Ministry of Economy, Trade and Industry
Agency of Natural Resources and Energy

NEXT GENERATION BIOFUEL TECHNOLOGY DEVELOPMENT – NOW AND IN THE FUTURE

November 2014

Ritsuko SANUKI
New and Renewable Energy Division
Agency for Natural Resources and Energy
Ministry of Economy, Trade and Industry (METI), Japan

Biofuel Policy, Related Guidelines and Regulations

- **Next-generation Vehicle and Fuel Initiative (adopted by METI, May 2007)**
  - The development of cellulosic biomass will be key for expanding the use of bio-ethanol as fuels and lowering dependence on fossil fuels.

- **Cool Earth Innovative Energy Technology Program (adopted by METI, March 2008)**
  - BTL (Biomass to Liquid) is regarded as one of the important technologies that significantly contribute to GHG reduction in 2050.

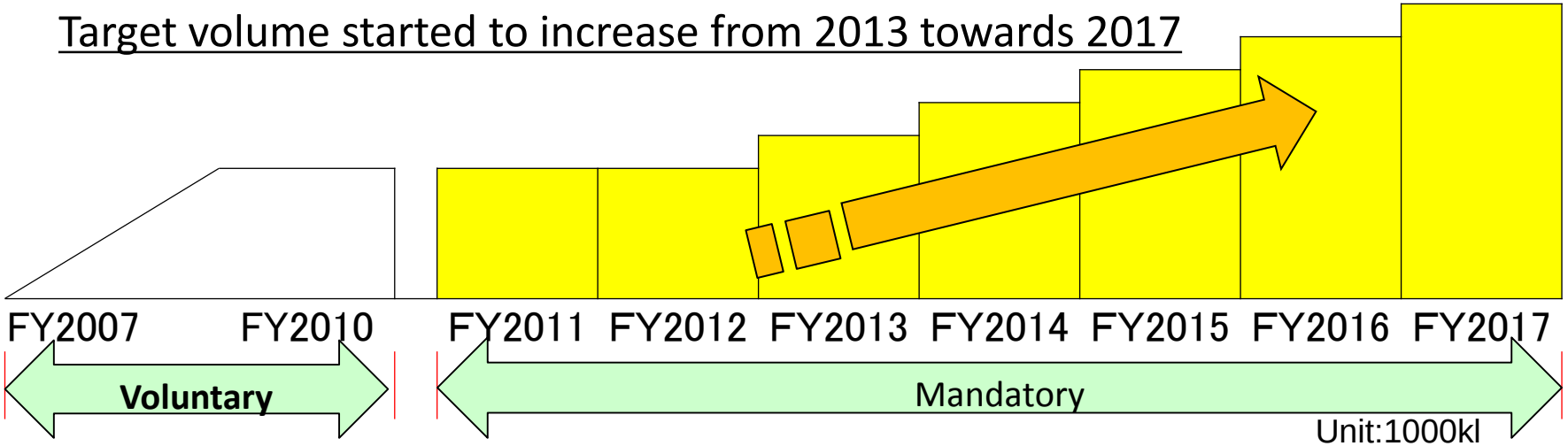
- **The Law Concerning Sophisticated Methods of Energy Supply Structures (basic policies and criteria of judgment developed by METI, 2010)**
  - An obligation to use a certain amount of biofuel is imposed on oil refiners.
  - The development of next-generation biofuel technology, whose GHG emission reduction is more than 50% compared to fossil fuel, shall be promoted and introduced in the oil refining industry.

- **Strategic Energy Plan (the newest (4th) version approved by the Cabinet, April 2014)**
  - Continues to import biofuels while taking into consideration international situation and technology development of next-generation biofuel.
  - Accelerates to diversify energy resources in the fields of transportation by strategic measures including technology R&D.

Biofuel Target

- The Law Concerning Sophisticated Methods of Energy Supply Structures obligates oil refiners to use a certain amount of bioethanol to be blended with gasoline to produce automotive fuel.
- The aggregate target amount of bioethanol used by oil refiners for the seven years (from FY2011 through FY2017) of each year shall be as listed in the following chart (crude oil equivalent). The use of bioethanol produced from cellulosic biomass feedstock can be doubled in volume when figuring out achieved target amount.
- Efforts for promotion of technology development and use of biofuel production from grass and wood cellulose, microalgae, etc. by oil refiners is also encouraged by the Law.

Target volume started to increase from 2013 towards 2017

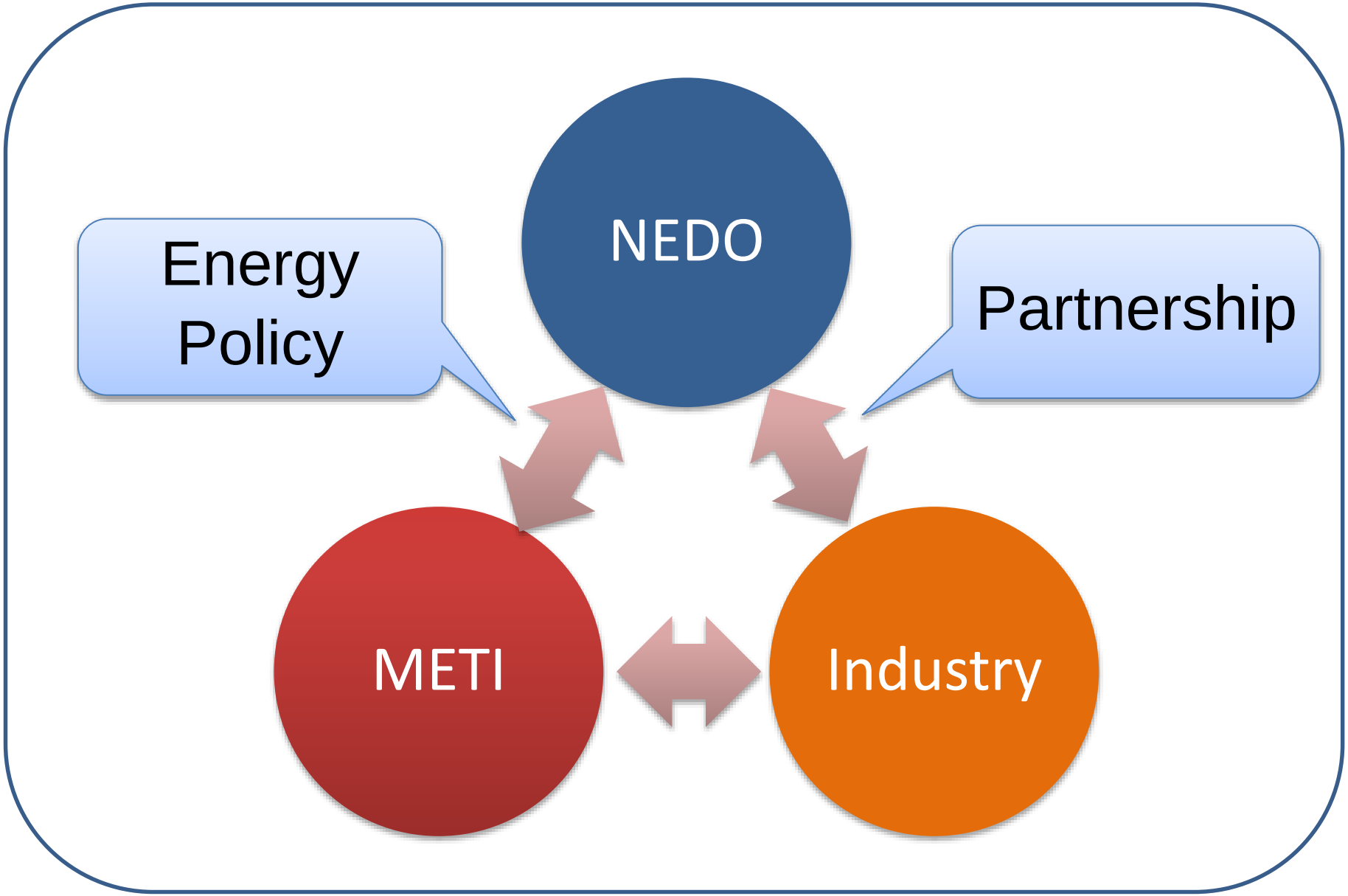


Unit:1000kl

	FY2011	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017
as Crude	210	210	260	320	380	440	500
as Ethanol	346	346	428	527	626	725	824
as ETBE	817	817	1011	1244	1478	1711	1944

NEDO's Role in Japan's Renewable Energy Development

Ministry of Economy, Trade and Industry
Agency of Natural Resources and Energy



What is NEDO?

As Japan's largest public R&D management organization,
Combining the efforts of industry, government and academia, and leveraging established international networks,
NEDO promotes research and development that:

- Contributes to the solution of energy and environmental problems, and
- Further enhances Japan's industrial competitiveness.

History

1980: Established as the *New Energy Development Organization*

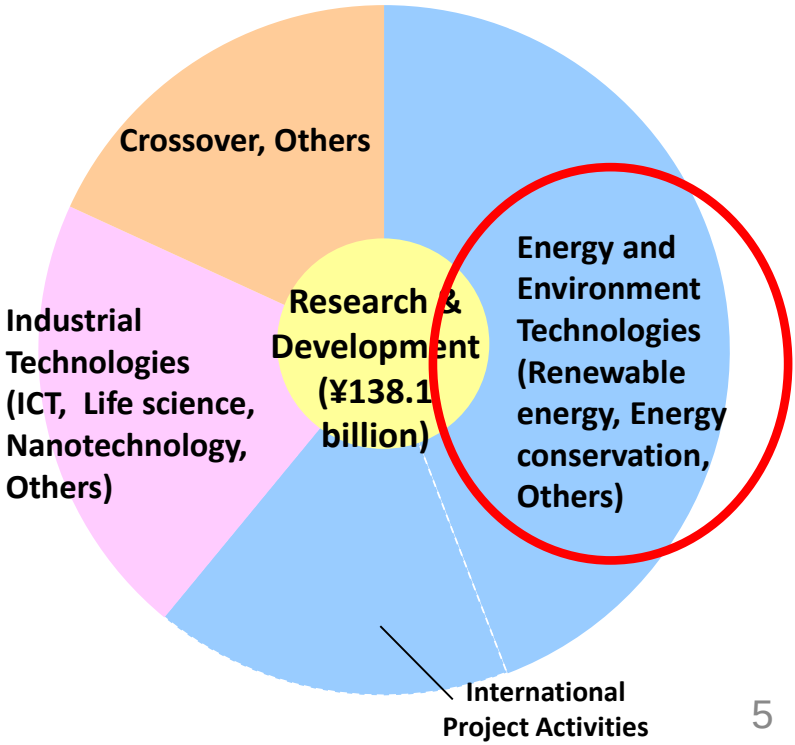
1988: Reorganized as the *New Energy and Industrial Technology Development Organization*

2003: Reorganized as an **Incorporated Administrative Agency** under the Ministry of Economy, Trade and Industry (METI)

Personnel

Approximately 800

Budget : 148.4 billion yen in FY2014



NEDO's R&D Portfolio in Renewable Energy

Ministry of Economy, Trade and Industry
Agency of Natural Resources and Energy

R&D Budget for New Energy: 28.1 billion Yen

Solar PV 9.3 billion yen

Higher efficiency, lower cost PV system. Innovative PV technologies

Biomass 3.6 billion yen

Bioethanol from woody biomass, BTL, biodiesel from microalgae

Wind 5.0 billion yen

Offshore wind power generation, 7 MW-class wind turbine

Ocean 2.5 billion yen

Ocean wave power, tidal current power

Geothermal 0.5 billion yen

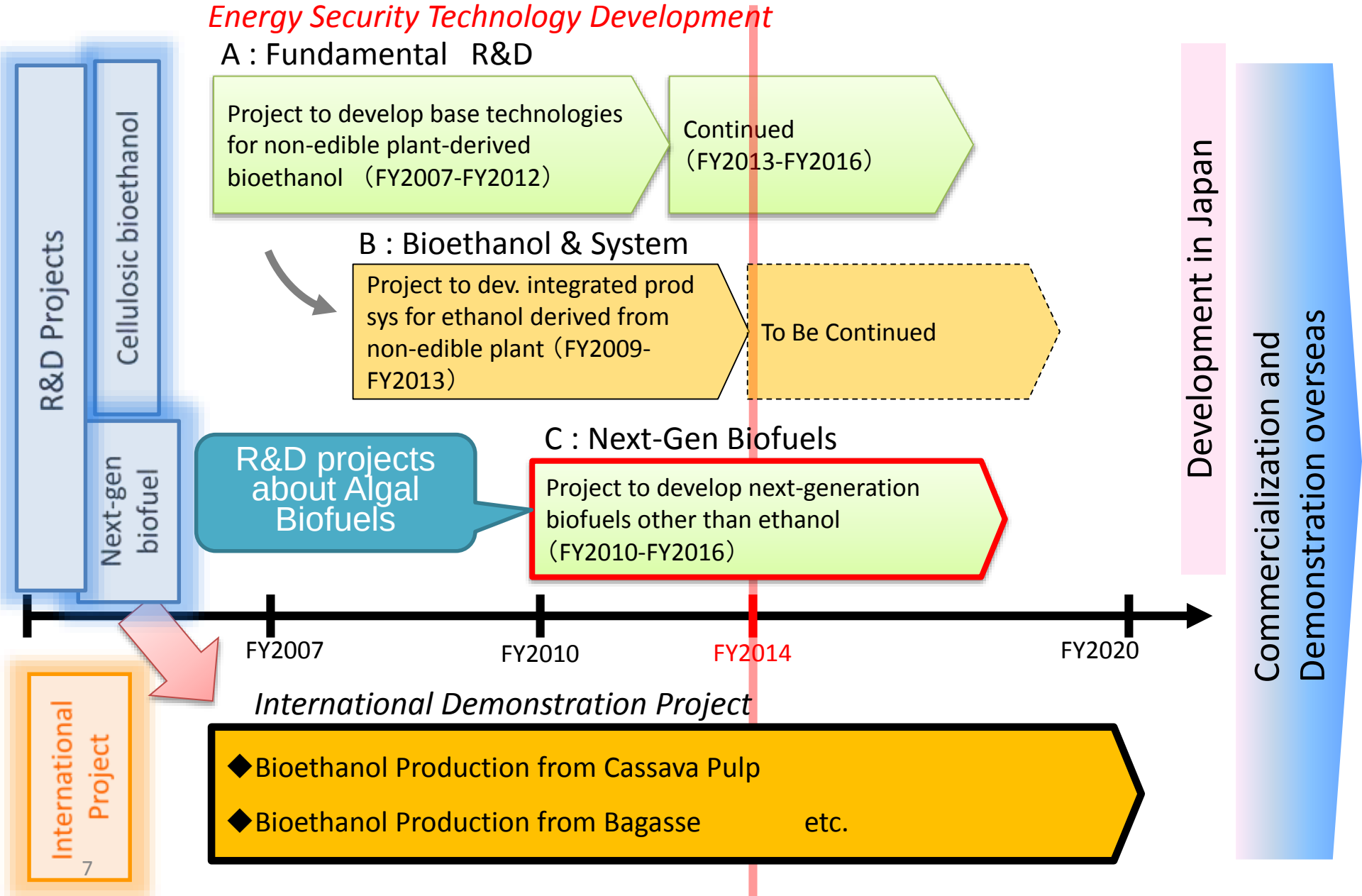
Binary power system

Hydrogen and Fuel Cell 7.2 billion yen

Hydrogen production, transportation and storage, hydrogen infrastructure, SOFC

Programs and Schedule of Biofuels R&D in NEDO

Ministry of Economy, Trade and Industry
Agency of Natural Resources and Energy



Biofuels Development Challenges

Ministry of Economy, Trade and Industry
Agency of Natural Resources and Energy

○Currently fuels in transportation sector is almost totally dependent on fossil fuels. It is important and urgent issue to further ensure energy security and diversify fuel sources by introducing biofuels.

<Sugar cane, Corn, etc. (1st Generation)>

○Biofuels produced from edible farm goods by fermentation technology. The market is already established and widely distributed centering around main producer country Brazil. On the other hand, as feedstock is edible agri product, it is necessary to develop technology to avoid competing with food resources.

<Woody plants, Herbaceous plants (Cellulosic Bioethanol: 2nd Generation) >

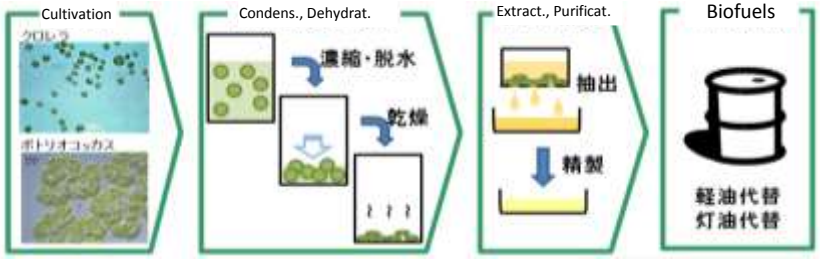
○Biofuels produced from cellulosic biomass by fermentation technology. Aiming to create a market around 2020, currently making efforts to establish integrated system for low-cost production which does not compete with food and avoid environmental problems.

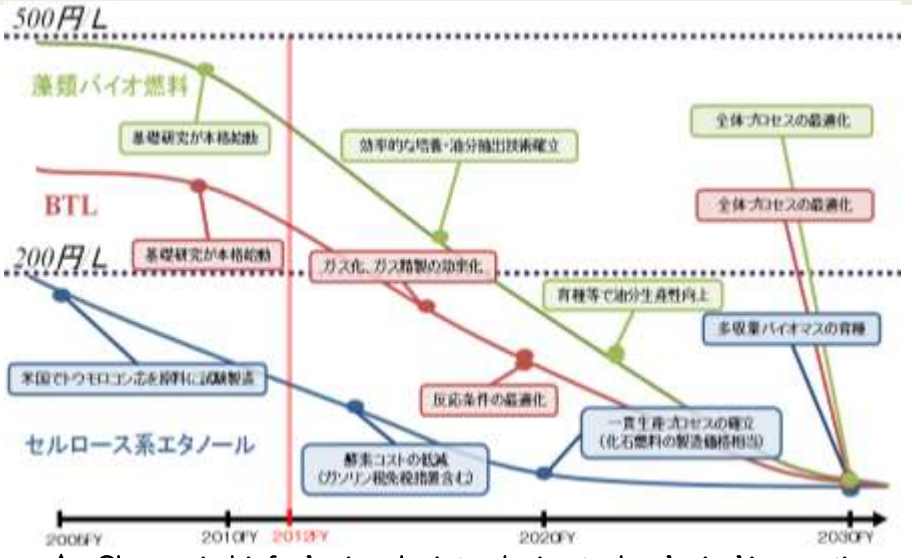
<Microalgae, BTL (3rd or Next Generation)>

○In addition to urgent need to tackle by accumulated technology of fermentation for a long time, in order to ensure further energy security and expand the market at around 2030, conducting R&D on utilization of microalgae biomass and BTL (Biomass to Liquid) technology which can make maximum use of feedstock, etc., to develop high-efficient and high-yield biofuel production technology.

Cellulosic Bioethanol

Microalgae





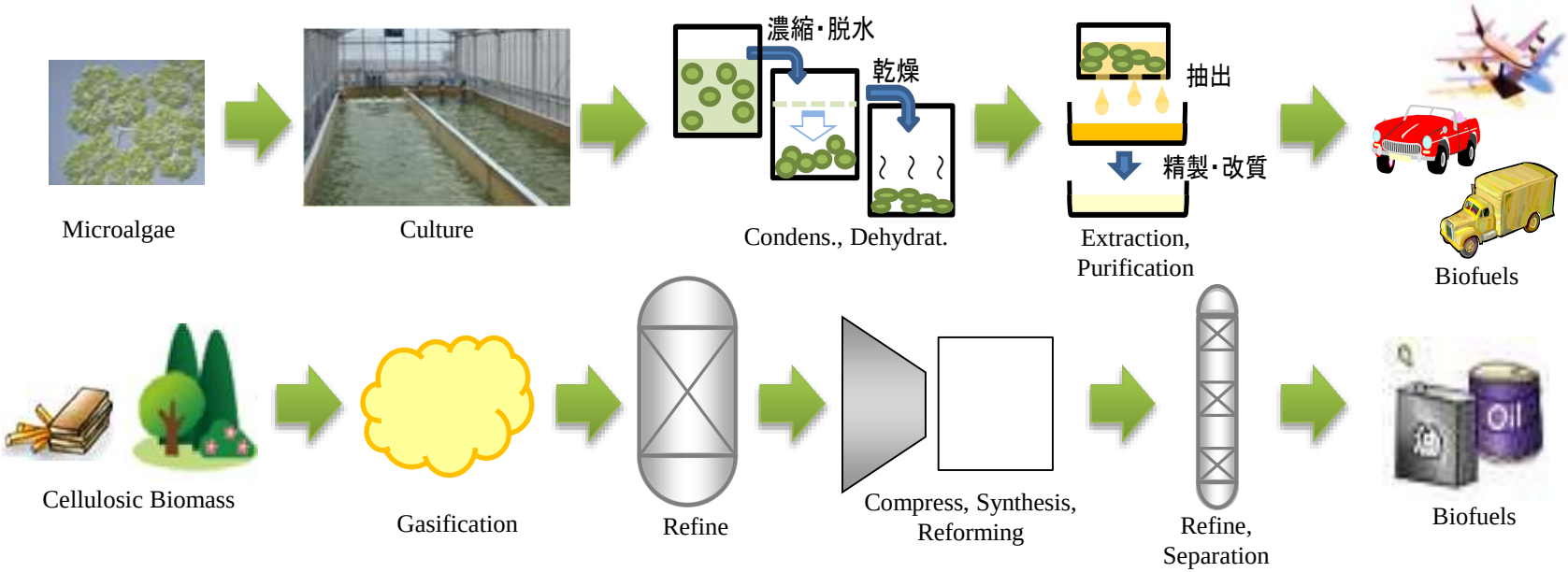
↑ Change in biofuel prices by introducing technological innovation

NEDO's Current R&D Project on Next-Gen Biofuels

"Strategic Development of Next-Generation Bioenergy Utilization Technology"

- Aim to further broaden and diversify biofuel resources which do not compete with food supplies by conducting technology R&D on microalgal biofuel production and biomass gasification and liquefaction.

  - identify and develop high- oil producing strain
  - high-efficiency culture, condensation, extraction technology
  - low-cost gas refining technology
  - high-efficiency synthesis/reforming technology in low pressure condition, etc.



Programs and Schedule of Next-gen Biofuels R&D

Ministry of Economy, Trade and Industry
Agency of Natural Resources and Energy

	H24Fy 2012	H25Fy 2013	H26Fy 2014	H27Fy 2015	H28Fy 2016	H29Fy 2017	H30Fy 2018	H31Fy 2019	H32Fy 2020		H37Fy 2025

Strategic Development of Next-generation Bioenergy Utilization Technology

Technology Development

algal biofuels

- Selection & Breeding
- Open huge cultivation
- Harvesting
- Improvement of Oil content

Demonstration (Internal) > 1000 ㎡

"From cultivation to fuel production"
Establishment of consistent process

Demonstration (outside) > 5000 ㎡

scale-up for commercial use

Technology Development

BTL

- Gasification
- Hydro thermal liquefaction
- FT synthesis to bio-jet, bio-diesel

Current problem is
"securing of materials" with cheaply in large quantities

Demonstration (Internal)

scale-up for commercial use

Major R&D Projects regarding Algal Biofuels

Ministry of Economy, Trade and Industry
Agency of Natural Resources and Energy

	Algae Species	Lipids (#Carbon)	Cultivation	Scale (m^2)	Strain Selection	Oil Refiner
1	***Euglena***	wax-monoester (C14)	Hitachi	raceway (25)	Euglena	JX
2	***Pseudococcomyxa sp.* KJ**	Glyceride (C16～18)	Denso	raceway (60)	Chuo Univ	Idemitsu
3	***Chlamydomonas orbicularis* Tai-04**		DIC	raceway (50)	Kobe Univ	—
4	***Fistulifera solaris* JPCC DA0580**		J-Power	round-pool (10)	Tokyo U of A&T	—
5	***Botryococcus* (improved strain)**	hydrocarbon (C30～32)	IHI	square pond (100)	Neo-Morgan	—
6	**Thraustochytrids**	Glyceride (C16～18)	Biomaterial in Tokyo	(30 L jar Fermentor)	Miyazaki Univ	Cosmo

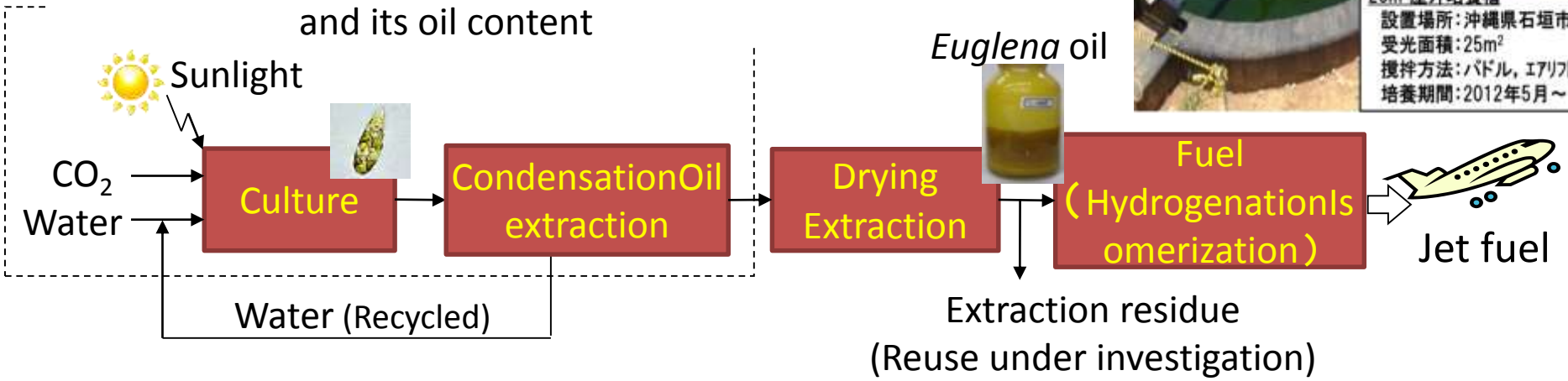
R&D project 1: Euglena

R&D Theme

In this project, technology development for improving the productivity and oil content of *Euglena*, establishment of ideal culture conditions and basic experiments on mass culture and oil production or analysis of the metabolic pathway for paramylon accumulation, which is a precursor of oil production in *Euglena*, along with the suitability of its oil as jet fuel will be investigated.

Species	*Euglena*
Scale	raceway (25m^2)
Lipids	wax-monoester
Company	JX, Euglena, Hitachi, Keio Univ.

Improvement in productivity of *Euglena* and its oil content

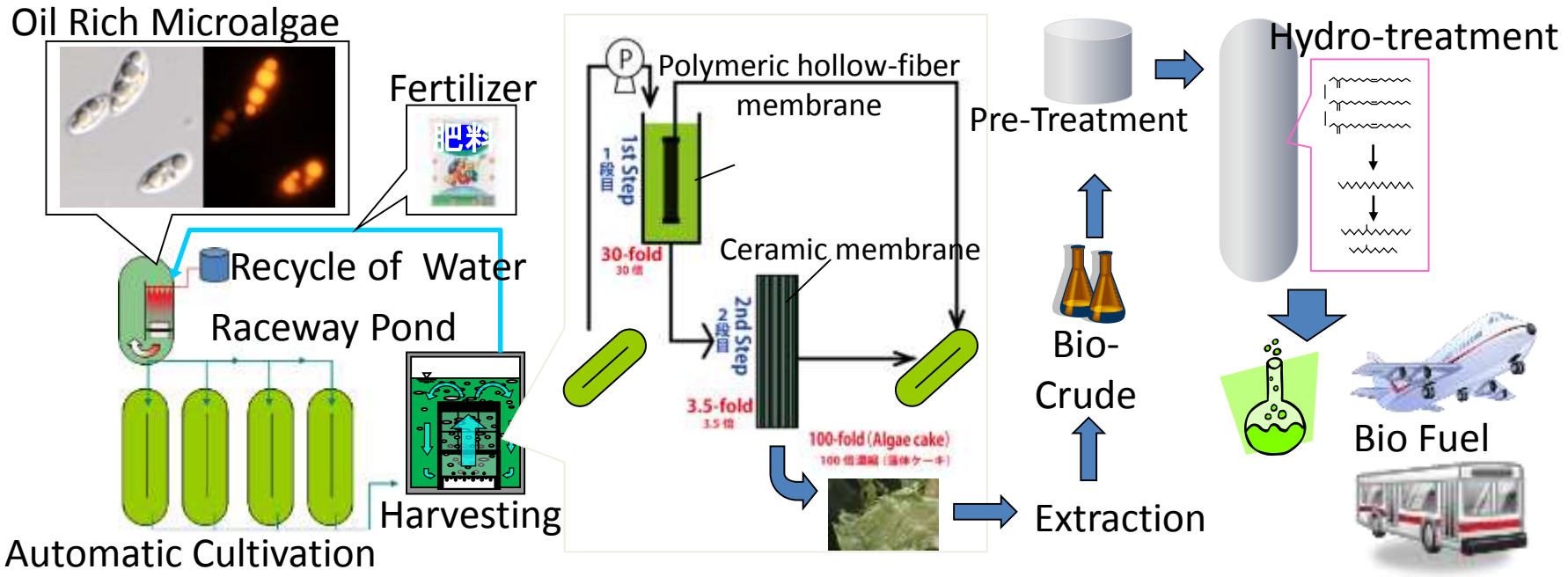


R&D project 2 : Pseudococcomyxa

R&D Theme

The objectives of this R&D are development of automatic cultivation system which can maintain the oil rich microalgae as the dominant species more than two months, development of membrane filtration system for 100-fold cell concentration and development of catalytic conversion technology from bio-crude oil to hydrotreated biofuel.

Species	*Pseudococcomyxa sp.* KJ
Scale	raceway (30m^2)
Lipids	TGA
Company	Denso, Chuo Univ, Kubota, Idemitsu

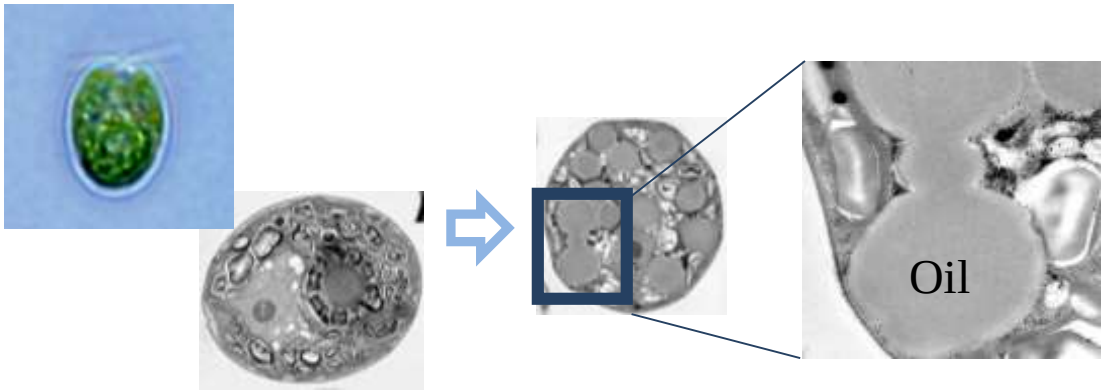


R&D project 3: Chlamydomonas orbicularis

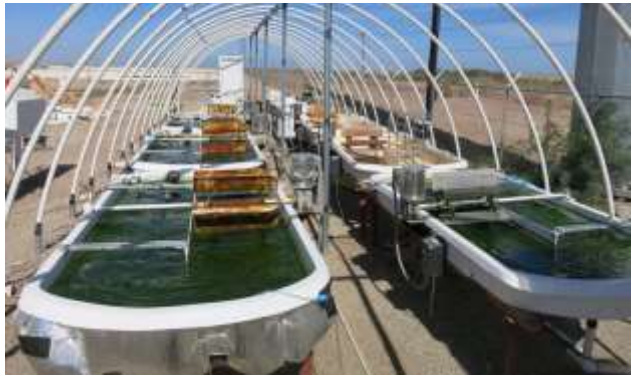
R&D Theme

Novel cultivation system is developed to maximize oil productivity by realizing both high cell density culture and high oil content in the cell. Mass cultivation is also performed with 50 m^2 pond to develop the optimized system. Economics, material and energy balance are estimated based on the cultivation data. Construction of high-oil producing green alga through metabolic engineering is intended by the development of genomic transformation of *C. orbicularis*.

Species	*Chlamydomonas orbicularis* Tai-04
Scale	raceway (50m^2)
Lipids	TGA
Company	DIC, Kobe Univ, Nat'l Inst of Basic Biology



Under seawater environment, to form the oil droplets after the nitrogen source consumption



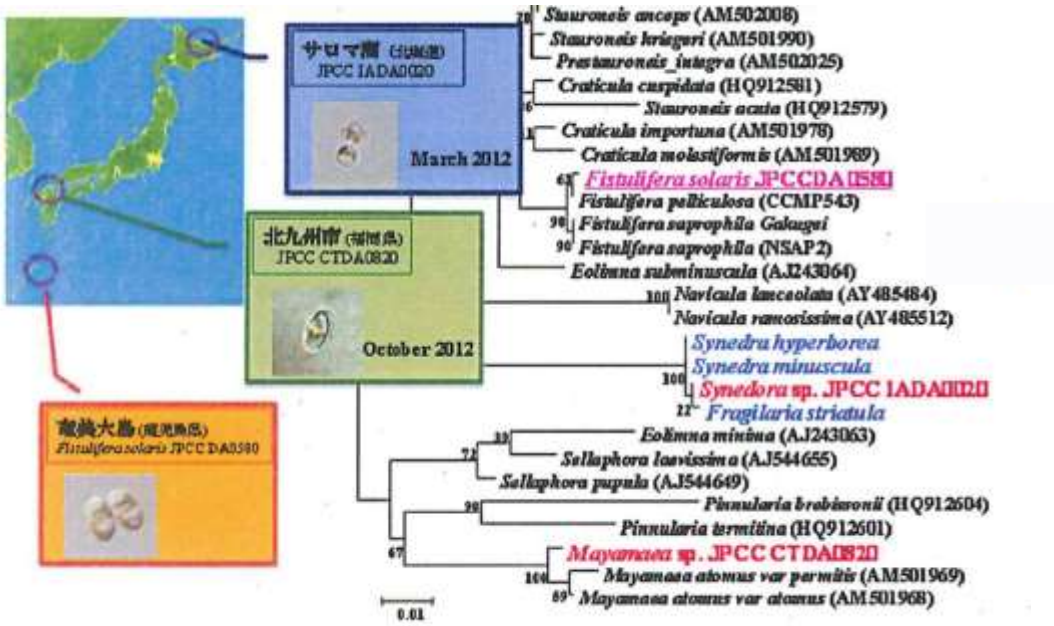
R&D project 4 : Fistulifera solaris

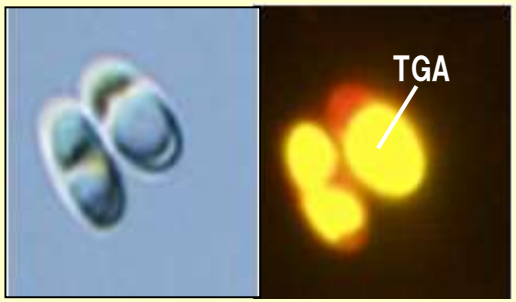
Ministry of Economy, Trade and Industry
Agency of Natural Resources and Energy

R&D Theme

This project aims to create new basic system for green oil production throughout the year using mesophilic and cryophilic oil producing diatoms. Based on the considerations of four factors described above, the entire process for green oil production will be designed to improve the EPR (Energy Payback Ratio) and the cost-performance. Furthermore, the metabolic engineering by genetic engineering will be performed to enhance the oil productivity in candidate strains.

Species	*Fistulifera solaris* JPCC DA0580
Scale	round-pool (50m^2)
Lipids	TGA
Company	J-Power, JGC, Tokyo U of A&T





Oil content (max): 60 wt%（C16:0, C16:1）

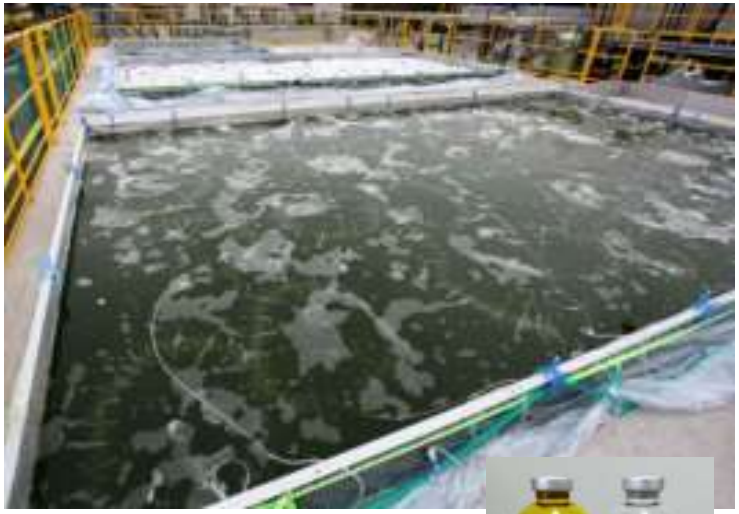
growth rate: > 1/day

R&D project 5: High-yield Botryococcus

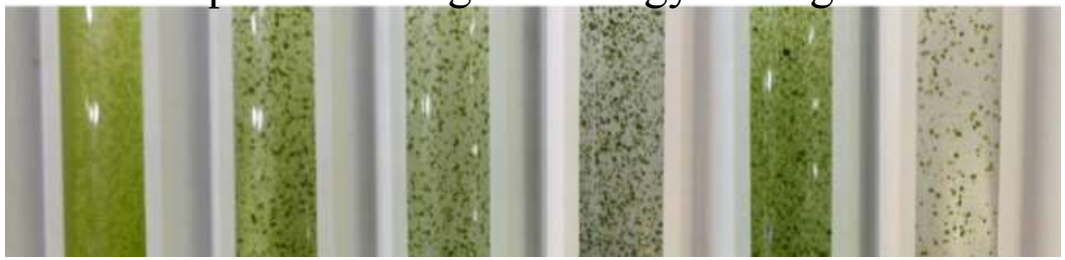
R&D Theme

To produce algae oil at low cost and with minimal energy, it is necessary to increase cell size, optimize density and reduce byproducts. Also, development of recombinant DNA technology for algae is very important for a breeding method. In this R&D, these traits are being added for high-speed cultivation of *Botryococcus* to improve economic efficiency and the energy balance by constructing a large-scale cultivation system.

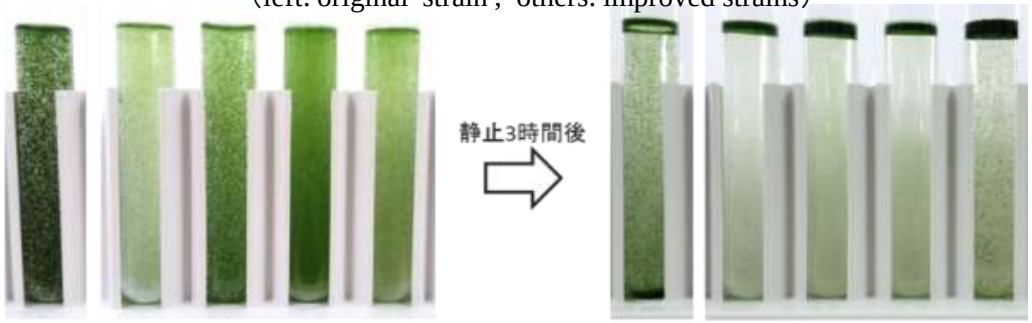
Species	*Botryococcus* (improved strain)
Scale	Square open pond (100m^2)
Lipids	hydrocarbon
Company	IHI, Neo Morgan Lab, Kobe Univ.



Resent Topics: leading to "Energy-saving harvest"



particle size was increased
(left: original strain , others: improved strains)



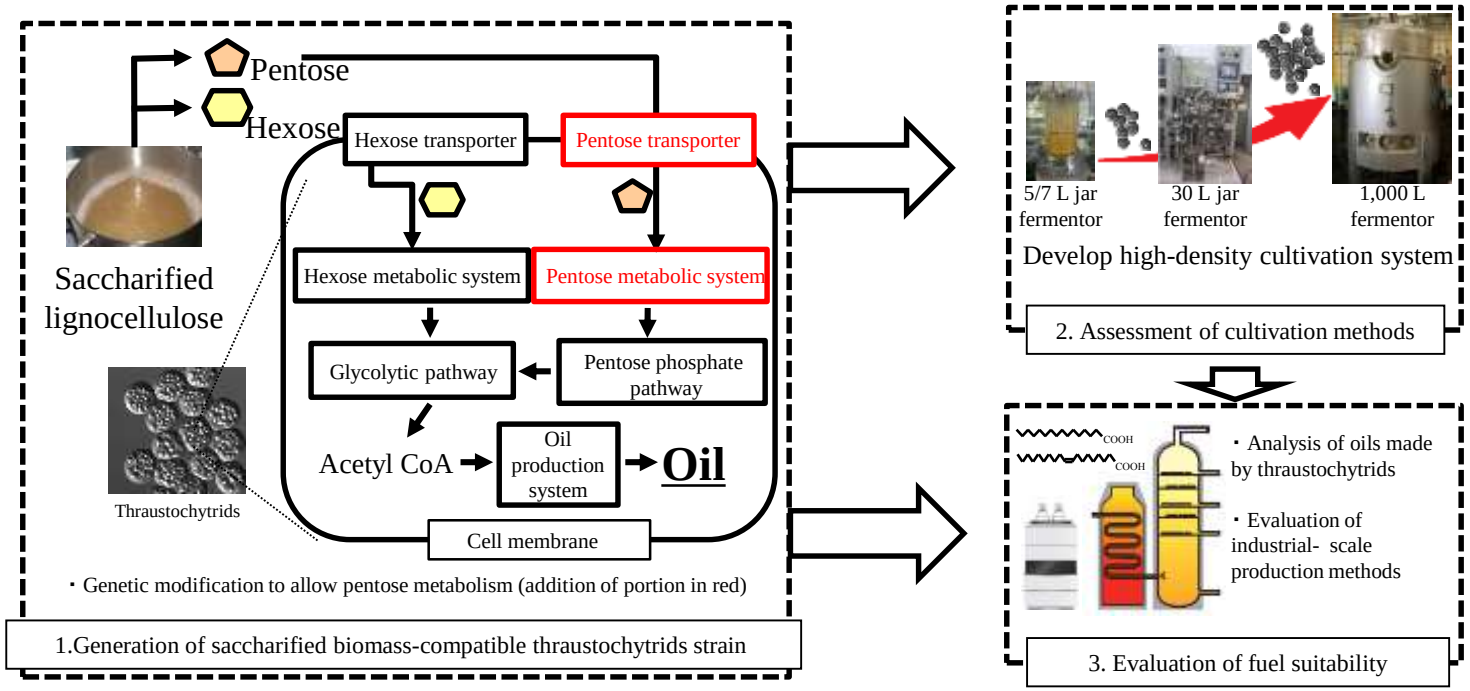
Flotation ratio was improved
(left: original strain , others: improved strains)

R&D project 6: Thraustochytrids

R&D Theme

This project aims at developing a production system with thraustochytrids that are genetically modified to utilize lignocellulose-derived (corn fiber, rice straw, etc.) sugar solutions efficiently. Other areas such as production cost, methods of oil extraction, fuel quality, and energy conversion will also be examined.

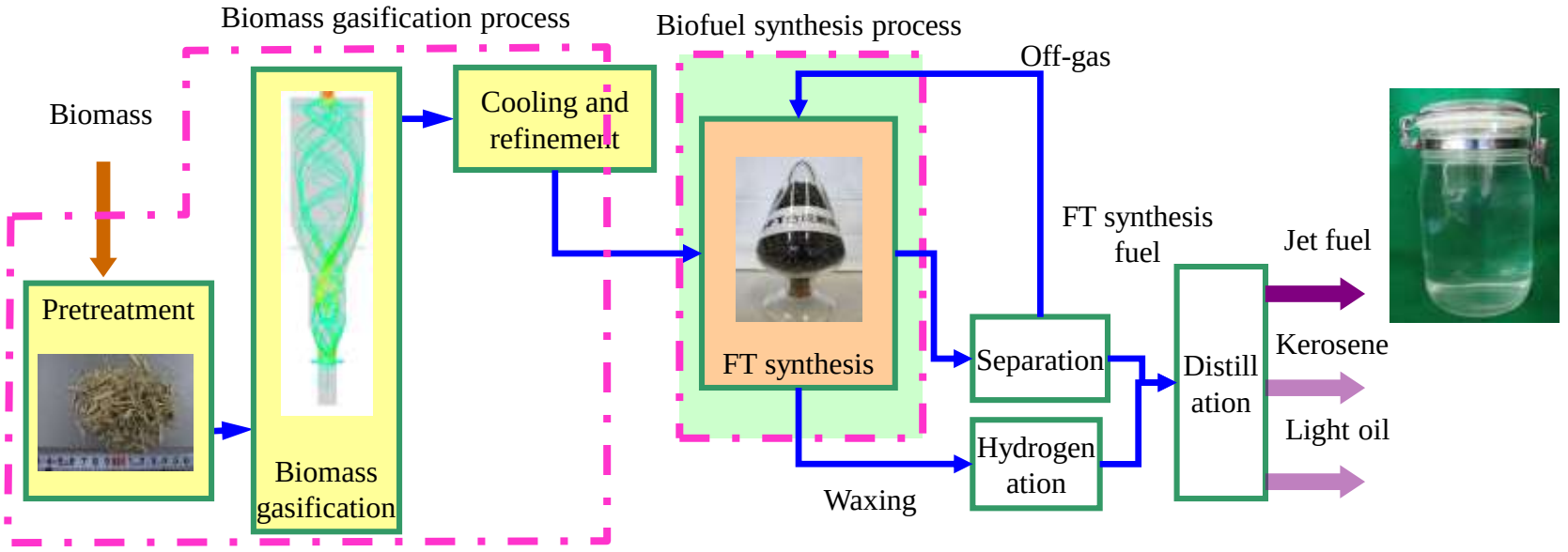
Species	Thraustochytrids
Scale	reacter (30L)
Lipids	TGA
Company	Biomaterial in Tokyo Co., Ltd. Miyazaki Univ



R&D project 7: Biomass to Liquid by MHI & Toyama Univ

R&D Theme

The commercialization of biomass to liquid (BTL) technology requires not only development of stand alone processes but a total system solution. This R&D targets the development of an innovative biojet fuel production system. This R&D focuses on the development of entrained flow gasifiers suitable for BTL and FT synthesis catalysts for biojet fuel with high selectivity and durability. This development is aimed at improving efficiency and reducing the cost of BTL systems, which are challenges in biomass energy consumption.



Technology Steadily Developing …

… Advancing step by step, METI/NEDO have been tackling various challenges with the spirit of

“Slow but Steady Win the Race”.

- ✓ Above all, crucial to establish a solid, large-scale cultivation system to prove its feasibility – before moving into whole integrated production system;
- ✓ Simultaneously further promote development of cost/energy-efficient process technology;
- ✓ Once proved, speeding up decision making and stepping forward to next stage is absolutely necessary!!!

THANK YOU FOR YOUR ATTENTION

November 2014

Ritsuko SANUKI
New and Renewable Energy Division
Agency for Natural Resources and Energy
Ministry of Economy, Trade and Industry (METI), Japan