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BUTALCO
Bio-based Innovations

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BUTALCO

Competence for Second Generation Biofuels Based on Lignocellulose

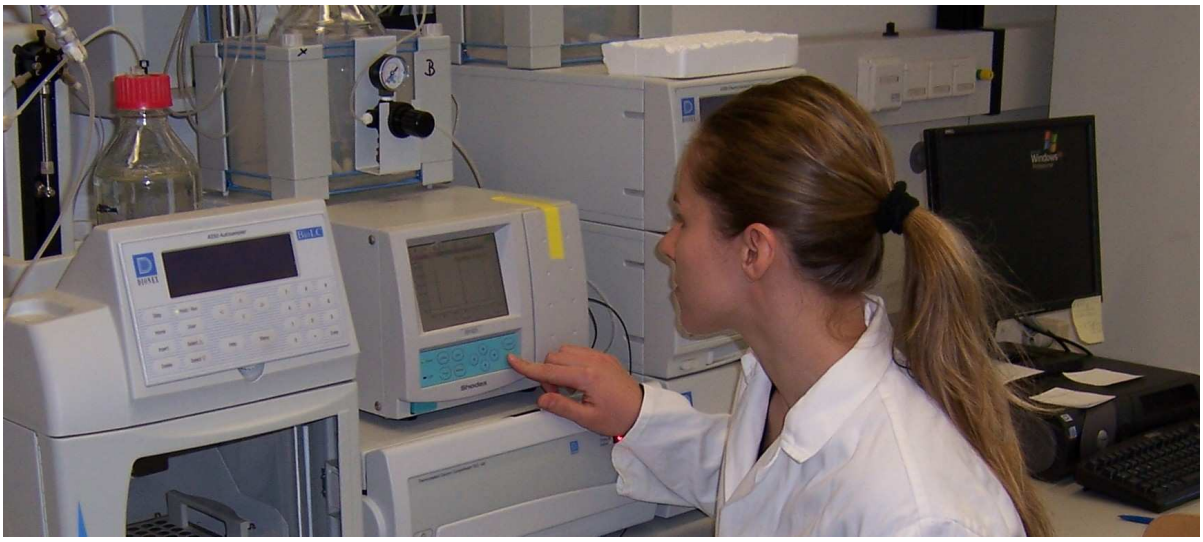
Summary

The Swiss company BUTALCO assesses and develops new production processes for second generation biofuels and biochemicals based on lignocellulose. The core technology based on (genetically) optimised yeasts (Saccharomyces cerevisiae) enables increased yields in bioethanol production by using C5 sugars in the fermentation process. Furthermore, BUTALCO develops, together with partners in the field of lignocellulose hydrolysis and downstream processing, production processes for advanced biofuels like biobutanol and other biobased chemicals.

Company

BUTALCO is a start-up company founded in August 2007 with its headquarters in the Swiss cantone Zug. Founders are the biologist Prof. Dr. Eckhard Boles, professor at the Institute of Molecular Biosciences at the Goethe University Frankfurt/Germany, and the chemist and economist Dr. Gunter Festel, founder of the Swiss advisory and investment firm FESTEL CAPITAL.

Based on an agreement with the Goethe University Frankfurt, BUTALCO has available research facilities and personnel at the university. The research is ongoing and first results have been achieved. The company is wholly privately financed and is currently looking for additional investors to strengthen the research activities and to identify new attractive fields.



Second Generation Bioethanol

Restrictions of Bioethanol Production

An attractive feedstock available in large amounts is lignocellulosic biomass, such as herbaceous and woody plants, agricultural and forestry residues, and a large portion of municipal solid waste and industrial waste streams. Cellulosic biomass is a complex mixture of carbohydrate polymers. Therefore, hydrolysates will contain hexoses (C6 sugars) and pentoses (C5 sugars), including glucose, galactose, mannose, D-xylose and L-arabinose. Because the feedstock represents a significant portion of all process costs, an economical fermentation process will require rapid and efficient conversion of all sugars present.

A lack of microorganisms that will efficiently convert hexoses and pentoses to ethanol is a major constraint to the economical conversion of biomass. Most industrial ethanol fermentations use the yeast Saccharomyces cerevisiae (S. cerevisiae) as it exhibits fast sugar consumption, high yields and ethanol tolerance. Although S. cerevisiae is able to ferment hexoses rapidly and efficiently, it is unable to ferment pentose sugars, and to use these sugars for growth.

D-xylose is the most abundant hemicellulosic sugar. Nevertheless, some of the lignocellulosic biomasses, such as corn fibre and many herbaceous crops, contain significant amounts of L-arabinose. Genetic engineering had previously been used to establish D-xylose-utilizing pathways in S. cerevisiae. Prof. Boles has recently constructed a yeast strain able to ferment L-arabinose efficiently to ethanol. Moreover, it was also able to construct a strain able to co-ferment D-glucose, D-xylose and L-arabinose. These yeast strains and the knowledge derived from the work should greatly enhance the development of an efficient biomass-to-ethanol fermentation process.

Approach of BUTALCO

C5 sugars in bioethanol fermentation are becoming increasingly important as there is pressure on bioethanol margins and the usage of C5 sugars can significantly improve the yield and cost position of existing bioethanol producers using corn, wheat or sugar cane as raw material. Based on past extensive worldwide research, the patent situation in the field of using C5 sugar for the fermentation is complex and the usage through bioethanol companies difficult. Therefore, BUTALCO is currently developing a new process to use C5 sugars for bioethanol fermentation. The first patent applications are in progress and the aim is to licence this technology to bioethanol producers.

Biobutanol as Advanced Biofuel

Advantages of Biobutanol

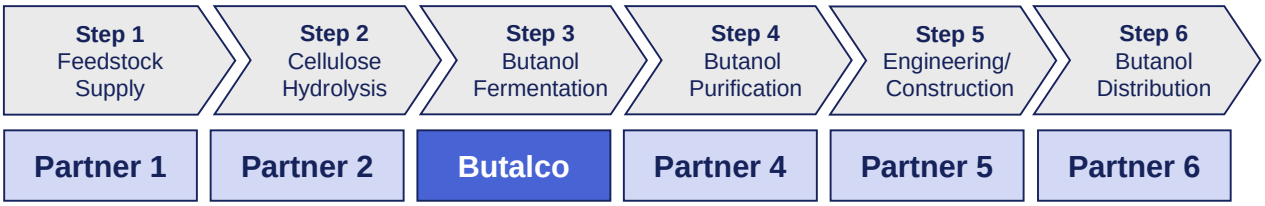
Butanol is being seen as a more superior alternative fuel than ethanol due to its more favourable chemical / physical properties. Butanol has clear advantages such as lower vapour pressure (butanol 5,6 hPa, ethanol 58,5 hPa) and higher flashpoint (butanol 36^{o}C, ethanol 12^{o}C). Butanol is less miscible with water and far less corrosive so it can be shipped and distributed through existing

infrastructure (pipelines and filling stations). Butanol can replace fossil fuels up to 100% without modifying the engine and can be blended with diesel / biodiesel and burned in diesel engines.

Yeasts as production organisms for biobutanol have decisive advantages compared to bacteria: Yeasts have GRAS (Generally Recognized as Safe) status and are easy to genetically modify. They are well established, highly robust, and the production process is easier to control. As ethanol producers are used to working with yeast, it is much more probable that the ethanol production plants in Brazil, Europe or North America will use yeasts rather than bacteria should they switch from ethanol to butanol.

Approach of BUTALCO

BUTALCO uses a special technology to modify the yeasts for butanol production. BUTALCO is working together with partners to develop a competitive biobutanol production process using ligno-cellulose as feedstock. The development covers the whole process chain including all production steps from feedstock supply to engineering/construction and distribution.



Appendix

Founders of BUTALCO

Professor Dr. Eckhard Boles

Professor Dr. Eckhard Boles is professor of Molecular Biosciences at J.W. Goethe Universität Frankfurt since 2002. His research is focused on metabolic engineering of yeast strains for industrial purposes and transport of nutrients across the yeast plasma membrane. He has strong experience in using molecular genetics and molecular biology methods to study and manipulate sugar metabolism in yeast.

He has published more than 50 articles in international peer-reviewed journals, and contributed to 7 important patents in the field of yeast biotechnology. Landmark patents were the construction of the first recombinant yeast strain able to ferment the pentose sugar L-arabinose and a yeast strain expressing human glucose transporters in a functional form.

Dr. Gunter Festel

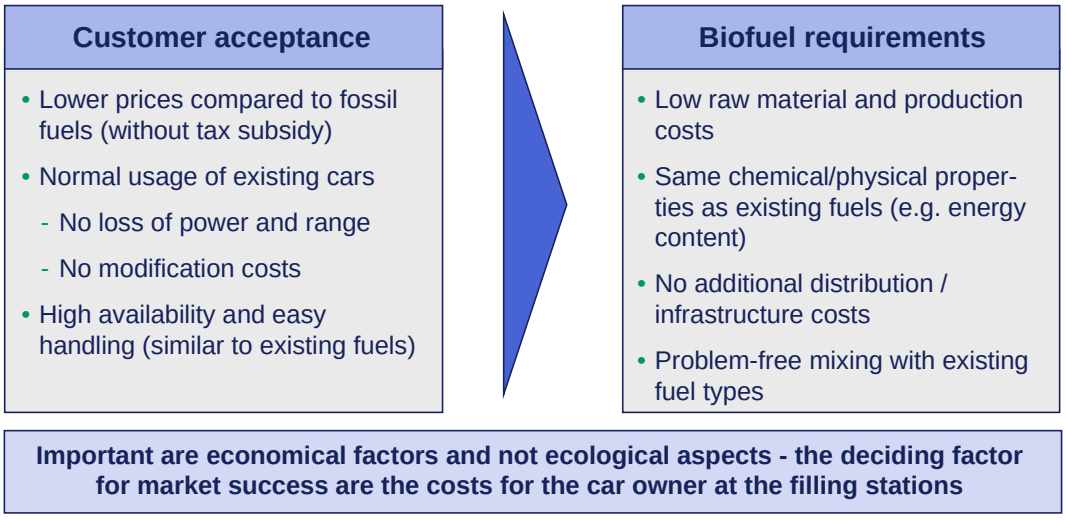
Dr. Gunter Festel founded the advisory and investment firm FESTEL CAPITAL with headquarters in the Swiss Cantone Zug. His company specialises in the commercialisation of technologies in the areas of energy, environment, health, materials and nutrition, and invests in selected companies, preferably in early stages.

Up to the end of 2002, he was a member of the management team and head of the consulting business for the chemical and healthcare industry with Arthur D. Little in Zurich and a consultant with McKinsey. He started his career with Bayer, where he held various management positions in R&D and marketing. Dr. Gunter Festel has a PhD in chemistry, BA in business studies and MA in economics. Furthermore, he has an Executive Master of Corporate Finance.

Evaluation of Different Biofuels

Biofuels have many different influencing factors, such as technical (e.g. raw material supply, conversion and engine technologies), economical (e.g. fuel and engine modification costs, infrastructure) and ecological/political factors (e.g. greenhouse gas emissions, efficient land use, reduced dependency on crude oil).

At the end of 2006, FESTEL CAPITAL carried out a quantitative comparison of different biofuels to identify interesting technologies for investments. An analysis of customer acceptance and attitude towards biofuels showed that important to customers are prices no higher than those of fossil fuel, no engine modification costs or loss of power, high availability and easy handling.



Therefore, biofuels need to meet the following criteria: competitive production costs, no additional distribution/infrastructure costs, problem-free blending with existing fuel types as well as similar chemical/physical properties. Therefore, as costs for the customer are a deciding factor for market success over the short to mid term, the comparative analysis considered only the economical factors and not the ecological aspects.

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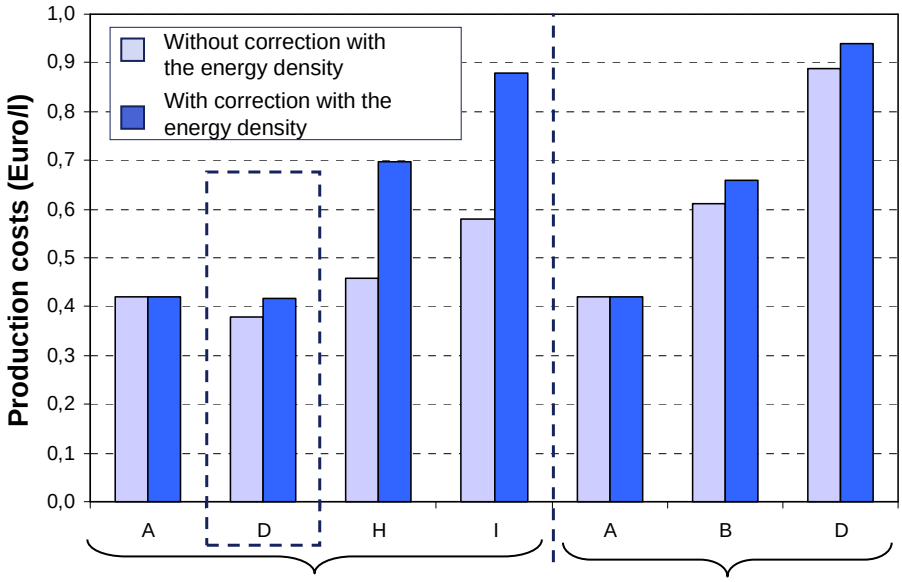
In order to identify interesting biofuel technologies for investors, publicly obtainable data regarding production costs were evaluated and included in a consistent model calculation. Besides plausibility checks, data comparability was evaluated and, if necessary, corrections were made. The results showed the costs and profit margins of the considered biofuels. As well as the raw material costs and production costs also the capital costs, blending costs and distribution costs to the filling pumps were calculated for each fuel separately. In order to reflect the various development stages and the economies of scale, realistic scenarios were calculated. In the calculation and comparison the normal mineral oil tax was considered also for biofuels. The profit margin (price at the filling station minus all costs and taxes) was the criterion for the profitability.

In the 2006 evaluation, a price of US$ 60 per barrel of oil for petrol and diesel production was taken and the results were conclusive. Both biodiesel and bioethanol produced in Europe from wheat are not profitable. The producers' high margins are only due to the current mineral oil tax concessions. Also, biomass-to-liquids (BTL) fuel can also not be produced competitively. At the taken oil price, only bioethanol and biobutanol produced on a large scale from lignocellulose-containing raw materials have the potential to be produced competitively. The model calculation showed that, in Europe, biobutantol produced from lignocellulose is mid term the most cost-effective biofuel, which can be produced with 38 Euro cent/litre and, therefore, with a reasonable profit margin without tax exemption.



A: Petrol (crude oil, 60 USD/barrel)

D: Biobutanol (lignocellulose, Europe, Large scale 2008)

H: Bioethanol (straw, Europe, Large scale 2008)

I: Bioethanol (corn, Europe, Large scale 2006)

A: Diesel (crude oil, 60 USD/Barrel)

B: Biodiesel (rape seed, Europe, Large scale 2006)

D: BTL (wood, Europe, Large scale 2012)

Source: FESTEL CAPITAL analysis

Disclaimer

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