Movement for the Introduction of Cellulosic Bioethanol in Japan

- *Biofuel for transportation*

August 26, 2009

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NIPPON OIL
Your Choice of Energy

Backgrounds

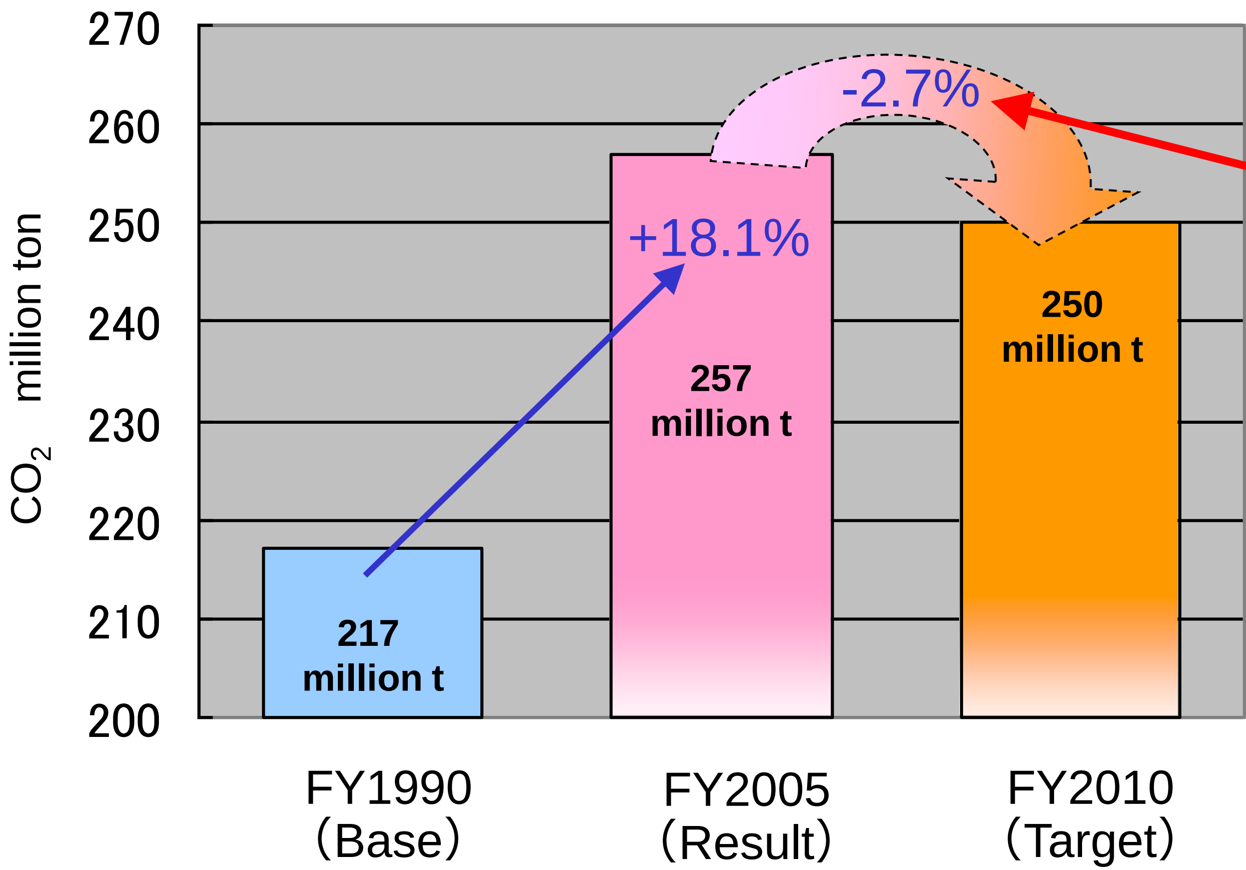
Contexts

“New National Energy Strategy” 2006.5

“A Next Generation Automobile Fuel Initiative” 2007.5

CO_2 emission of transport sector in Japan

CO_2 emission of transport sector and reduction plan



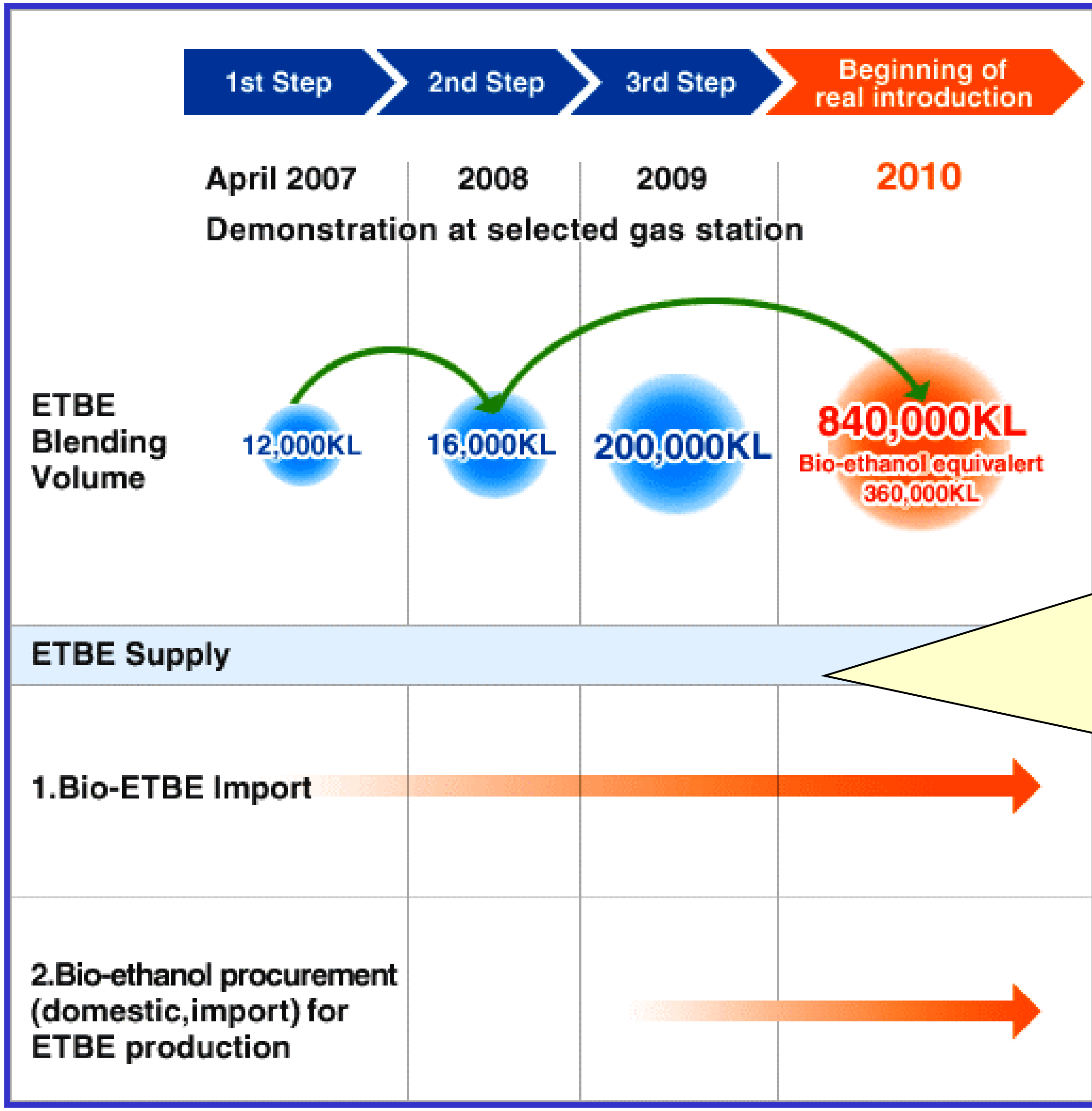
(The Kyoto Target Achievement Plan, revised on 2008)

Reduction plans (example)

- **Fuel economies improvement : CO_2 ▲21 million ton**
- **Public transportation : CO_2 ▲3.8 million ton**
- **Clean energy vehicle (233 million vehicle) : CO_2 ▲3 million ton**
- **Biomass fuel for transportation. (500 thousand kl as crude oil) : CO_2 ▲1.2 million ton**

Bio-Gasoline Introduction Scenario
by Petroleum association of Japan

Target : 840thousand kl* Bio-ETBE application as 7% blend gasoline at FY2010
***360thousand kl as Bio-ethanol**



JAPAN BIOFUELS SUPPLY LLP
(Limited Liability Partnership)

<u>Date of Establishment</u> : January 26, 2007

<u>Partners</u> : Idemitsu, Tonen General, Taiyo Oil, Fuji oil, Cosmo Oil, Kyokuto Petroleum, Kyushu Oil, Showa shell, Nippon Oil, Japan Energy

<u>Main Activities</u>

1. Importing of Bio-ETBE and Bio-ethanol
2. Purchasing Bio-ethanol from domestic production
3. Storing/distributing

"A Next Generation Automobile / Fuel Initiative"

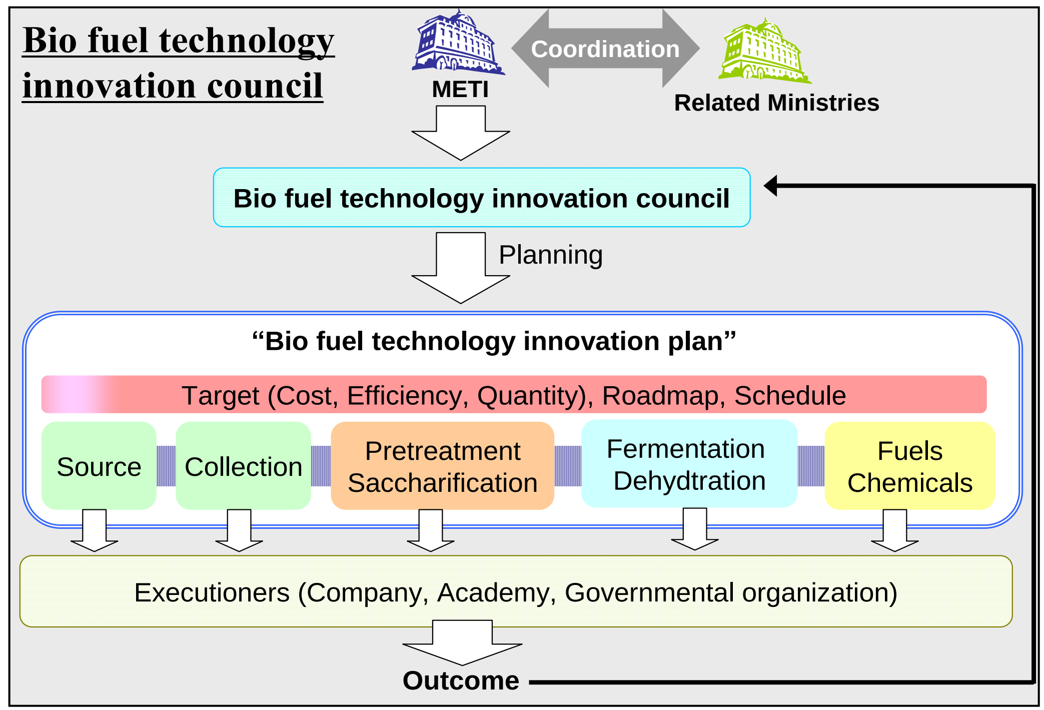
By Ministry of Economy, Trade & Industry (METI), 2007.5.28

Target: 30% fuel economies improvement and 20% reduction of petroleum utilization

- Strategy 1: Battery
- Strategy 2: Hydrogen/Fuel Cells
- Strategy 3: Clean Diesel
- **Strategy 4: Biofuels "Worry-Free, Safe and Fair" Expansion and the Second-Generation Bio"**
- Strategy 5: World's Most Friendly Automobile Society Initiative

○Setting up the **bio-fuel technology innovation council**
(The industrial, academic and government sectors cooperate with each other to accelerate the development of **next-generation biotechnology**)

Bioethanol production from lignocelluloses not to compete with food



Bio-fuel Technology Innovation Plan

Contexts

“Bio-fuel Technology Innovation Plan” 2008.3

“Bio-fuel Technology Innovation Plan”

40 yen/L Specific production model

13,270 ha

Collection area:
6.5 km radius

(1) An example of high-yield herbaceous plants

(Erianthus, Miscanthus, and others)

* Perennial, environmentally adaptable, and fuss-free.
(Low fertilizer use)
Benchmark yield: 50 dry-ton/ha･year or more

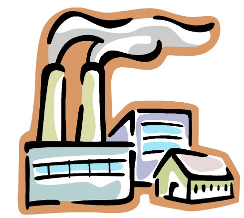
Requires 3 blocks, that is, 40,000 ha.

Collection area:
6.5 km radius

Total quantity;
1.3 million tons
Dry quantity;
670 thousand tons

Cultivation and harvest of raw material

Storage of biomass raw material



Ethanol production plant

Ethanol Production;
200 thousand kL/year

EU: Short-rotation Willow Biomass Plantations Irrigated and Fertilized with Wastewaters, Final report, 2003

(2) An example of fast-growing broadleaf trees

(Willow, poplar, and others)

* Harvest is possible in 3-4 years, and year-round harvest is possible.
Benchmark yield: 17 dry-ton/ha･year or more

(A modified slide from “Bio-fuel Technology Innovation Plan”)

“Bio-fuel Technology Innovation Plan”

Erianthus (an example of raw material)

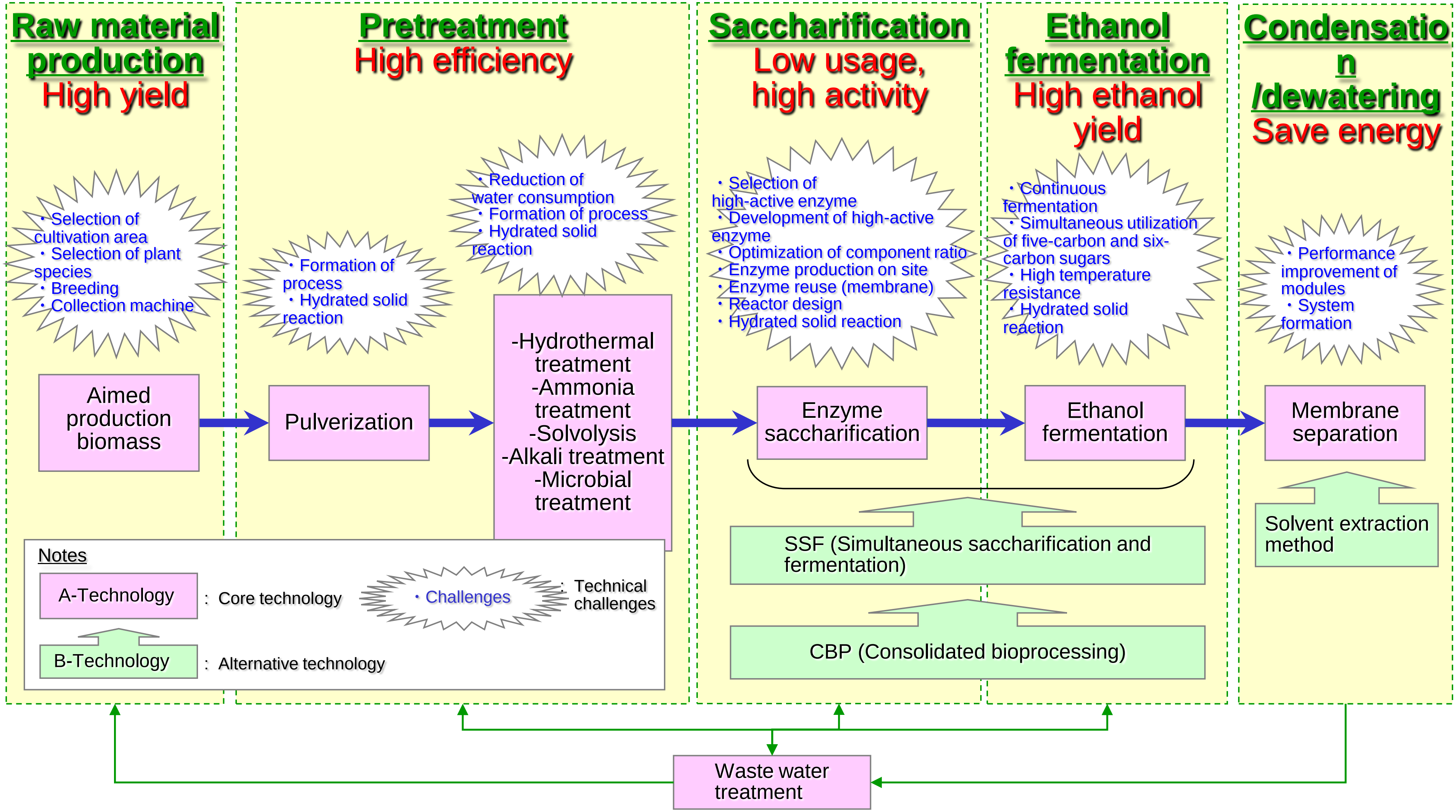
Erianthus

- **Poaceous perennial plant**
- **Grows well even in a barren land such as a land of acidic soil and at a land with insufficient fertilizing.**

(A modified slide from “Bio-fuel Technology Innovation Plan”)

“Bio-fuel Technology Innovation Plan”

Specific examples of technologies



(A modified slide from “Bio-fuel Technology Innovation Plan”)

“Bio-fuel Technology Innovation Plan”

Technology roadmap for raw materials

2008 — 2015

Selection/development of biomass raw material plants

Selection/development of high-yield plants

- Selection/verification of available high-yield plants
  - Poaceous plants (high-yield): Erianthus, Miscanthus, and others
  - Leguminous plants (nitrogen-fixing, high-yield)
  - Fast-growing trees: willow, poplar, eucalyptus, acacia and others
- Establishing transgenic strains → (Development of low-cost high-yield energy-plants by gene-recombination technology and others)

Cultivation technology

Development/verification of cultivation technology

- Collection of cultivation basic data
- Yield-increase by combination of the existing technologies (multiple harvesting, multiple cropping)
- Reduction of input energy (no-tilling farming, direct-seeding cultivation, perennial breeds)
- Mixed-cropping of poaceous and legninous plants (Reduction of fertilizer use by nitrogen-fixing)

Collection/transportation technologies

Collection technology Compression/transportati on technologies

- Development of harvesting machines
- Development of drying technology
- Development of compressing/transporting technologies
- Cost and energy reduction of machines and storing technology

Search of land

- Research and survey of biomass-land combination

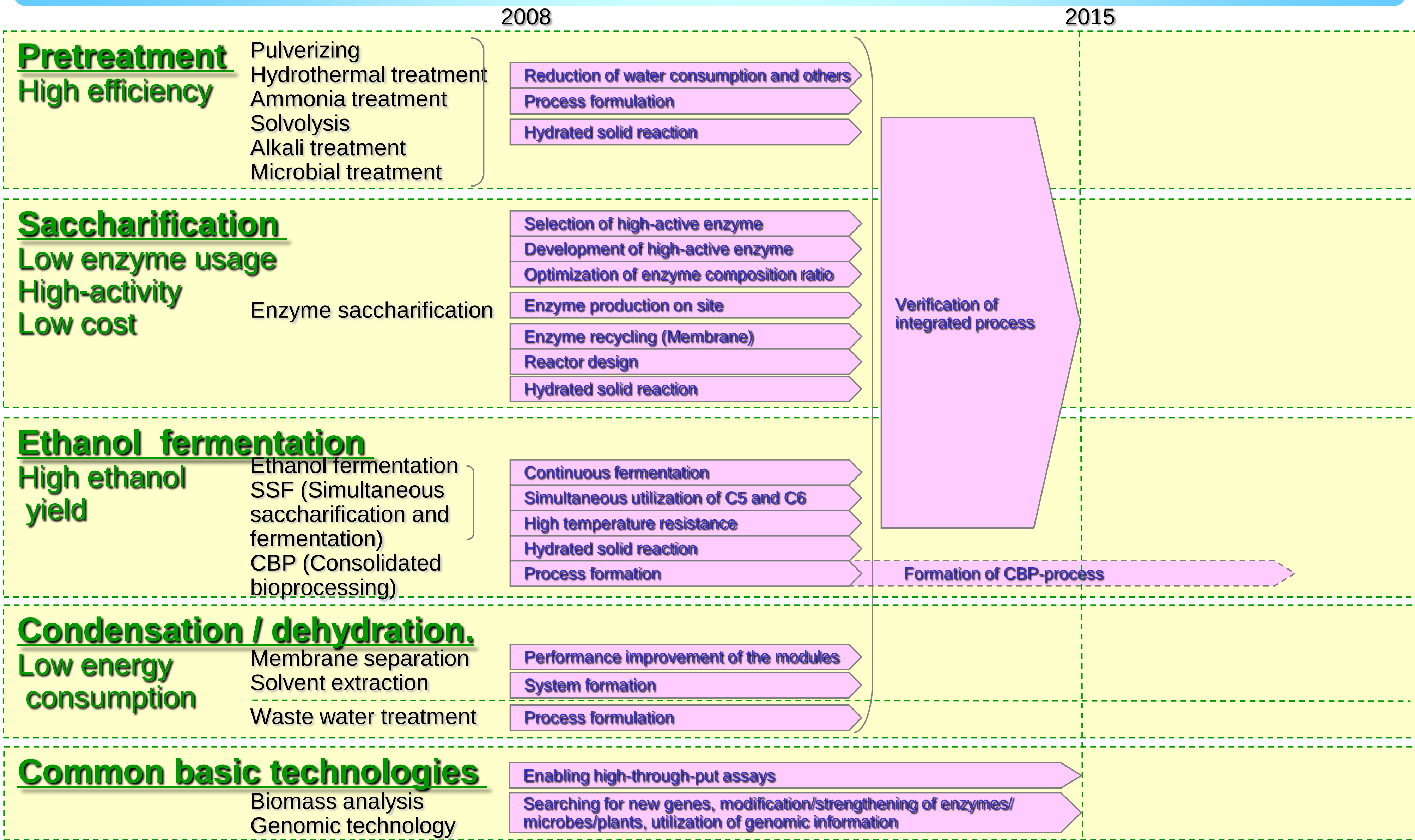
Basic technologies

- Upgrading genomic information (DNA marker, genomic analysis and others)
- Imparting stress-tolerance, development of plants with high photosynthetic efficiency
- Development of plants with easy saccharification by improvement of cell-wall composition, diastatic enzyme production and others
- Mineral/neutral (Development of mineral recovery/recycle technology

(A modified slide from “Bio-fuel Technology Innovation Plan”)

"Bio-fuel Technology Innovation Plan"

Technology roadmap for production



(A modified slide from "Bio-fuel Technology Innovation Plan")

"Bio-fuel Technology Innovation Plan"

40 yen/L Benchmarks 2015

Raw material	Dry-yield	Herbaceous plants: **50t/ha・year**, woody plants: **17t/ha・year**
Production	**As an integrated process**	Energy consumption **6MJ/kg-biomass** or lower (independently operate on biomass), ethanol yield **0.3 L/kg-biomass** or higher, energy recovery **35% or higher**
	Pretreatment	Pretreatment that makes enzyme saccharification efficiency **80%** or higher
	Enzyme saccharification	Enzyme consumption **1mg/g-produced sugar** or less, enzyme cost **4 yen/L-ethanol** or lower, sugar yield **500g/kg-biomass** or higher
	Ethanol fermentation	Ethanol yield **95%** or higher
	Condensation/ dewatering	Energy consumption **2.5 MJ/L-ethanol** or less (10% ethanol solution → anhydrous ethanol separation/recovery)
	Waste water treatment	Treatment cost excluding energy-recovery portion **5 yen/L-ethanol** or lower

Environmental/ social assessment	・Assessment of discharged CO_2 quantity and energy balance throughout the lifecycle ・Assessment of environmental, social, and economical sustainability such as competition with food-production and influence on the ecosystem

(A modified slide from "Bio-fuel Technology Innovation Plan")

“Bio-fuel Technology Innovation Plan”

Promotional System for Development

Bio-fuel Technology Innovation Conference

Effective promotion of inter-industry, industry-academia, and different-fields collaborations to drive forward the development relating to bio-fuel.

(Consisting of research institutes of universities/colleges and independent administrative agencies [IAA]; private businesses; Ministry of Economy, Trade & Industry [METI]; Ministry of Agriculture, Forestry & Fisheries [MAFF]; etc.)

Implementing bodies (businesses, universities/colleges, IAAs)

Each specialized businesses or other body implements the technology development in cooperation with each other. It is important to facilitate interactions among basic-research, technology-development, and practical-application phases, with getting hold of the technological challenges of each field.

<An example of implementing businesses>

Conversion technology constructing optimal processes through integrated technology development

Raw material production — Pretreatment/ saccharification — Fermentation — Condensation/ dewatering → Waste water treatment

Raw material production: Paper, petroleum, automobile, MAFF, universities, IAAs, etc.

Pretreatment/ saccharification: Paper, biotechnology, petroleum, engineering, universities, IAAs, etc.

Fermentation: Fermentation, biotechnology, petroleum, engineering, universities, IAAs, etc.

Condensation/ dewatering: Engineering, chemical, petroleum, universities, IAAs, etc.

Biomass raw material technology ↑ (Raw material production)

Enzyme technology ↑ (Pretreatment/ saccharification)

(A modified slide from “Bio-fuel Technology Innovation Plan”)

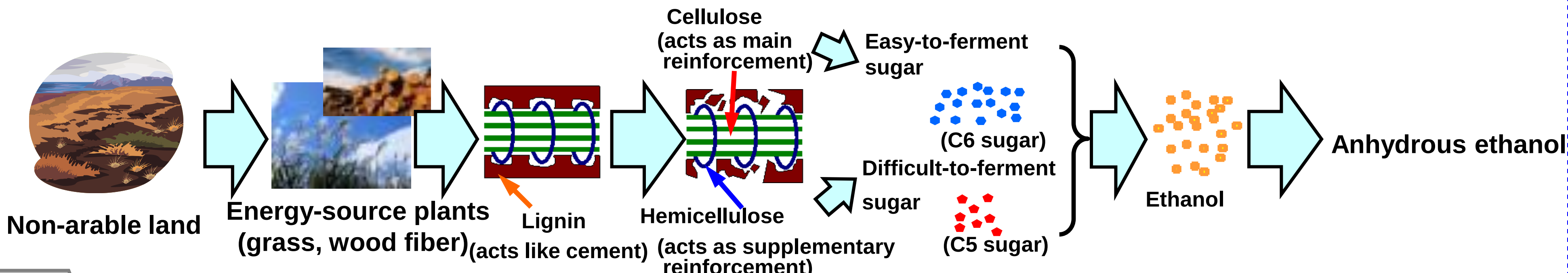
Research Association of Innovative Bioethanol Technology (RAIB)

Nippon Oil Corporation,
Mitsubishi Heavy Industries, Ltd.,
Toyota Motor Corporation,
Kajima Corporation,
Sapporo Engineering Ltd.
and Toray Industries, Inc.

Cellulosic Bioethanol Manufacturing Process and Technical Issues

The ultimate goal is to develop production-process technology **by 2015** that will enable **200 thousand kiloliters** of bioethanol—priced **at 40 yen per liter** to compete with crude oil—to be produced annually.

Process	Raw material production	Harvesting, transportation, and storage	Pretreatment	Enzyme saccharification	Yeast fermentation	Concentration and dehydration
Issues	Large-scale, high-efficiency plant material production	Harvesting, transportation, and storage cost reduction	High-efficiency pretreatment	Low-cost enzyme saccharification	High-efficiency fermentation	Concentration and dehydration energy reduction

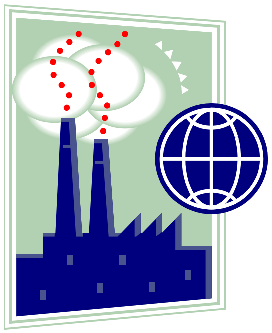


Schedule

2009

2012

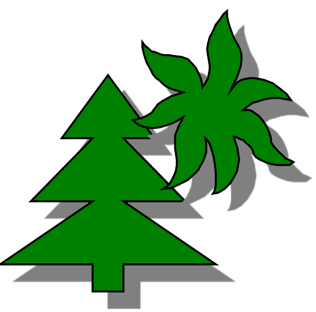
2015



Bench Scale

Scale Up ~10thousand kL/y

Commercial Scale ~200thousand kL/y

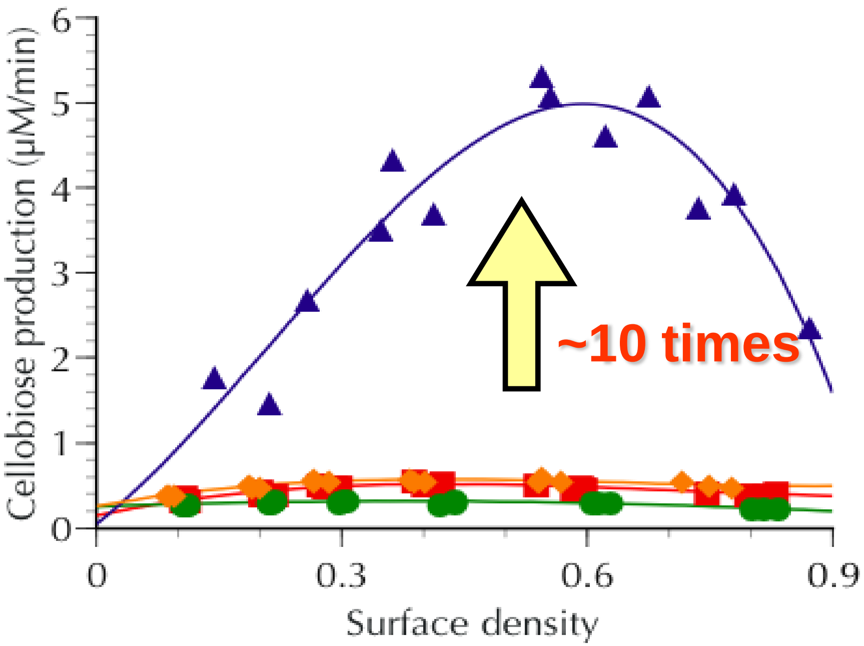


Establishment of Cultivation Technology & Plantation Model

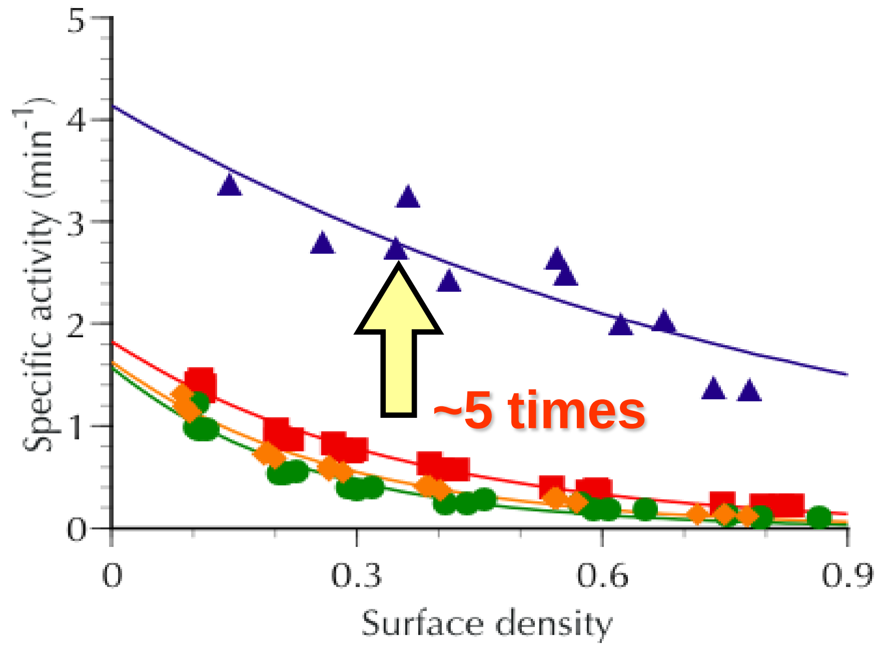
Seed Technology

Importance of combination of Pretreatment and Enzyme
>Improvement Enzyme activity by alternation of crystal structure

Total Enzyme activity



Specific activity of absorbed Enzyme

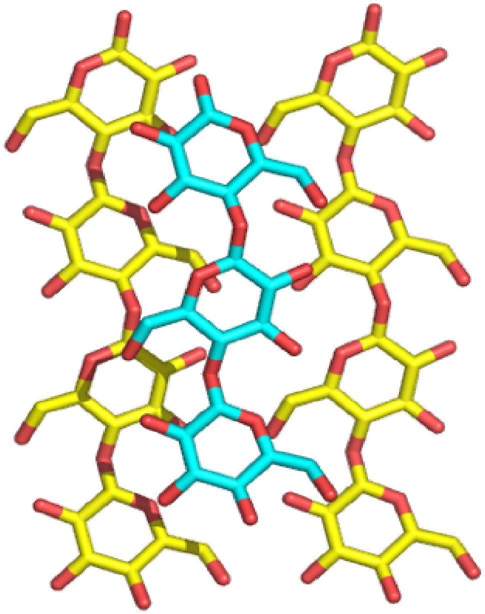


■, Cellulose I_{α}-rich; ●, Cellulose I_{β}; ▲, Cellulose III_{I}; ◆, Cellulose I_{β}'

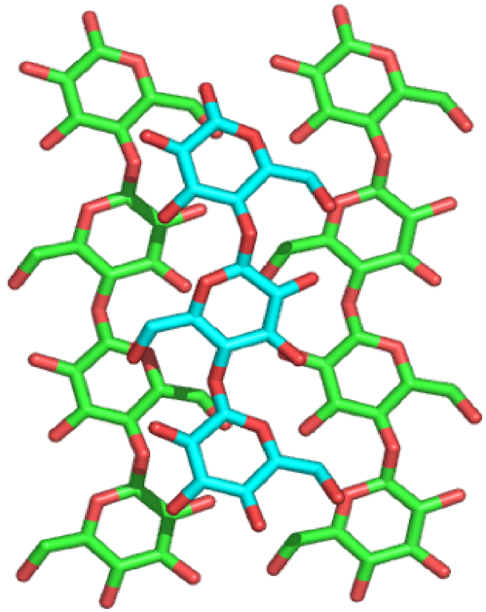
K. Igarashi, M. Wada, and M. Samejima: FEBS J.,2007, 274, 1785-1792 .

Seed Technology

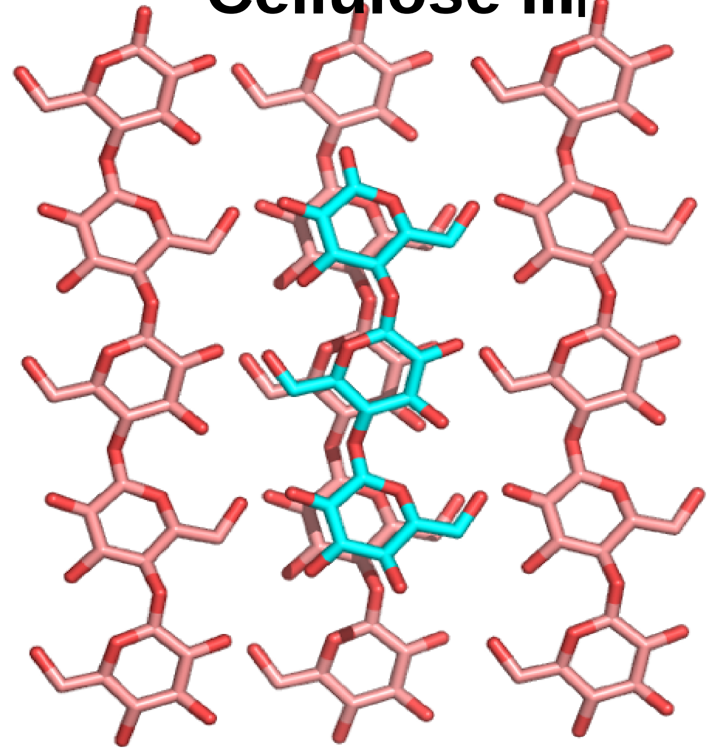
Cellulose I$_{\alpha}$

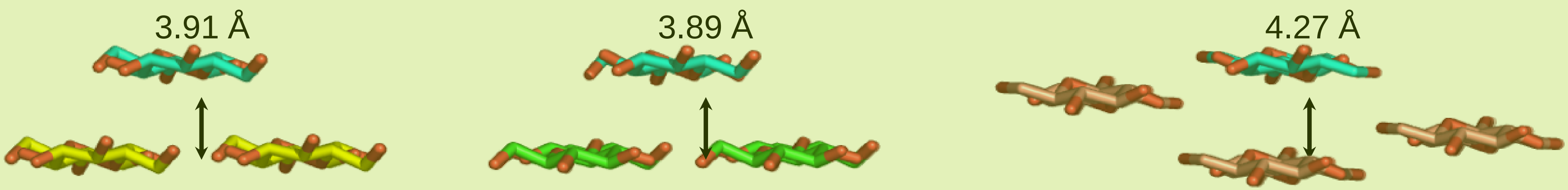


Cellulose I$_{\beta}$



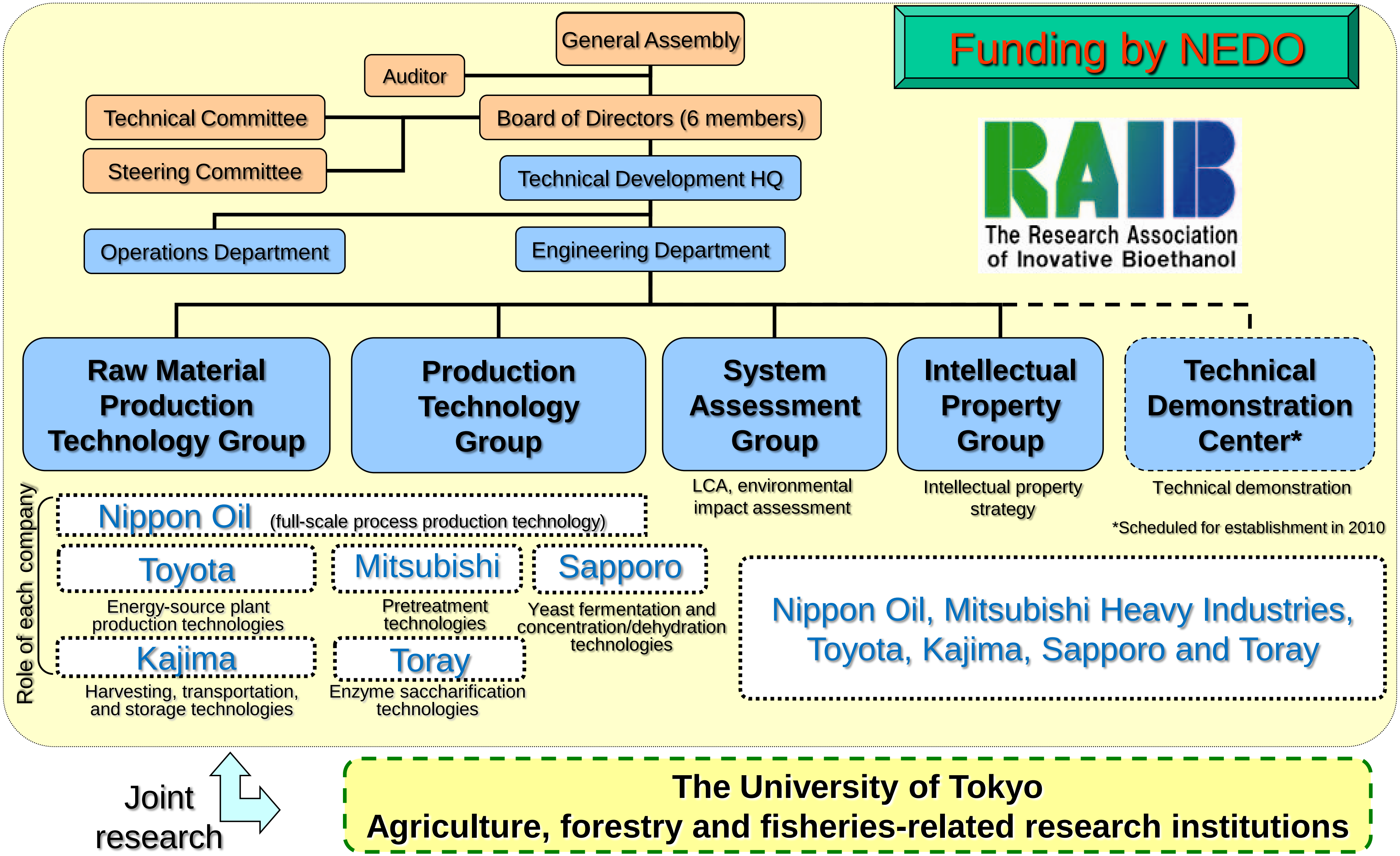
Cellulose III$_{I}$





M.Wada et al.: Macromolecule 2004, 37,8548-8555

Structure of Research Association of Innovative Bioethanol Technology (RAIB)



RAIB

The Research Association of Inovative Bioethanol

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