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Renewable energy from biomass fermentation

Edited by **Piet Lens, Peter Westermann, Marianne Haberbauer and Angelo Moreno**

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Polymer Electrolyte Membrane Fuel Cell (PEM-FC) pilot plant, which is connected to an agricultural biogas plant, at the Institute of Technology and Biosystems Engineering of the Federal Agricultural Research Centre (FAL) in Braunschweig (Germany). *Top*: Biological desulfurisation unit, inside and outside, *Left*: PEM – FC test stacks, *Bottom*: Hydrogen Reforming System. Photographs courtesy of Dr. Thornsten Ahrens (FAL, Germany).

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Foreword

This book has been edited within the Network "Biomass Fermentation towards Usage in Fuel Cells" (BFCNet) that has been funded by the European Science Foundation. It has been running from January 2002 to December 2004 and involved nine partners from eight European countries in the field of biomass fermentation, biofuel upgrading and usage of biofuels in fuel cells.

The main activities of the network have been:

- Three Workshops have been organized: the first one was held in Genoa, Italy in February 2003 with the title "State of the Art and Perspectives in the Development of Less Contaminant Sensitive Fuel Cells Using Biomass Fermentation Fuels". It focused on the research on fuel cells in Europe and gave an overview of current research efforts on fuel cells. The second Workshop was held in Braunschweig, Germany and focused on "Biomass Fermentation as Basis for High Quality Fuel for Fuel Cell Applications – Fundamentals and Special Aspects". The third and final Workshop was held in Steyr, Austria with the title "Biomass Fermentation and Fuel Cells as Key to a Sustainable Decentralized Power Generation in Europe" with the main focus on biomass and fuel cell integration into the European energy supply.
- The BFCNet funded seven exchange visits of young scientists between European research institutes. The short-term visits enabled the benefiting researchers to learn more about the combination of biofuels and fuel cells which would not have been possible at their home institutions.
- The BFCNet has been operating a website where the most important data on the Network, about the participating institutions, events and calls for research projects in the respective field have been published.
- Finally, the Network prepared the present book where all member institutions of the Network contributed a chapter. The book described comprehensively the state of the art of biomass fermentation for the usage in different types of fuel cells and gives insight into the research activities in this field.

As chair of the BFCNet, finally I would like to thank the partners of the network for their cooperation: Thorsten Ahrens, Loreto Daza Bertrand, Marianne Haberbauer, Peter Holubar, Kevin Kendall, Piet Lens, Angelo Moreno, Åke Nordberg, Ewald Wahlmüller, Peter Weiland and Peter Westermann. Furthermore I would like to thank Svenje Mehlert and Stéphanie Pery representing the European Science Foundation for the financial and administrative support.

Werner Ahrer
Chair of the BFCNet

Preface

The current way to produce, convert and consume energy throughout the world is not sustainable. Our economic growth and social development can, however, only be implemented by means of appropriate availability of energy services. Due to their high efficiency, fuel cells are considered as a strategic technology for future energy supply systems. Biomass fermentation can be regarded as an energy-efficient technology for the mineralization of organic compounds in waste streams, as it results in the production of energy-rich compounds (biogas, hydrogen and ethanol). The unique and advantageous point in the combination of biomass fermentation and fuel cells results from the fact that biomass is a renewable source of energy which can be utilized most efficiently using fuel cells technology. This book discusses the optimal combination of biomass fermentation with energy production technologies using fuel cells for decentralised heat and power generation.

Due to limited amounts of fossil fuels and concern about the global warming, there is an increasing urge to develop more renewable energy sources. Biogas production via anaerobic digestion is an already established technology to produce biogas from renewable sources as biological wastes and energy crops. However, the potential of biogas is thus far not realized, as biogas is mainly produced locally, far away from the major energy consuming locations like urban and industrial areas. Also, there is a tendency towards centralization of plants in very large scale facilities to reduce costs and increase the earnings. Moreover, the electricity market was until a few years ago monopolised by a few companies and local energy production has been strongly discouraged. With the recent opening of the energy market, there is an incentive to develop alternative, low cost and on site electricity production technologies in an environmental friendly way. Thus, anaerobic conversion of organic wastes (biowaste, manure, biomass) gets a facelift from “dead end waste processing” into “energy production”. This allows upgraded anaerobic digestion plants to be integrated in the energy cycle and thus contribute to sustainable development of our society, both in rural and industrialised areas.

The major bottleneck to upgrade anaerobic digestion to an “energy plant” is to link production and consumption of energy. In case the biogas quality is sufficiently high, it can be injected directly into the natural gas grid, as is already done in e.g. Sweden and Austria. Alternatively, methane (upgraded biogas) can be used as a car fuel or in combustion engines for local electricity production. A number of newly developed technologies, i.e. fuel cells and microturbines, can, however, be used to convert the biogas into electricity at a much higher efficiency than currently used technologies. Fuel cells have a high efficiency as they directly transform chemical energy into electricity. Electricity can be very easily transported from the production location to the consumption location. Fuel cells are easily scalable, i.e. they offer a high energy conversion efficiency independent of the size. Fuel cells thus make local high-efficiency electricity production possible. In this way, the use of fuel cells could facilitate the application of anaerobic digestion for the production of renewable energy at small scale. This scenario for renewable energy production is discussed in detail in the book volume.

The common end products of anaerobic digestion are biogas and a kind of compost. Biogas mainly consists of methane and carbon dioxide in an average ratio of 50–60% and 40–50% respectively. Such a ratio is theoretically well suited for fuel cells. As a matter of fact, pure methane cannot be used in fuel cells because of their inactivation by carbon production and pure methane needs to be spiked with carbon dioxide before it can be used in a fuel cell. Fuel cells enable an increased electrical output out of biofuels while reducing drastically the usual particle emissions in the exhaust gas. If using a biofuel, these advantages are joined by the fact that the system reduces the CO_2 emissions.

Several national and super national strategies have been outlined for a future in which hydrogen serves as a central energy carrier. As suggested by, e.g. DOE, a near term approach to the hydrogen economy is steam reforming of natural gas, followed by a mid and long term plan to use wind turbines, photovoltaics and biological production of hydrogen from biomass. Most studies of biological hydrogen production are performed at the laboratory scale with axenic cultures grown in laboratory media. Even in combined processes, the yield is still low and considerable developments are needed before the processes are economically exploitable. Several chapters of this book give an overview and discussion of the state of the art of this field.

Instead of concentrating on the biological production of only one energy carrier, a simultaneous production of hydrogen, methane and ethanol creates the possibility to optimise the exploitation of specific energy carriers to suit specific needs corresponding to the current fossil fuel use for specific purposes. Hydrogen can for instance be used in fuel cells for urban transportation. Ethanol can be used in fuel cells in rural areas, and methane can be used in fuel cells or microturbines for local electricity and heat production. Despite the obvious advantages of combining the production of different energy carriers, only a few concepts have so far been presented. In these concepts, the different processes are exploited in a sequential fermentation, transforming most of the energy available in the substrate to usable energy carriers. These so called biorefineries can be considered as more environmentally friendly processes since process water and nutrients from the different processes can be recirculated and waste production can be kept minimal. The biotechnological development and optimisation of the process conditions to produce these compounds from biological wastes and energy crops is an area of large interest, which is addressed in this book volume.

We wish to thank all the contributors for their enthusiastic support and timely submission of their manuscripts. This book has evolved out of the activities of the network "Biomass fermentation towards usage in fuel cells – BFCnet", see www.Bfcnet.info for more information. This network (2002–2004) was financially supported by the European Science Foundation. We are grateful to Alan Click and Alan Peterson of IWA Publishing for their help and editorial support in realizing this book.

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