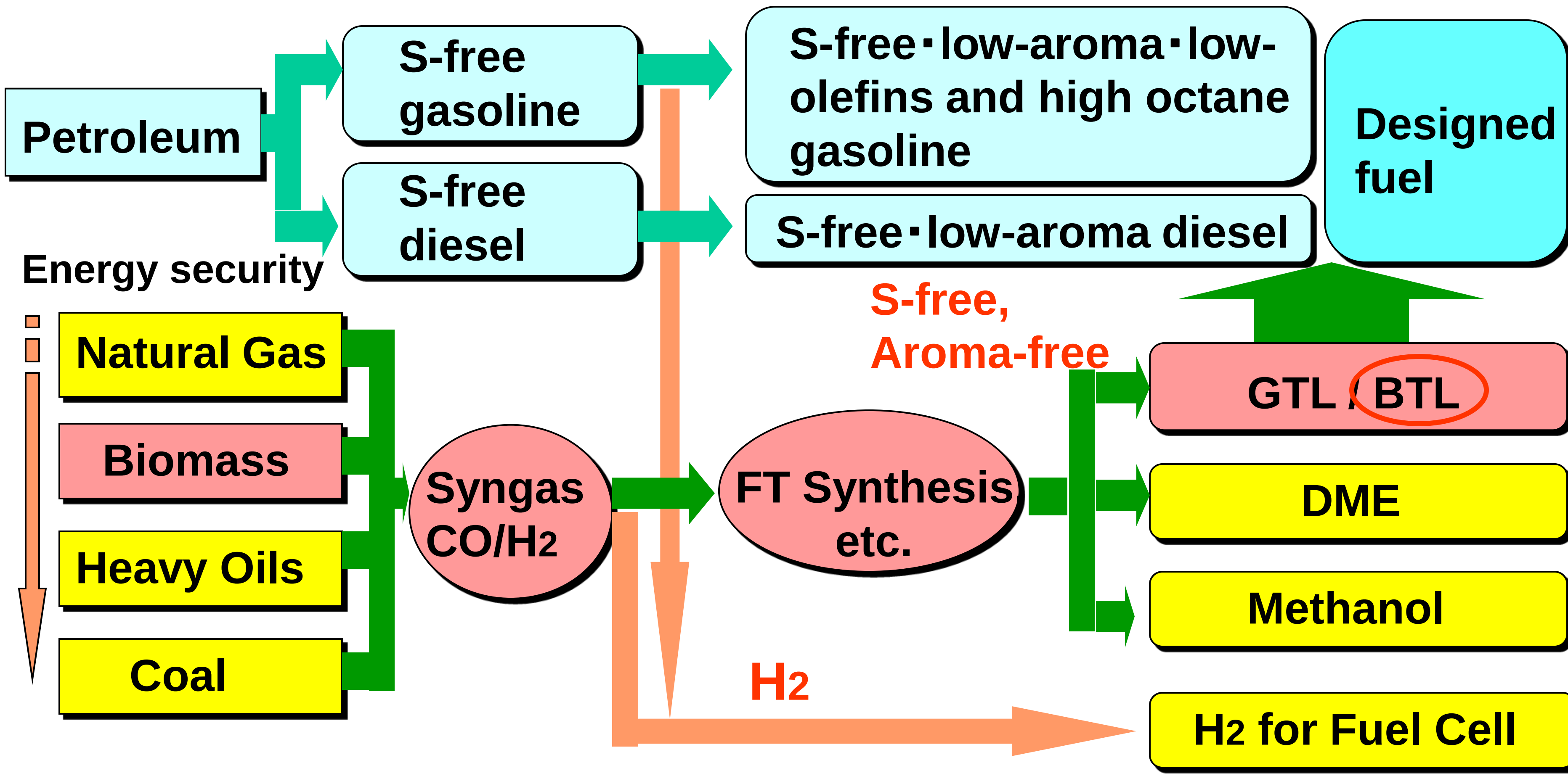
2000-2010
Fuel technologies for urban environment

*PM,NOx reduction
*Advanced end-of-pipe technologies

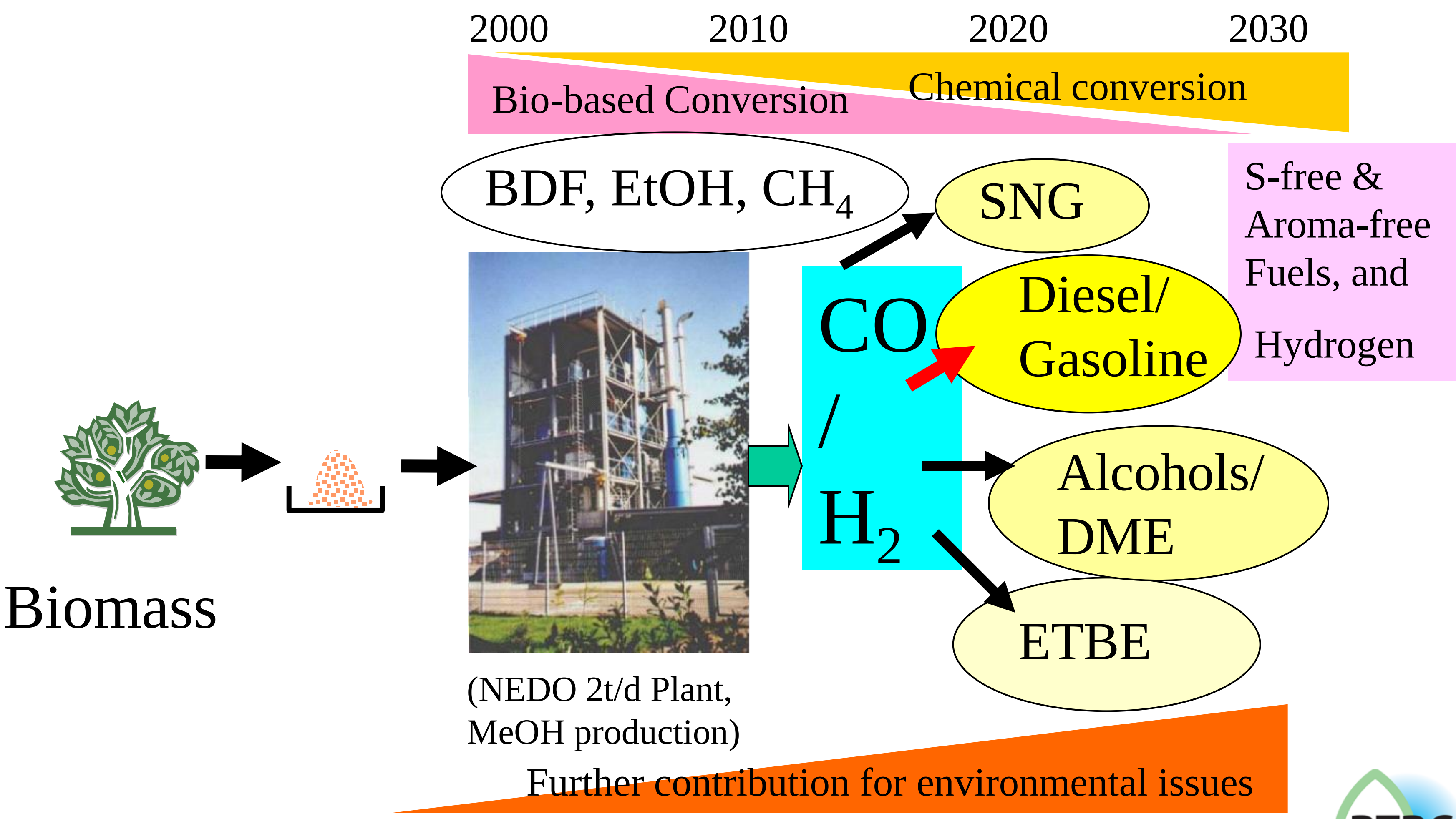
2010-2020
Fuel technologies for mini-minimizing fuel consumption

*CO_2 reduction
*New engine system/new fuel

2020-



Combined BTL by Bio- and Chemical- Conversion



Photograph of bench-scale BTL plant

Wood

Gasifier

Scrubber

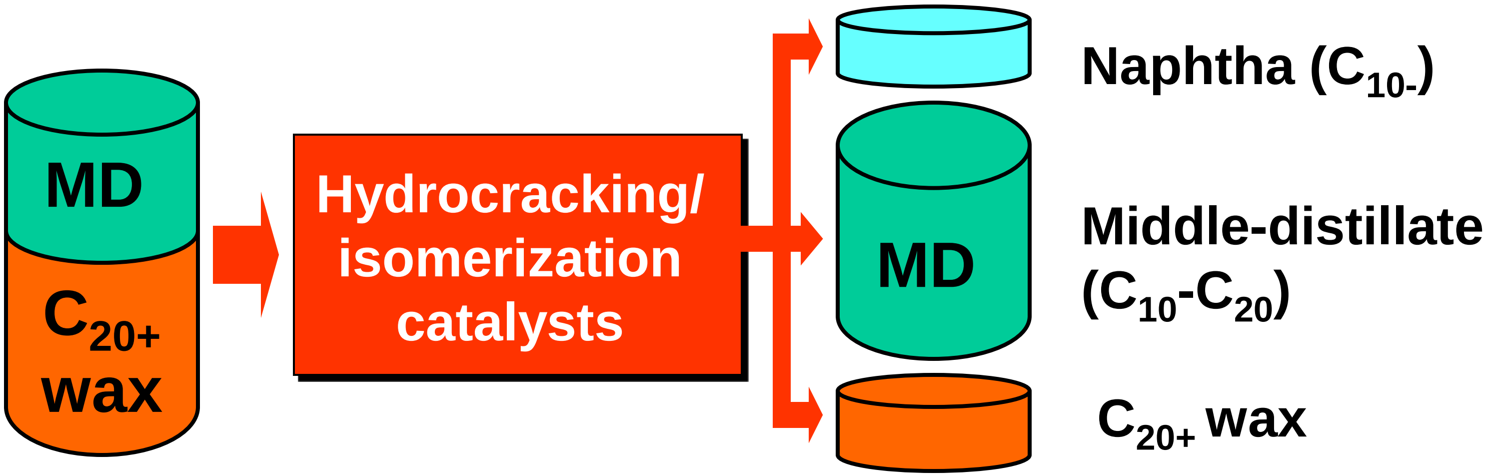
Desulfurization tower
CO_2 removal tower

Compressor &
Gas holder

FT synthesis reactor

Liquid fuel

Research Target in Upgrading of Primary FT Products



Targets in C_{20+} wax upgrading:
* conversion >80%
* selectivity to MD >75%
* iso-paraffins in MD >65%

Quality of MD:
* Sulfur < 1ppm
* Aromatics ~ 0
* Cetane No.>70

R&D of hydrocracking/isomerization catalysts:
*Solid catalyst preparation and in depth characterizaition of catalysts.
*Hydrocarbon fuel analyses for elucidating the reaction mechanism.
*High-pressure continuous flow reactors (micro, bench) operation.
*Thermodynamic analyses the for hydrocarbon reactions and for the catalysts deactivation

BTL(Biomass to Liquid) Process Scheme;

Biomass gasification with FT Synthesis via Hot Gas Cleaning => *Design of "Mobile BTL Plant"*

Pressurized Gasification of biomass (1～3MPa, ～900 ℃) → **H_2, CO** **Tar** **H_2S, COS** **NH_3, HCl etc.** ***Removal of Catalyst Poisons at 300 - 400 ℃ for Direct Coupling*** → **FT Synthesis DME synthesis (1 ～3MPa, ～250 ℃)**

Biomass System Analysis and Simulation

Objectives;

1. To develop biomass system simulation technology, Ground database（DB) should be constructed.
2. To design economic feasible total system for biomass.

The simulator can be used for optimization, economic & environmental analysis.

INPUT → Simulation → OUTPUT

INPUT

Wood DB
- Structures
- Molecules
- Elements
- …..

Cost DB
- Devices
- Processes
- Products
- …..

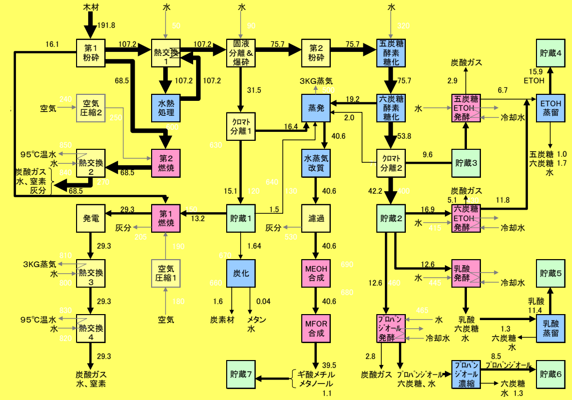
Thermo DB
- Calorie
- Moisture
- Enthalpy
- Entropy
- …..

Process DB
- Separation
- Fermentation
- Chemical
- Thermal
- …..

Simulation

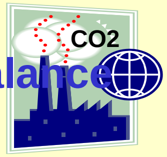
Analysis
- Mass & energy analysis
- Cost analysis

Ex.: Process model for ETBE & BTL



OUTPUT

- Carbon balance



- Energy balance
- Efficient

- Impact (LCA)
- Economics

- Cost recovery

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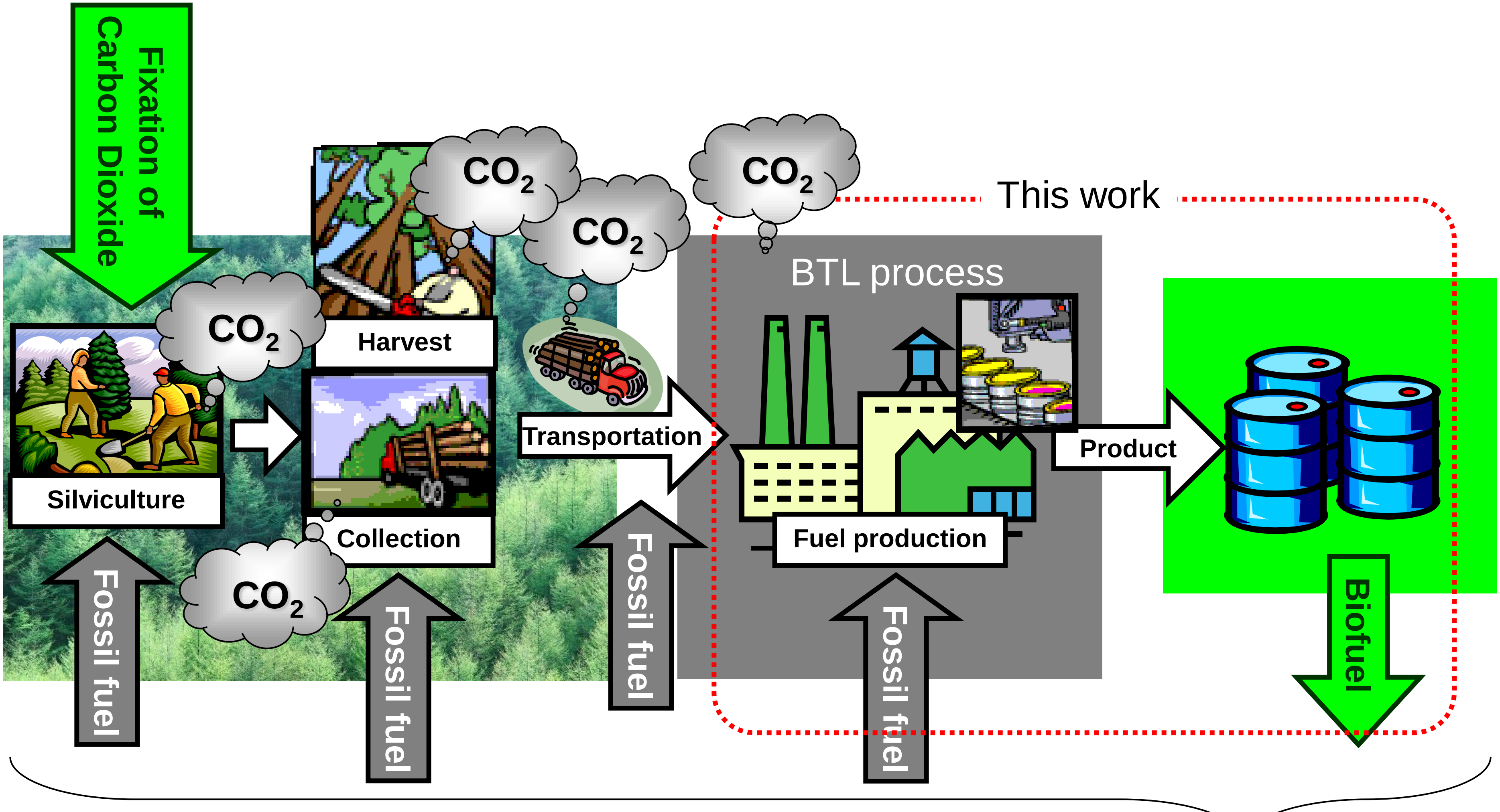

How much CO_2 can Biofuel mitigate?

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Project Scheme on Sustainable Asian Biomass Strategy

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Best Practice Scenario and System for Sustainable Biomass Utilization Models in East Asian Countries

Total Promotion of Biomass Asia Strategy
Extensive Win-Win Collaboration in Asia
International R&D Joint Projects on Biomass,
Especially agriculture and engineering fields

Technology, IP, Human resources

Resources, Economical development, Technology transfer

Energy, Materials, CO_2 reduction：
CDM ⇒ Sustainable Development

Estimated Biomass Yields as Main Product and Residues

(million tons)

Crops	Biomass		Thai-Land	Vietnam	Indonesia	Malaysia	Philippines
Oil Palm (Coconut Palm)	Main Product	33	1		13 (1)	16	(2)
	Factory Residue	38	1 (1)		10 (8)	11	(7)
	Field Residue	71	2 (1)		26 (6)	31	(5)
Sugar-cane	Main Product	15	7	2	3		3
	Factory Residue	44	21	6	8		9
	Field Residue	32	19	5	8		8
Cassava	Main Product	11	5	1	5		
	Factory Residue	14	6	2	6		
	Field Residue	20	9	2	9		
Rice	Main Product	74	15	20	31		8
	Factory Residue	34	7	9	14		4
	Field Residue	84	17	23	35		9
Timber (Wasted Trunk)	Main Product	18	2	1	8	6	1
	Factory Residue	18	2	1	8	6	1
	Field Residue	32	1 (1)	1	6 (9)	4 (7)	(3)

for 2003 or 2004

Proposal Content (draft)

Resources ⟷ **Technology**

1. Hybrid Agricultural Refinery Model (ex. China)
Corn, Rice, Wheat, Sugarcane, Cassava etc.

2. ASEAN Continental Model;
Rice & Sugar Energy Complex Model
(ex. Thailand, Viet Nam etc.)

3. ASEAN Islands Model;
Palm Oil Energy Complex
（Malaysia, Indonesia etc.)

1. Sustainable Biomass-Refinery
(1) Bio-Fuels
1-1. Bio-ethanol
1-2. Bio-diesel fuel(BDF)
(2) Bio-chemicals

2. Evaluation & Design of Biomass Utilization System
(1) Life cycle assessment(LCA)
(2) Demonstration plant projects
(3) Design of optimized local models

3. Research and Development for Sustainable Biomass Production

Proposal of Efficient Recovery and Utilization Model of Agricultural Wastes

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Ethanol Production from Palm Wastes

Oil Palm

→ **Trunk waste**

Fresh Fruit Bunch

→ **Empty Fruit Bunch**

Fruit

→ **Fiber, Shell**

Crude Palm Oil
Palm Kernel

Lignocellulosic Biomass

Pretreatment

↓

Saccharification

↓

Fermentation

↓

Purification

↓

ETHANOL

New Materials from Oil Palm Biomass

Oil Palm

Palm Oil

Palm oil industry

BDF

Crude glycerol

Bio-waste

trunk **EFB** **shell**

- **lignocellulosic materials**
- **Ethanol production**

lignin etc.

Development of polymer materials

Standardization for Biodegradable plastics in AIST

- ISO 14855-2 (Aerobic biodegradation test)
  - participated International Round-robin test (RRT)
- ISO/AWI 10210 (Preparation method of test materials for biodegradation tests)
  - proposed by AIST
- ISO 15985 (Anaerobic biodegradation tests)
  - participated RRT
- ASTM D6866 (Measuring method of biomass carbon ratio)
  - on research work in order to propose as ISO in future

Collaborative Research for Palm Industry Complex

November, 2007
Joint Research Agreement (JRA) among University Putra (UPM) Malaysia, Kyushu Institute of Technology (KIT), and Biomass Technology Center (BTRC), AIST

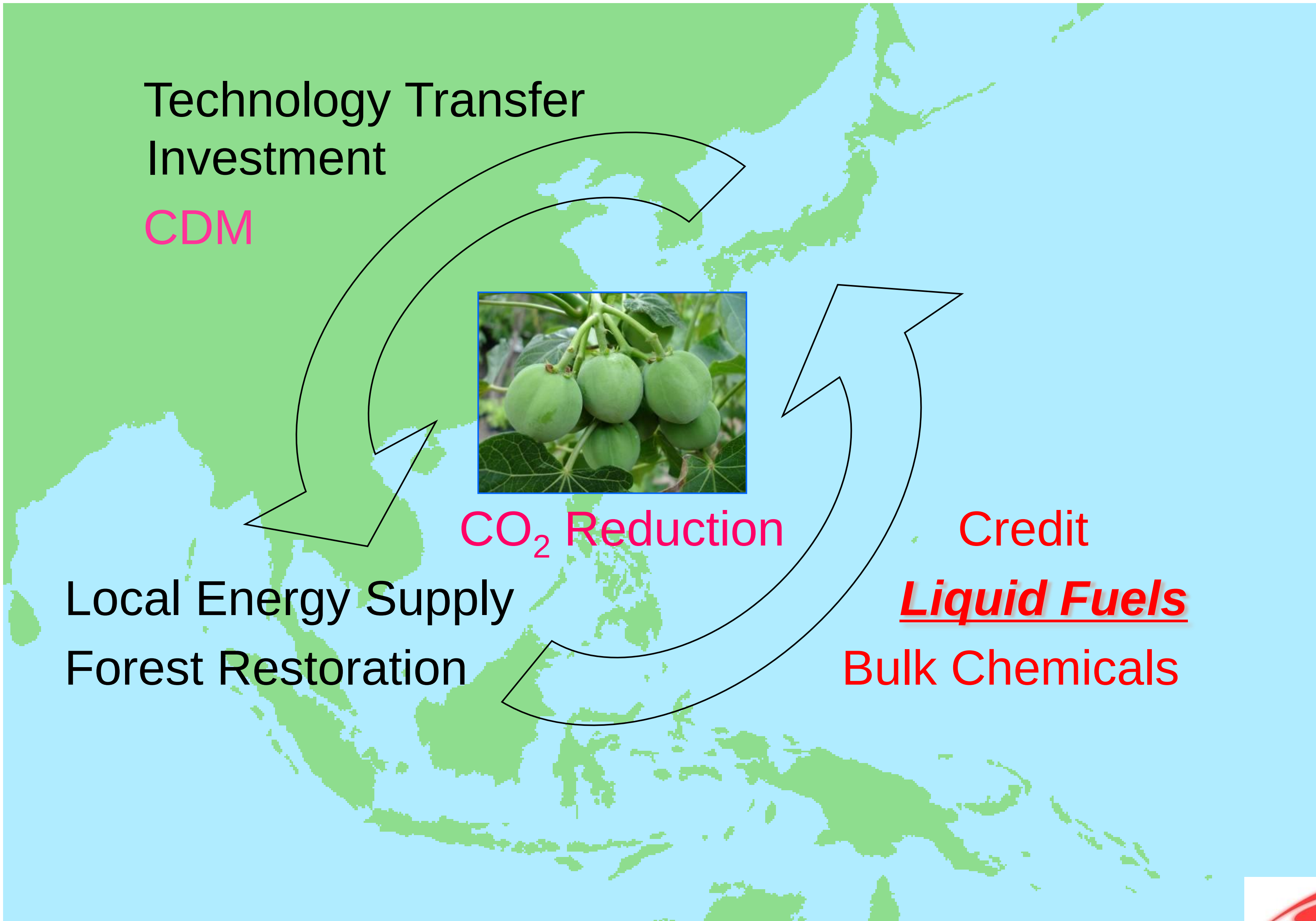
April, 2008
Collaborative research on bioethanol production from palm residues by collaboration of UPM, KIT, and BTRC

November, 2008
Collaborative laboratory (Biomass Technology Centre) in UPM

Signing ceremony of JRA at UPM

Opening ceremony of Biomass Technology Center at UPM

Fruitful Collaborations Using Biomass



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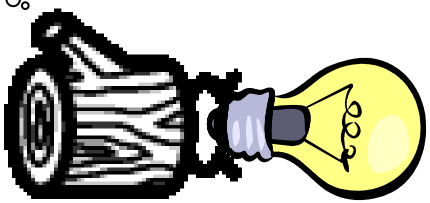
Small- & Large-scale Biomass Utilization System !!

Bio-fuel Cell !



High efficiency and convenience

Local Energy Supply

As small as possible

As large as possible

Industrial Utilization

High economical viability

Stable law material supply,
High demand in product

Summary & Proposals for Effective Biomass Utilization

1) Palm Energy&Chemicals Complex ;

- Combined production of bio-fules and bio-carbons by optimizing bio-conversion and thermochemical routes

2) Sugar and Rice Energy&Food&Chemicals Complex;

- Large-scale bio-ethanol production from agricultural wastes for simultaneous supply of food and bio-fuels

3) Wood Refinery Complex for Fuels and Chemicals;

- Total multi-production system of timber, paper pulp, ethanol, and bio-chemicals including lignin-derivatives

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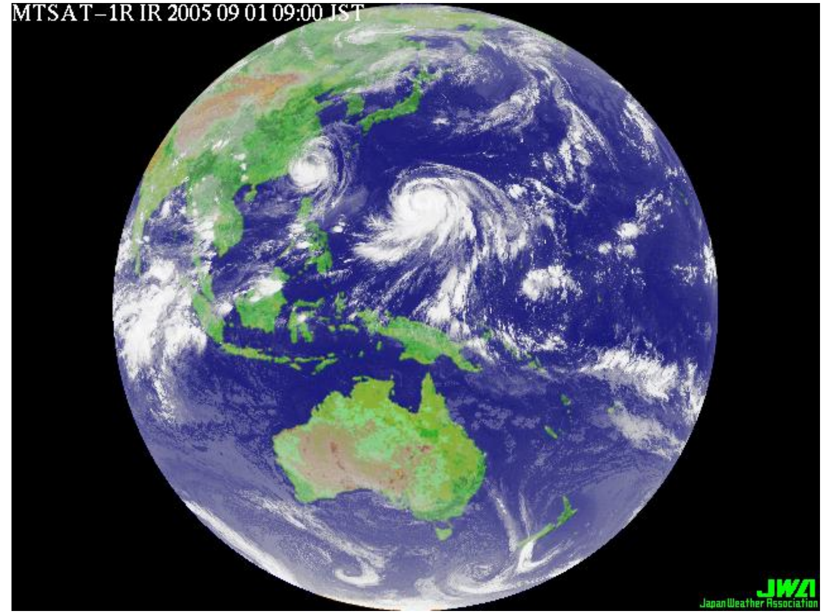

“Green Biomass for Cool Earth”

Thank you very much for your attention！

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