# *Molecular Microbiology and Biotechnology Group*

## Global Trend of Biorefinery and Research Overview

### 1. Global trends and the Japanese situation

Since world energy demand has been increasing every year, we have to make efforts for a reduction of greenhouse gas emissions and realize a sustainable and low-carbon society to prevent global warming. In this respect, recent heightened interest in renewable resources including solar, wind, and biomass can help address the overdependence on fossil fuels that is the primary driver of adverse climate change. With regard to biomass, growing plants sequester $CO_2$ and release it only when they burn, contributing no net changes in atmospheric $CO_2$. A biorefinery concept, proposed to use biomass in place of fossil fuels in future energy production systems, can facilitate environmentally-friendly commercial production of chemicals and biofuels.

Soaring grain prices in 2008 were blamed on the diversion of food crops to bioethanol production in the U.S., attracting attention at the 2008 G8 Hokkaido Toyako Summit. A consequent global economic downturn triggered a steep decline in crude oil prices, with severe adverse effects on the economic performance of the U.S. bioethanol industry in 2009. Nonetheless, with the "Green New Deal" program of the incoming Obama administration, financial support for biorefinery development through the Stephen Chu-headed U.S. Department of Energy (DOE) was enhanced.

The 2007 U.S. Renewable Fuel Standard (RFS2) program, targets an annual production of 36 billion gallons of renewable biofuels by 2022. Considering that the 2009 U.S. bioethanol production of 10.5 billion gallons consumed as much as 30% of total U.S. corn produced that year, diversification into non-food and cellulosic biomass resources is imperative. Though no firm targets are set yet, the RFS2 roadmap calls for production of up to 100 million gallons of cellulosic ethanol by 2010. Accordingly, the DOE and U.S. Department of Agriculture (USDA) allocated $564 million of Recovery Act funds to spur 19 biorefinery projects in cellulosic ethanol plants, power from biomass feedstock, biodiesel plants, etc, in 15 states. Moreover, the U.S. Environmental Protection Agency (EPA) has mulled increasing the arbitrary ratio of ethanol blended in gasoline from E10 to E15 (15% ethanol to 85% gasoline). This has been an incentive for the several commercial-scale (over 10 million gallons per year) cellulosic ethanol plants that are scheduled to go on line in the U.S. after 2010.

In contrast to the U.S. counterpart, the European biofuels industry is dominated by biodiesel made from rapeseed oil. The European Union (EU) Biofuels Directive 2003/30/EC that came into effect in 2003 to encourage less dependence on crude oil has resulted in half of all new car sales in Europe being powered by diesel. The Directive set a reference value for a market share of biofuels at 5.75% by the end of 2010, although each country sets its own national target. Nonetheless, the EU is a net importer of biodiesel since its domestic productivity cannot meet demand (ca. 8M ton). Inevitably issues concerning environmental degradation and competition with food oils in biodiesel-exporting countries have surfaced. The coming into force of the Euro 6 standard in 2014 is projected to trigger an increase in the price of new cars, with a concomitant increase in bioethanol production in 5 to 10 years' time.

In Japan, the government set an annual target of 500,000 KL bioethanol by 2010, and demonstration plants constructed in Hokkaido have been operating since last year. The plants have a combined annual capacity of 10,000 to 30,000 KL utilizing non-standard wheat or sugar beet as feedstocks. With regard to cellulosic ethanol, a few small-scale pilot plants are now getting online in Japan. Thus Japan lags other developed countries in the biorefinery field, however, the incoming administration is committed to huge reductions in greenhouse gas emissions and wants to raise the proportion of renewable energy in the primary energy supply to as much as 10% by 2020. Further support of the government is expected for the development of technologies in the biorefinery field.

### 2. Research activities

We aim to develop an efficient biomass utilization technology based on the characteristics coryneform bacteria. The process was named "Growth-arrested bioprocess (RITE Bioprocess) " , and it has so far enabled elevated productivities in organic acids and biofuels. It is a global pioneer technology for simultaneous utilization of mixed sugars from cellulosic biomass in biorefinery settings. In collaboration with Honda Motor Company, we applied it in a production system of ethanol from cellulosic biomass, earning the Grand Prize at the 18th Nikkei Global Environment Award (see RITE Today 2009). The key to the high productivities of the process lies largely in its separation of microbial growth from production of target compound. This property enables productivities, expressed as space-time-yield (STY), that so much exceeds those of conventional bioprocesses as to be comparable to those of chemical processes. The Growth-arrested bioprocess therefore continues to receive much interest from both domestic and international industry players.

## 3. Future development

Production of green chemicals as well as biofuels derived from non-food biomass is a core technology for the reduction of GHG emission and achievement of a low-carbon society (Figure 1). The targeted green chemicals include commodity plastics such as polypropylenes, engineering plastic, special polymer like carbon fibers, etc. Japanese makers producing these special polymers command a sizable share of the world market. If these chemicals are produced from cellulosic biomass and used as materials or parts, they will help boost competitiveness of Japanese industry. Major foreign chemical companies such as DuPont and Dow Chemical also plan to produce the green chemicals as a core business, and have already started research and development.

We are developing technology for the production of biofuels and green chemicals from non-food cellulosic biomass resources by using the novel "Growth-arrested bioprocess" . In the process, mixed sugars (C5 and C6 sugars) derived from cellulosic biomass are utilized simultaneously and converted to biofuels or platform chemicals, then they are modified to the targeted green chemicals by using suitable chemical processes. To develop technologies for the production of biofuels and green chemicals, we hope to carry out collaborative research with industry in the future.

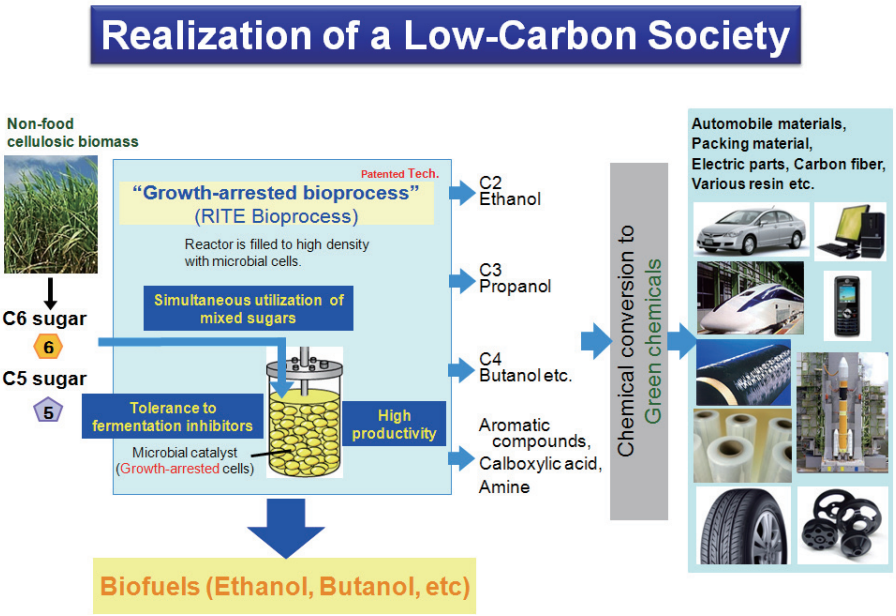


**Figure 1 Application of "Growth-arrested bioprocess" in the biorefinery field to achieve a low carbon society**