NACHHALTIGwirtschaften
konkret

FORSCHUNGSFORUM
2/2008

FUEL CELL SYSTEMS – THE ENERGY TECHNOLOGY OF THE FUTURE?

NEW AUSTRIAN RESEARCH AND DEVELOPMENT ACTIVITIES WITHIN THE SUBPROGRAMS "ENERGY SYSTEMS OF TOMORROW" AND "FACTORY OF TOMORROW"

bmvit

TOPIC

NEW RESEARCH PROJECTS IN FUEL CELL TECHNOLOGY

Fuel cell systems are seen as an energy technology with future potential, given that the technology involved converts energy while keeping resource consumption exceptionally low.
In ***fuel cells*** chemical energy can be converted to electricity efficiently. Today, though, the most usual way to obtain electricity from chemical sources of energy is to burn them in a heat engine which drives a generator (i.e. by means of a detour via thermal and mechanical energy).

Fuel cells are designed to achieve this conversion with no intervening stages, which is good for efficiency. Possible applications include both fixed systems in power stations and compact mobile systems for use in cars or in portable devices such as laptops and mobile phones.

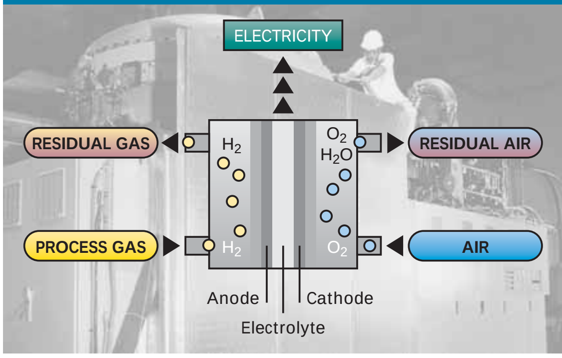
Different designs of fuel cell are employed for the various fields of application; for instance, the SOFC Solid Oxide Fuel Cell, which involves high operating temperatures (around 900°C), is particularly suitable for use in stationary applications with infrequent on/off switching. For compact systems, from cars to mobile phones, the proton exchange membrane (PEM) fuel cell, operating at around 80°C, turns out to be particularly efficient. Today the production of fuel cells and the components that go into them involves a great deal of costly individual fabrication processes, and to some extent assembly by hand; so production costs are extremely high.

Research is thus focused on developing mass production facilities for manufacturing individual fuel cell system components, so as to cut costs and achieve a basis for disseminating this new technology more widely.

In the field of stationary applications fuel cells currently use mainly hydrogen or methane gas as fuel. Alternative approaches employ methanol or diesel. Within new programs of research into applications, ways of combining fuel cell technology with sources of energy derived from renewable local raw materials (comparable with cogeneration plants burning biogas) are being investigated.

Various projects to develop fuel cell technology further and put it to work in Austria have been conducted with support from the subprograms “Energy systems of tomorrow“ and “Factory of tomorrow“:

Fuel Cell Function Diagram



>>> A fuel cell is a galvanic cell which converts the energy of a chemical reaction between a continuously supplied fuel and an oxidant into electricity.

BIOVISION I & II
Using stationary fuel cell systems to provide refrigeration, heat, electricity and other services / planning a biogas fuel cell demonstration facility

MASSENFERTIGUNG FÜR PEM-BRENNSTOFFZELLEN
(Mass-Producing PEM Fuel Cells)

EASYCELL
Optimizing the design of PEM fuel cells

MINIATURISIERTE KERAMISCHE HOCHTEMPERATUR-BRENNSTOFF-ZELLEN-KOMPONENTEN
(Miniaturized Ceramic Components for High-Temperature Fuel Cells)
Developing an energy-efficient mass-production process for manufacturing SOFC fuel cell components


Hot Module, Photo: CFC Solutions

In 1999, the Austrian Federal Ministry of Transport, Innovation and Technology (bmvit) launched the “Sustainable Development” research and technology program, which aims to effectively support approaches towards sustainability in economic activities through research. Various research and development projects as well as demonstration and diffusion measures, which give new impetus to innovation in Austria's economy have since been supported within the scope of a number of subprograms. The “Energy Systems of Tomorrow” subprogram aims to encourage innovative and trend-setting technologies and concepts in the field of renewable energy sources that are capable of safeguarding energy supply on a long-term basis. The “Factory of Tomorrow” subprogram aims to encourage trend-setting pilot projects in the field of sustainable technology development. Model examples include sustainable technologies and innovative manufacturing processes, the use of renewable raw materials or future-oriented products and services with a consistent focus on the usefulness of the product.

Since the end of 2004 Austria has been a participant in the International Energy Agency (IEA) “Implementing Agreement on Advanced Fuel Cells”. The main aim of this Implementing Agreement is international cooperation on developing fuel cell components and systems and getting them to the market.
www.energytech.at

BIOVISION I & II

Hot Module, Photo: CFC Solutions

Renewable resources available at the local level are not yet widely used to supply energy in Austria. Cogeneration plants burning biogas play a pioneering role here. This form of energy supply could be expanded by means of fuel cell technology. Used multifunctionally, fuel cells exhibit high overall efficiency and produce significantly more electricity per unit of fuel than conventional cogeneration plants based on biogenic raw materials (e.g. gas engines).

As part of BIOVISION I & II (project management: PROFACTOR GmbH) the engineering and economic essentials of implementing demonstration facilities using renewable raw materials available at the local level in Austria in fuel cell systems are being determined in a three-stage sequence of projects.

How such facilities function, and how cost-effective they are, depends on how the fuel is supplied, on the conversion technology and on the demand for the associated coproducts. In the first stage various model systems have been developed, analysed and evaluated with respect to these separate dimensions.

CFC Solutions' HotModule system (see front page), a molten carbonate fuel cell (MCFC), provides the right technology for these aims. High-temperature fuel cells can convert the energy content of hydrocarbon fuels, particularly renewable energy sources such as biogas, into electricity directly.

Whereas cogeneration plants burning gas fuels achieve at most 38 % efficiency, the MCFC fuel cell currently achieves 49 %. This makes a big difference to the profitability of the models investigated.

The following tasks were performed during stage 1 of the project:

- Investigating what local energy resources are available and how suitable they are for use in a HotModule MCFC fuel cell as regards cost-effectiveness and sustainability
- Drawing up user profiles for potential operators (saving primary energy, earnings on electricity fed into the grid, demand for electricity, heat, refrigeration etc.)
- Developing a process for converting the resources into a suitable fuel for the HotModule
- Designing a process to identify and remove troublesome contaminants
- Economic analysis of selected model system

The project partner CFC Solutions carried out tests to find out how well the fuel properties of various raw materials matched the MCFC fuel cell's requirements, and identified biogas (with modest purification effort) and bioethanol (with more substantial purification effort) as suitable renewable fuels for this high-temperature fuel cell. Biodiesel's tendency to carbonize makes it necessary to provide completely new reformers before it can be used as a fuel here. So model systems based on biogas were then developed.

User profiles were drawn up for a number of sectors, and ranked in terms of selected guiding criteria. The comparison revealed that hospitals, hotels, breweries, dairies and distilleries were particularly suitable for setting up a molten carbonate fuel cell system (with a rating of 250 kW_{el}) as a power centre.

In many cases providers of secondary raw materials (biogas plants, sewage gas plants) do not themselves need much electricity, heat or refrigeration; that lowers their total score. Such facilities would score much better if demand for heat, refrigeration and electricity in the immediate neighbourhood can be demonstrated.

Six model systems were then investigated in detail: two dairies, two breweries and two hospitals.

Summary of model system evaluation (at most 2 points per criterion)

criterion / system	size of market	turnover	inhouse raw materials	demand for heat	demand for electricity	demand for refrigeration	constancy of demand	total	total
hospitals	high	high	medium	high	high	medium	high	high	12
market garden	high	low	medium	high	medium	medium	low	medium	7
hotels	medium	medium	medium	high	high	medium	high	high	10
farm biogas plants	medium	low	high	medium	medium	low	medium	medium	6
sewage gas plants	low	high	high	medium	medium	low	high	medium	8
distillery	low	medium	high	high	high	medium	high	high	10
breweries	low	high	medium	high	high	high	high	high	11
dairies	low	high	medium	high	high	high	medium	high	10

Source: STUDIA

Economic analysis of model systems/ factors influencing prospects

model system	fuel	electricity	heat	other	IRR (in %)
MS1 (dairy)	inhouse biogas	feed-in tariff	h.temp.-heat	none	+1.8
MS2 (dairy)	inhouse biogas	feed-in tariff	refrigeration	none	+2.8
MS3 (brewery)	sewage gas (stub line)	feed-in tariff	refrigeration	none	+3.4
MS4 (brewery)	brought-in biogas	feed-in tariff	refrigeration	none	-7.7
MS5 (hospital)	brought-in biogas	feed-in tariff	h.temp.-heat	UPS	-6.6
MS6 (hospital)	brought-in biogas	feed-in tariff	refrigeration	none	-7.2

Source: Energy Economics

The internal rate of return method can be used to show whether implementing a given project makes economic sense. This is the case – and value is thus increases – whenever the cost of capital is less than the internal rate of return.

The following factors were identified as crucial for success:

- Cost of fuel
  How profitable a model system is depends very largely on the unit cost of fuel, which needs to be guaranteed for the entire service life of the facility.
- Feed-in tariff for electricity
  A feed-in tariff of 15.2 ct/kWh guaranteed for a period of 15 years from start-up is essential for operating the facility to be profitable.
- Selling heat
  The model systems become much more profitable if the heat produ ced by the fuel cell is sold at a good price. This is the case with high-temperature heat and/or cooling.

Profitability is specially high in cases where biogas fuel can be generated from inhouse waste.

The investigation of the model systems also revealed that any additional products from the fuel cell process do not, in the specific cases considered, contribute significantly to improving profitability. Attention should therefore be concentrated on the keystone products electricity and heat.

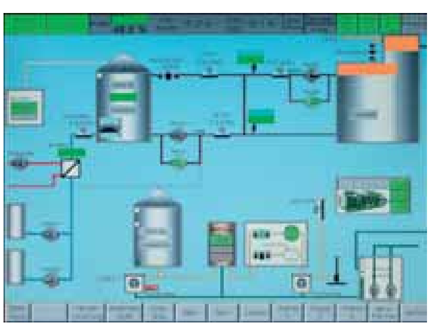
In the follow-up project BIOVISION II a full-blown planning process is now to be carried out for two very promising sites, a dairy in Upper Austria and a brewery in Lower Austria, where demonstration facilities should be implemented.

The dairy has its own biogas plant capable of using inhouse waste materials to generate biogas at relatively low cost and take advantage of the special feed-in tariff for electricity from renewable resources. In 2006 this dairy received the Austrian Energy Globe Award for its pioneering technology to generate biogas from whey; it is continuing the search for ways to improve energy efficiency, i.a. by utilizing fuel cell technology.

In the case of the brewery the effluent from the brewing process is currently piped to the municipal sewage farm close by, where it is digested in two digester towers together with sludge. The biogas produced is burnt in a cogeneration plant. Biogas could be piped to the brewery via a short stub line.

The idea of using process waste from brewing as a feedstock for generating more biogas also looks very promising. Both sites have optimum user profiles, with an excellent constellation of feedstock availability and demand for energy in each case. On both sites electricity can be generated and heat and/or refrigeration used all year round.

As part of BIOVISION II the existing infrastructure and the best way to tie in the heat (or the resulting refrigeration capacity) available from the MCFC are to be investigated in depth technically. Inhouse synergies and special features of the demand for energy over time are to be matched with the MCFC's characteristics, and to be taken into account in the planning process.



Both sites are to be analysed in detail on the basis of the profitability model developed in the first phase of the project. An accurate projection of the costs and yields to be expected (investment and running costs, proceeds from the sale of products, tariff situation) is the starting-point for a comparative evaluation of profitability. Finally, the documents needed for planning permission are to be drawn up.

The demonstration projects are intended to aid in launching stationary fuel cells with a rating of the order of 250 kW_{el} commercially in Austria. The facilities in question should both serve as a model of this new technology and document the methodology employed to to identify suitable sites and to implement energy generation projects.

Biogas Plant, Landfrisch Molkerei, OÖ Photo: Landfrisch Molkerei

P R O J E C T S

MASS-PRODUCING PEM FUEL CELLS

For compact systems, from cars to mobile phones, the proton exchange membrane (PEM) fuel cell, operating at around 80°C, turns out to be particularly efficient. A PEM fuel cell consists of a membrane with electrode/catalyst material, a gas diffusion layer and a bipolar plate on each side of it. PEM fuel cell components are fabricated in various resource-intensive processes. The manufacturers obtain the individual components from various different suppliers, and fabricate the modules in a series of manual production steps. Production costs are thus high – a significant obstacle to this technology becoming widespread.

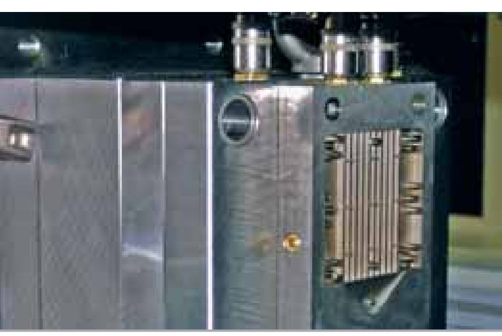
In phase 1 of a project conducted by FOTEC GmbH the feasibility of mass-producing components for PEM fuel cells by means of injection moulding was investigated. The main task was to develop a tooling system capable of producing microstructured mouldings (bipolar plates) and membranes. The central challenge here was to realize variotherm injection moulding – essential for success in component moulding. Developing new, more suitable compounds for the bipolar plates, and producing and processing a new membrane material, were other important tasks.

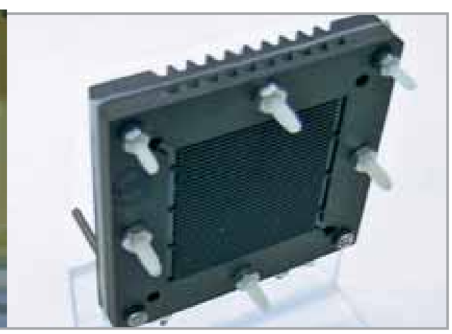
It turned out that the components' properties differed too much for it to be feasible to injection mould all parts of the PEM fuel cells. Bipolar plates, which account for a substantial portion of total production costs if fabricated by conventional methods, were successfully injection moulded in the course of the project. Building on this, the project team developed a process engineering concept for variotherm processing, including machine and process settings; they also achieved the process engineering conditions necessary for fabricating the membranes, and progressed as far as the prototype stage.

Starting from PEEK polymer (a Victrex product), the project partner ECHEM produced the membrane material SPEEK by sulphonation. However, adequately sulphonated SPEEK cannot be injection moulded.

Applying the electrode/catalyst material to the membrane material by compression moulding was successfully demonstrated. A huge technological effort was necessary to to satisfy the requirements on the GDL material as regards conductivity and foam porosity. That is why the carbon paper used for the gas diffusion layer in the past will continue to be used in the short to medium term.

Finally a fully functional PEM fuel cell was assembled from the components developed in the course of the project.





PEM Fuel Cell , Photo: FOTEC

EASYCELL

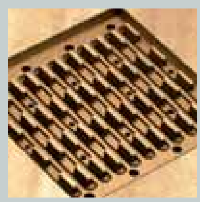
Easycell , Photo: FOTEC

In the follow-up project EASYCELL the design of the PEM fuel cell was improved further. One approach was to replace the three-dimensional structure of the fuel cell by a two-dimensional structure. Development work focused on simplifying material flow management, reducing the amount of ancillary equipment, and possible mass-production methods.

EASYCELL is a completely new development: a fuel cell based on lateral diffusion. The humidifier needed in cells of conventional design can be omitted in the case of lateral diffusion. Humidifying can be done with the reaction water produced in operation, which simplifies material flow considerably. Apart from cost savings, this innovation results in a smaller, lighter fuel cell – highly significant in connexion with mobile applications such as notebooks.

In the course of the project EASYCELL prototype series were produced and their performance was investigated. Injection moulding was used to fabricate the base plate, saving costs. The membrane was fabricated, and the catalyst applied, by means of a specially developed process.

Moulded Plate,Photo: FOTEC



The project team successfully demonstrated that PEM fuel cells can work with lateral diffusion. To date such cells' performance data are inferior to those of conventional cells. The next development tasks will be: improving individual components further, e.g. as regards fabricating the electrode/membrane composite, and modifying the design of the base plate.

PROJECT

MINIATURIZED CERAMIC COMPONENTS FOR HIGH-TEMPERATURE FUEL CELLS

The high-temperature fuel cell SOFC (Solid Oxide Fuel Cell) is an environmentally sound energy system low on emissions; it starts to conduct oxygen ions at temperatures between 800 and 1000°C, and can use both primary (fossil) and secondary (renewable) energy sources to generate heat and electricity. Its low emissions are of particular importance – when hydrogen reacts with air, pure water is produced.

Manufacturing involves a variety of processes, depending on design. In the case of two-dimensional systems tape casting, tape calendering, screen printing and electrostatic processes are employed. Tubular systems are fabricated by means of extrusion, plasma and other spray processes. All these production processes require large quantities of energy and material resources.

In this project (headed by ARC Austrian Research Centers) the basics of an energy-efficient process to mass-produce miniaturized oxide ceramic components for high-temperature fuel cells were to be developed. The goal was to boost resource efficiency considerably by combining new materials and technologies, and to improve the overall system of fabricating multi-layer miniaturized hollow articles.

Project aims:

- Developing nano-scale ceramic SOFC materials to lower processing temperatures
- Developing suitable feedstocks (powder mixed with bonding agent) for co-sintering these materials
- Evaluating resource-economical mass-production processes such as powder injection moulding, extrusion and dip-coating
- Developing an energy-efficient co-sintering process

A successful development: tubular anode supports were assembled into SOFC stacks and achieved, when hydrogen was fed in at 850°C, a power density of 0.36 W/cm^2, which an international comparison shows to be an excellent value.

Co-sintered NiO-YSZ/YSZ und NiO-YSZ/YSZ/LSM tubular anode supports, Photo: ARC Austrian Research Centers GmbH

FIGURES/DATA/FACTS

PROJECT PARTNERS

BIOVISION I & II
Steyr, 2007/2008
Project management:
DI Johann Bergmair
PROFACTOR GmbH
Project partners:
STUDIA Schlierbach
Energy Economics Group - Vienna University of Technology
CFC Solutions GmbH
Landfrisch Molkerei reg.Ges.m.b.H.
Brauunion Österreich AG - Wieselburg

MASSENFERTIGUNG FÜR PEM-BRENNSTOFFZELLEN
(Mass Producing PEM Fuel Cells)
EASYCELL
Wiener Neustadt, 2006
Project management:
DI Friedrich Lehner, Thomas Schlauf
FOTEC Forschungs- und Technologietransfer GmbH
Project partners:
ECHEM-Kompetenzzentrum für angewandte Elektrochemie GmbH
Battenfeld Kunststoffmaschinen GmbH

MINIATURISIERTE KERAMISCHE HOCHTEMPERATUR-BRENNSTOFFZELLEN-KOMPONENTEN
(Miniaturized Ceramic Components for High-Temperature Fuel Cells)
Seibersdorf, 2006
Project management:
Dr. Nils Stelzer
ARC Austrian Research Centers GmbH
Project partners:
ALPPS Fuel Cell Systems GmbH
GABRIEL-CHEMIE Gesellschaft m.b.H.

INFORMATIONS PUBLICATIONS

Final reports on these projects have been published in the bmvit series "Berichte aus Energie- und Umweltforschung"
25/2006, 69/2006, 87/2006

The reports can be ordered via:
www.NachhaltigWirtschaften.at
or from
PROJEKTFABRIK
A-1180 Wien, Währinger Straße 121/3
versand@projektfabrik.at

FORSCHUNGSFORUM on the internet:
www.NachhaltigWirtschaften.at

in German and English

You will find a complete list of the bmvit series ***„Berichte aus Energie- und Umweltforschung"*** with order form on the website:
www.NachhaltigWirtschaften.at

IMPRINT

FORSCHUNGSFORUM provides information on selected projects withtin a bmvit program focusing on "Sustainable Development". Published by the Austrian Ministry for Transport, Innovation and Technology (bmvit), Division for Energy and Environment Technologies; Director: Dipl.Ing. M. Paula; Renngasse 5, A-1010 Wien.
Photos and diagrams: ARC Austrian Research Centers, FOTEC Forschungs- und Technologietransfer GmbH, PROFACTOR GmbH, CFC Solutions.
Editors: Projektfabrik, A-1180 Wien, Währinger Straße 121/3. Layout: Wolfgang Bledl, gdwb@council.net.
Printed by: AV+Astoria Druckzentrum GmbH, A-1030 Wien, Faradaygasse 6.

FORSCHUNGSFORUM is published quarterly; subscriptions (free of charge) are available from:
Projektfabrik, A-1180 Wien, Währinger Straße 121/3, versand@projektfabrik.at

P.b.b. Erscheinungsort Wien,
Verlagspostamt A-1010 Wien.