Practitioner's Section

The Future Belongs to Renewable Resources

Dr. Stefan Nordhoff *#

* Degussa AG, Creavis Technologies & Innovation, Corporate Coordinator Biorenewables, Paul-Baumann-Str. 1, 45764 Marl, Germany, Phone: +49 2365 49-4661.

\# Correspondence to: stefan.nordhoff@degussa.com.

Abstract: Degussa has held its first conference on natural raw materials and their importance for the chemical industry. The drift of the conference was that there is a plethora of possibilities for corn, plant oils, enzymes, and bacteria and that these possibilities are far from being exhausted.

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Introduction

Day after day, the world economy has been feeling the impact of crude oil prices, which are ranging between US$ 60 and 70 per barrel. But these same prices have also drawn more attention to renewable resources. The chemical industry, for example, already meets up to 8 percent of its demand for starting materials with renewable resources. "The change from fossil to renewable resources is one of the biggest challenges we face in the next 50 years," said Dr. Alfred Oberholz, deputy chairman of the Management Board of Degussa AG, at the BioRenewables Days.

Over 170 professionals from Germany and abroad met at the Marl Chemical Park for the Degussa-sponsored event held on March 14th and 15th. In addition to Degussa employees and politicians, the conference attendees included countless scientists from universities and research institutes, as well as representatives from companies active in the area of renewable resources. For the two days of the conference, the experts focused on the industrial use of biorenewables, oils, fats and surfactants, and white biotechnology. Politicians on both the national and European level have recognized the need for all-out efforts in research and development to expand the use of renewable raw materials.

Financial assistance through the next EU framework program

"All the leading companies have announced their investment in the use of renewable raw materials," said Dr. Christian Patermann of the Biotechnology, Agriculture and Food Directorate General of the European Commission. The important thing now is that Europe play a key role in future developments.

This is why the European Commission in 2005 incorporated proposals and requirements for biorenewables within the 7th EU Framework Program for Research, that covers the period from 2007 to 2013. "We in the EU must promote better and stronger industry-oriented research," said Patermann. To this end, the EU Commission has planned to increase European investment in research and development to 3 percent of the gross domestic product, and strengthen private research. Another proposal is the creation of a Europe-wide network to coordinate the wide range of activities. According to Patermann, there's another figure that underscores the need for the "old continent" to act: "In the United States, investment in industrial biotechnology is ten times higher than in Europe."

Dr. Peter Paziorek, parliamentary state secretary in the Federal Ministry of Food, Agriculture and Consumer Protection (BMELV), stressed the importance of renewable raw materials for Germany: "Biorenewable products reduce environmental pollution, because they lower CO_2 emissions and reduce the amount of waste." Not least, the cultivation and use of renewable raw materials ensure that the domestic agriculture and forestry industries have alternatives in production and income that benefit "the rural areas as a whole."

An annual € 54 million from the government

According to Paziorek, the BMELV is earmarking an annual € 54 million for future research, development, and demonstration projects, as well as for market-launch projects. Despite cost-cutting pressures, this amount has already been budgeted for 2006. As in the past, the project will be sponsored by the Agency of Renewable Resources (FNR), which was established in 1993 as an initiative of the federal government. Since its inception, the organization has promoted nearly 1,700 research and development projects.

FNR director Dr. Andreas Schütte took stock of the current biomaterials situation in Germany. Last year, the country grew about 1.4 million hectares (roughly 3.5 million acres) of renewable resources, which corresponds to about 12 percent of domestic farmland – a nearly five-fold increase since 1993. And in 2002 (the most recent figures), about one quarter of domestic timber, or 55 million cubic meters, went to bioenergy. "About 2.7 million metric tons of renewable resources go into bioproducts in the chemical, pharmaceutical and natural fibers industries," says Schütte. The chemical industry accounts for the lion's share of 2 million metric tons. "This value contrasts with the roughly 17 million metric tons of petrochemical

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resources currently used by the German chemical and pharmaceutical industries," says Schütte. Imports still account for the largest percentage of renewable resources. Only one-third comes from domestic crops.

In Germany, Schütte sees opportunities for renewable resources in four areas: biolubricants, bioplastics, fine chemicals, and bioenergy. At about 4 percent, the share of biolubricants is still extremely small, although a market share of 90 percent is a realistic projection. According to Schütte, this is because "biolubricants have technical advantages that outweigh their higher costs." Bioplastics, which currently represent a negligibly small share, have a potential of 5 to 10 percent. "Based on its market importance, the packing industry will be a key consumer of bioplastics," said Schütte.

Competition for agricultural land

With enzymatic and microbial processes, the industry already produces about 5 percent of fine chemicals. "According to experts, this percentage could climb to between 10 and 15 percent in the next five to ten years," said Schütte. "Optimistic predictions even put the share as high as 20 percent over the next ten years." Finally, bioenergy includes biofuels, wood for heat and electricity generation, and biogas. "If you add up the potential of all agricultural and forest land, as well as biowaste in Germany, these sources could make up about 17 percent of all energy consumption in Germany," said Schütte. In 2003, that share was 3.9 percent.

Schütte reminds us, however, that while renewable resources have tremendous potential, they are not available in endless quantities: "consequently, there is competition between renewable resources and food production for agricultural land, as well as competition between the use of the resources as starting materials for bioproducts and for the generation of bioenergy."

Life cycle assessments can provide information about the environmental benefit of renewable resources for certain fields of application. Dr. Martin Patel of Utrecht University in the Netherlands reported on an environmental and economic assessment of around 15 white biotechnology products. In this so-called BREW project (http://www.chem.uu.nl/brew), which was conducted with several industry partners Patel and his colleagues analyzed various biorenewables for their energy consumption, greenhouse gas emissions and land use, and compared them with the values for a current petrochemical process. Some biorenewables showed very promising results. The results of the project will be published in the near future.

Dr. Michael Binder from the marketing department in Degussa's Feed Additives Business Unit reported on a life cycle assessment of technically manufactured essential amino acids for the nourishment of poultry and pigs. Based on the nutritional requirements of the animals, such essential natural animal feed as wheat, soybeans, peas and rapeseed will each result in different deficits of one or more amino acids. Pure amino acids can fill this gap quite effectively, and significantly improve the quality of the nutrition. The alternative is increasing renewable feed so that the animals receive an adequate amount of amino acids.

"We wondered which of these is environmentally safer," said Binder. So the entire process was examined, from producing the crop to filling the feeding trough. "The total balance is significantly more advantageous with the use of technically produced amino acids, because it saves feed, and it creates less environmental pollution through nitrogen-fraught liquid manure, for example," explained Binder. As a result, the amino acids can be produced quite sustainably – no matter whether chemical or biotechnological methods are used. "The biomass that would otherwise have to be added to the feed can be better used for other applications."

Sugar cane instead of crude oil

Dr. Jaime Finguerut of the Centro de Tecnologia in Canavieira, Brazil, described a country's experience with using biofuels. For over 30 years, Brazil has been running a program called Proalcool, which lays the framework for the nationally regulated admixture of 20 percent ethanol to the gasoline.

But the price of ethanol also dropped by roughly one-half between 1976 and 2005, so "we were forced to reduce costs," said Finguerut. Between 1978 and 2004, Brazil succeeded in boosting

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the efficiency of sugar cane production by 50 percent. According to Finguerut, "today, Brazil's sugar cane costs as low as € 25 per dry metric ton" – a figure Germany can only dream of right now. Brazil has achieved this value by spending the last 30 years conducting intensive research on improved sugar cane plants. "Between the years of 1980 and 2000, for instance, we were able to increase the yield per hectare by 2 percent per year," explained Finguerut. On the other hand, Brazil also has enough land to expand its sugar cane capacities, and, he adds, "our present Brazilian fermentation process has several important characteristics that can be used in other fermentation processes, particularly those based on sugar cane."

The fact that other countries have recognized the importance of producing renewable resources, was confirmed by the assertions made by Prof. Douglas C. Cameron, director of Biotechnology in the research division of the U.S.-based food corporation Cargill. The company also supplies the chemical industry, and is further expanding its capacities for this purpose. Take biodiesel, for example: Last year, Cargill announced that it would be quadrupling its annual output of about 110 million liters. Ethanol production is another example of Cargill's fast expansion of production capacities.

"The costs of renewable resources have either stabilized or are continuing to drop," Cameron statet. "This is why the decisive question is how much and how fast we can reduce process costs." Cargill's cost-cutting efforts are targeting biofuels as well as bioplastics and bioproducts. The Group is also interested in finding partners for this quest: "We see ourselves as a biotechnology company, as a developer of new platform chemicals. But we are not a chemistry company with access to completely different markets."

Degussa already supplies important raw materials for biodiesel. "We are the world market leader in alcoholate catalysts for transesterification processes," stressed André Noppe, head of marketing and sales for the Electrolysis Products & Alkoxides Business Line of the Building Blocks Business Unit. These alcoholates are the most efficient catalysts for such tasks as increasing biodiesel yields by 2 to 5 percent. Another group of fine chemicals from Degussa is solid and liquid antioxidants for stabilizing biodiesel during transport. According to Noppe, "each filling or transport process reduces the oxidation stability of biodiesel by one hour." Degussa's biodiesel portfolio also includes antifoaming agents and polyamides for fuel lines.

Plant breeding is a long process

Using the example of plants for producing energy, Dr. Ernst Kesten of the Einbeck-based company KWS demonstrated that renewable resources raise completely different questions from the standpoint of breeders: "Conventional plants have an inadequate energy balance, and are too expensive." This is why breeders are working on new energy plants that can supply maximum energy yield per hectare – a project that clashes with conventional breeding practices. The point now is to use the entire plant, not just increase the nutritional value of the fruit. And, according to Kesten, because the fruit no longer has to ripen, vegetation periods can be used more effectively. Kesten wants us to remember one thing, however: Breeding is a long, expensive process. "This is why it is important that breeders know the outlook for demand among future customers."

Speakers from completely different fields highlighted the wide range of applications for renewable resources. Prof. Rolf Schmid from the University of Stuttgart revealed in his presentation that, as valuable renewable raw materials, lipids make perfect substrates for biotransformation. To illustrate his point, Schmid discussed some of the lipids he and his colleagues had studied on behalf of industry, including biotechnologically manufactured substances for edible oils, nutritional supplements, and breast milk fat substitute.

Advantages of biomaterials

Dr. Rolf Blaauw of Wageningen University & Research Centre in the Netherlands also reported positive research results for functionalized fatty acids. The focus of Blaauw's research is biobased products such as adhesives, additives, solvents, and lubricants. Using epoxidized vegetable oil cured with polyacids, astounding properties for this two-component bioresin can be achieved. The institute has applied to patent the technology.

Prof. Peter Dürre of the University of Ulm, Prof. Bärbel Hahn-Hägerdal of the University of Lund, and Prof. Sven Panke of ETH Zurich emphasized the future importance of enzymes and

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bacteria in the production of chemicals. Dürre used the *Clostridium acetobutylicum* bacterium to illustrate its potential importance for the future production of solvents. "After the genes have been identified that participate in solventogenesis, we will be able to optimize the gene expression" Dürre said. In the past few years, various researchers have supplied important knowledge in this area, including ways of significantly enhancing the butanol production of *Clostridium acetobutylicum*.

In Sweden, Prof. Bärbel Hahn-Hägerdal researches the production of ethanol from pentoses, using yeast as the fermenting microorganism. "Our approach is to integrate process design, fermentation technology, enzyme technology, as well as metabolic and evolutionary engineering of yeast. For a biorefinery, it is crucial to find yeast strains that perform efficiently under harsh conditions," said Hahn-Hägerdal. Several strains of baker's yeast (*Saccharomyces cerevisiae*) have proven to be up to the task as demonstrated in a national Process Development Unit (PDU). In addition Sweden hosts a national pilot plant for the investigation and demonstration of complete process integration. Hahn-Hägerdal and colleagues are also researching the production of other substances, such as low molecular weight acids and chiral compounds.

For his part, Prof. Sven Panke contemplates transferring complex cellular processes to biocatalysis. The reason for this is the sometimes multistage nature of manufacturing steps in traditional fine chemistry processes, such as those used in the production of sugar-based therapeutic molecules in the pharmaceutical industry. Panke and his colleagues are researching a system of biotransformations. "The objective is to use the modular principle to build an appropriate organism to supply the desired molecule," said Panke. For this purpose, the EuroBioSyn Consortium, of which ETH Zurich is also a member, researches and adapts the dynamics of enzyme systems. The cost is enormous, but Panke is quite sure: "One day, it will be possible for a standard organism to function as a microfactory."

This same optimism imbued the entire two-day conference: Through intensive research and development, and with the right political environment, Europe can join the ranks of the serious players in the use of renewable resources. The important thing is not to try to do everything, but to step up activities that make sense technologically, geographically, and economically, so that Europe can catch up with or even outdistance other industrialized nations.