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FUEL CELLS – ENERGY TECHNOLOGY OF THE FUTURE?

AUSTRIAN STRATEGIES IN THE FIELD OF FUEL CELL RESEARCH AND TECHNOLOGY DEVELOPMENT

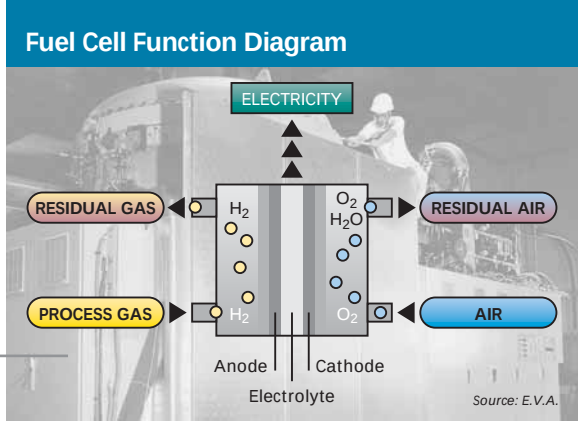
bmvft

Photo: 250 KW_e MCFC installation, MTU Company

T O P I C

RESEARCH, DEVELOPMENT, AND MARKETING IN THE FIELD OF FUEL CELLS

Austrian Activities for Stationary and Mobile Applications



Schematic Drawing of a Fuel Cel

The principle of operation in a fuel cell can be compared with an inversion of the electrolysis of water. While electrolysis uses electrical energy to split up water into hydrogen and oxygen, the fuel cell combines H2 and O2 to water and simultaneously generates electrical and thermal energy.

■ With a view to the objectives of a sustainable development and the improvement of Austria's economic position, fuel cell technology constitutes one of the most important topics for the future. For the medium term, experts have predicted a considerable market potential for this innovative technology on an international scale. Research, development, and innovation in this area may contribute to decisive progress in solving problems in energy management, transportation, and the development of small electric appliances. International efforts towards research and development, activities of major companies on a global scale, and public funds for stimulation programs reflect the expectations associated with this technology.

Sustainable concepts of energy supply concentrate on environmentally sound systems and on an efficient utilization of fuels. Fuel cells constitute the basis for extremely efficient and environmentally friendly energy technologies; they are characterized by a low level of pollutant emissions and high electrical and thermal efficiencies. In conventional combined heat and power systems (e.g. systems using a gas turbine) the chemical energy contained in the fuel ("enthalpy") is first converted into thermal energy by combustion; a second process is needed to convert this thermal energy into electric energy. The ***fuel cell***, in contrast, converts the enthalpy contained in the fuel directly into electric and thermal energy.

Fuel cell systems are being developed both, for stationary applications (miniature block-type thermal power stations, conventional block-type thermal power stations, combined plants using fuel cells and gas turbines) as well as for mobile applications in the automotive industry. There are, however, several technological and economic barriers to an introduction on the market. There is further need for research, especially with a view to an increased service life and the problem of decreasing efficiency during use. At present, there are only a few suppliers, and the investment costs, so far, are too high compared with conventional systems.

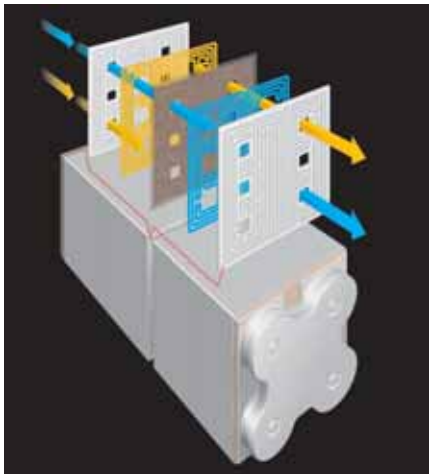
In order to support research and development in Austria and to create opportunities for projects conducted by industrial and public enterprises and institutions, it is necessary to provide for networking of national fuel cell activities and for a targeted transfer of know-how. The Austrian Federal Ministry for Transport, Innovation and Technology (bmvit) commissioned two studies that document the state of fuel cell development for stationary systems and small appliances as well as for mobile applications:

1 Forschung und Technologische Entwicklung (FTE) von Brennstoffzellen für stationäre Energiesysteme und tragbare Kleingeräte - Strategiepapier *(Research and Technological Development in the Field of Fuel Cells for Stationary Energy Systems and Portable Small Appliances – Strategy Paper)*
Author: Dr. Günter Simader, Energieverwertungsagentur, Vienna

This report presents comprehensive information on the state of development of the technology and is to serve as a basis for decision makers in industry and politics with the goal to reposition the topic of fuel cells in Austrian research. The paper analyzes, in addition to the state of development of the technology, possible applications, as well as R&D activities necessary for an introduction on the market. The report documents international fuel cell programs and the research situation in Austria; it also presents recommendations for future strategies and activities.

2 Österreichisches Strategiepapier: Brennstoffzellenforschung, -entwicklung und -vermarktung in der mobilen Anwendung (Austrian Strategy Paper: Fuel Cell Research, Development, and Marketing for Mobile Applications)
Author: Ing. Herbert Wancura et. al, INTEMA Consult GmbH, Graz

This report documents the two phases of the research project. Phase 1 surveyed and presented the state of international technology; the second part of the report involved actors from industry, research and competence centers as well as university institutes and focused on an analysis and evaluation of the strong and the weak points of fuel cell technology in Austria. The authors presented their results to a panel of international experts who commented on and supplemented the outcome within the scope of a workshop.



Courtesy of Ballard Power Systems

PROJECT 1

FUEL CELL R&D FOR STATIONARY ENERGY SYSTEMS AND PORTABLE SMALL APPLICATIONS

Ballard's Mark 902Fuel Cell Stack, Courtesy of Ballard Power Systems

Fuel cell systems should operate using conventional fuels. At present, stationary plants use predominantly fossil energy sources. Most of the systems developed so far use natural gas as an energy source. In recent years, R&D activities have also concentrated on the extraction of hydrogen from different types of renewable sources of energy. Development shows different trends: Medium term development concentrates on gaseous biogenous sources of energy, while the focus of long term development is on solid / liquid biomass and the generation of electrolysis hydrogen from wind, waterpower, and solar energy. In Austria, the University of Technology, Vienna, and PROFACTOR Company are major contributors in the field of R&D of "Biogas Fuel Cell Systems" (especially with a view to gas processing and gas purification).

APPLICATIONS FOR STATIONARY SYSTEMS

On account of their technical characteristics the main applications for fuel cells consist predominantly in block-type combined heating and power systems. Companies working in this field are currently developing the **following applications** for use in stationary energy systems:

- **Fuel cell heaters** (and micro / miniature block-type thermal power installations) for single and multiple dwellings and for the industry and trades sector (such as small hotels), mostly using natural gas as energy source, power range up to 5 kW.

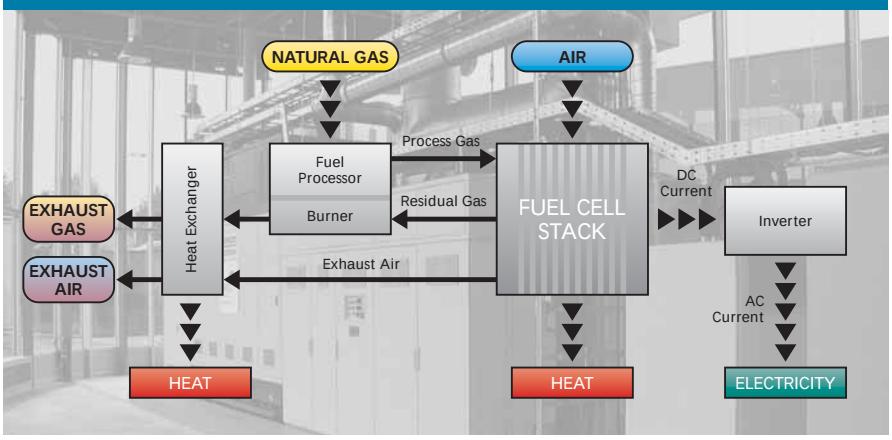
- **Block-type thermal power stations** in the 200 kW_{el} power range for public, industrial, and trade applications (such as hospitals, telecommunication centers, larger hotels), also using natural gas as source of energy. R&D activities in this field increasingly concentrate on biogas as energy source.

- **Combined installations** with fuel cells and gas turbines (for industrial applications and utility companies), also using natural gas as energy source. At present, these installations are in the 1 MW_{el} power range; however, concepts currently under development aim at power ratings of up to 70 MW_{el}.

Fuel cell systems show some decisive advantages compared with conventional energy systems. There are, however, some technological and economic barriers preventing a commercially viable introduction on the market, so far. Strong points include a high electrical and thermal efficiency, favorable partial load characteristics, extremely low pollutant emissions, prolonged opera-

Source: E.V.A.

Schematic Drawing of a Fuel Cell System

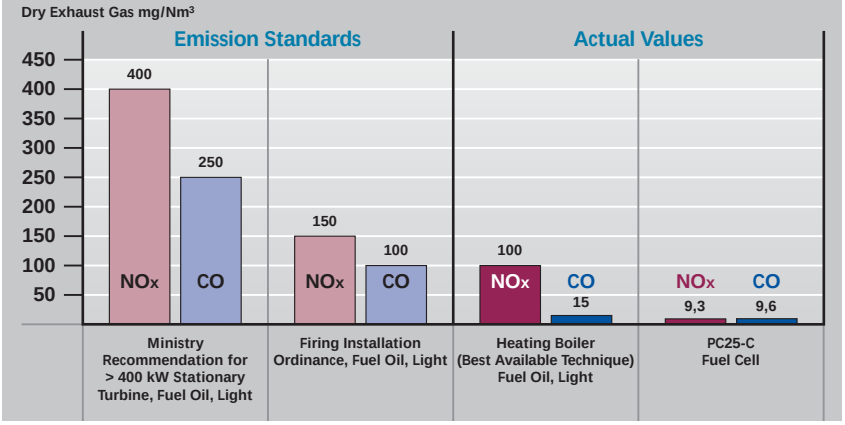


First, the natural gas is purified in a fuel processor. The desulphurizer removes possible sulphur constituents. Then, the reformer converts the hydrocarbons contained in the natural gas into a hydrogen rich process gas. This process gas is subsequently conveyed to the anode of the fuel cell stack. As much of the heat released in this reaction as possible is used for other applications. The direct current generated in the fuel cell is transformed by an inverter into alternating current with the desired frequency and voltage. The residual hydrogen from the fuel cell is conducted to a reform burner, which, in turn, delivers the energy necessary for the reforming process. The thermal energy contained in the waste gas from the process and the exhaust air from the cell stack is also utilized by means of a heat exchanger. The overall efficiency of the installation ranges between 80 and 90%.

tion during abnormal incidences, and low sound emissions. Weak points include uncertainties concerning the actual service life, decreasing efficiency during use, and high investment costs. However, the companies engaged in research and development expect these weak points to be eliminated in the course of the next few years as a result of targeted R&D activities.

The environmental friendliness of fuel cell technology can be shown using the ***example of emission characteristics*** of phosphoric acid fuel cells (PC25-C) as compared to relevant legal regulations concerning combined heat and power plants and heating boiler installations (Ministry for Economic Affairs Recommendation for Stationary Turbines, Ordinance on Firing Installations (FAV) and a "best available technique" oil boiler.

Fuel Cell Emission Characteristics



Source: BMWA, IWO-Austria

STATE OF DEVELOPMENT AND NEED FOR RESEARCH

The types of fuel cell developed so far can be categorized according to the process temperature (80 – 220°C and 600 – 1,000°C, respectively) as well as according to the electrolyte used. Low temperature fuel cells include the alkaline fuel cell (AFC), the polymer electrolyte fuel cell (PEFC), the phosphoric acid fuel cell (PAFC), and the direct methanol fuel cell (DMFC). High temperature fuel cells include the molten carbonate fuel cell (MCFC) and the solid oxide fuel cell (SOFC).

With the exception of PAFC block-type thermal power stations, fuel cell systems have not yet been developed beyond the status of pilot installations. The number of enterprises conducting research and development in the field of fuel cells has, however, clearly increased during recent years. Austrian utility companies (Energie AG, TIWAG, STEWEAG/ESTAG, AFG), too, are increasingly committed to this field of research. The utility companies' R&D activities focus on fuel cell heaters and combined installations.

The main **objectives** currently include the following issues:

- Reducing the cost of materials, components and the overall system
- Optimizing the individual components
- Improving availability
- Realizing demonstration projects
- Improving the fuel stack's service life to 40,000 hours

R&D activities for fuel cells aim to reach the benchmarks of conventional systems currently available on the market. If researchers succeed in achieving this goal, the new technology could bring about decisive advantages for the Austrian power and heating market. Important steps in the future will consist in establishing and integrating Austrian top level research in international activities (IEA or EU programs), furthering applied research with a view to an economically viable implementation in new or existing enterprises (in particular Austrian SMEs), and in stepping up efforts in fundamental research by making more intense use of existing tools for the promotion of R&D in Austria such as the FWF, FFF, etc.

FUEL CELLS FOR PORTABLE SMALL APPLIANCES

In recent years, there has been a marked trend to use portable electronic small appliances with integrated energy supply. Notebooks, laptop computers, cellular and cordless telephones, video cameras, camcorder, etc. use batteries or accumulators as a source of energy. In this field, there is a rapidly growing need for energy supply systems offering maximum independence of the stationary power grid. Alternative energy technologies that make optimal use of the available space (high energy/power density), do not impair handiness, and provide for long operation will achieve large market shares in the future.

Fuel cells that have been tested for such applications include the PEFC, DMFC, and AFC, the PEFC having attained the highest state of development. The fuel used in these small appliances is pure hydrogen. Consequently, research concentrates on the storage of hydrogen.

Estimates of the market perspectives of fuel cells for the use in portable appliances have been very positive. However, the structure of the market for such small appliances is quite different from that for stationary energy supply systems or for vehicles. Small appliances have a relatively short life cycle, which means that the introduction of new energy supply systems on the market would be possible within a relatively short time. Should consumers demand, for instance, longer running times for these appliances, they would probably be prepared to purchase systems with a more expensive, high-performance energy supply.

2 FUEL CELLS FOR MOBILE APPLICATIONS

State of Development, Activities, and Strategies for Mobile Applications

■ A study commissioned by the bmvit, Division for Mobility and Transportation Technologies, analyzed the strong and the weak points of fuel cell technology for mobile applications, and worked out future strategies for Austria.

All types of fuel cell used today may be used for mobile applications. The alkaline fuel cell is already being used in passenger cars and in riverboats; it is also suited for utility vehicles. A prototype of the SOFC is currently being tested in the field of auxiliary power (i.e. as additional energy source in vehicles); the MCFC could be used for locomotive and ship drive units. The polymer electrolyte membrane fuel cell (PEMFC) is particularly promising for automotive applications. On account of large-scale investments by the industry worldwide and considerable state grants, this type of fuel cell currently constitutes the most advanced technology.

Problems in fuel cell technology for mobile applications remain especially **in the following fields**:

■ The costs/kW are still too high compared with conventional internal combustion engines.

■ The issue of energy source has not yet been solved. The PEM low temperature fuel cell, for instance, is not capable of internal reformation. Therefore, it must either be operated with hydrogen, which would entail problems with energy storage or it must be fitted with fuel reformers, which would reduce efficiency and impair response and start-up time.

■ Components for the balance-of-plant are still lacking, i.e. conventional mechanical and electric components (humidifiers, compressors, capacitors,

SOFC-Fuel Cell, Research Center Jülich, FRG

electric drive units, etc.) have to be developed and specially adapted for application in fuel cells.

■ Other tasks refer to the development of cost-efficient membranes for high process temperatures, manufacturing technologies for membrane-electrode assemblies, and double-pole plates.

While some open questions remain, experts predict very good chances and a promising market potential for fuel cell technology. In recent years, research and development have made considerable progress, for instance, with a view to power density and efficiency.

The A3 technology program (Austrian Advanced Automotive Technology) was initiated by the bmvit and aims to improve the competitiveness of suppliers for the automotive industry by actively supporting cooperation in research and development in the automotive sector. One of the calls for proposals within this program addresses the topic of "New Drive Systems". This first call was to support papers dealing with the development of fuel cells for automotive applications. Results from the evaluation of the submitted papers and the ensuing research projects supported by the Ministry are available at: www.bmvit.gv.at/tech/a3.htm

Another important market segment calling for further advancement of fuel cell technology relates to auxiliary power units (APUs) for passenger and utility vehicles. Considering the growing power demand by an increasing number of on-board electric consumers and the resulting shift to 36/42 V on-board power supply offers the opportunity to use APUs as an energy source that operates independently of the engine. These systems may offer the customer improved user comfort (e.g. engine-off air-conditioning etc.), which could yield higher revenues for manufacturers.

An analysis of fuel cell activities in Austria shows that the strong points lie in the fields of electric drive units, production, reformation, and storage of fuels as well as in fuel cells with circulating fluid electrolytes. In addition, Austria's industry has shown great competence in the fields of materials sciences, measuring and testing technique, machine parts, and in manufacturing engineering and processing of polymers. These fields of competence may yield decisive contributions to research and development of fuel cell technology; consequently, the study also proposes adequate strategies and measures (see below).

RECOMMENDATIONS FOR FUTURE STRATEGIES

In order to further develop fuel cell technology, both, for stationary and mobile applications, it will be necessary to intensify the transfer of know-how and to create networks and new co-operative projects.

Departing from the strong and weak points of Austrian fuel cell R&D **for mobile applications, the study defined the following focal points for future strategies:**

- Taking advantage of Austria's excellent position in mechanical engineering through the development of suitable balance-of-plant components and adequate production technologies
- Further improving the strong position in the field of electromotive drive units
- Establishing "Centers of Excellence" concentrating on PEM technology, fuel cells with circulating electrolytes, and solid oxide fuel cells
- Research in the field of auxiliary power units (APUs)
- Development of novel vehicle architectures and concepts using the fuel cell as energy converter

These activities are to be supported by the establishment of a national thematic network and by the creation of a "Fuel Cell Leasing / Rental Pool" for research purposes.

In order to realize the **objectives defined for stationary applications,** the study recommends networking of R&D activities in Austria and a close cooperation between scientific research and the industry. The means proposed to realize this goal consists in the **formation of a cluster** including as many Austrian actors as possible. The cluster could offer and promote the following services:

- **Joint and individual projects:** Arranging partnerships, initiating (national and international) projects, supporting implementation, counseling on funding and grants
- **Location of enterprises:** Finding interested companies, creating appropriate site conditions
- **Information and communication:** Specialists' conferences, working groups, Internet platform, PR activities, specialist publications, flyers, etc.
- **Improving qualification:** Workshops, round tables, visiting enterprises active in this field
- **International activities:** Information trips by CEOs, joint stands at special fairs, international contacts to fuel cell initiatives

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Sulzer Hexis: Installation by "Energie AG"

FIGURES / DATA / FACTS

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"FTE von Brennstoffzellen für stationäre Energiesysteme und tragbare Kleingeräte – Strategiepapier"
Author: Dr. Günter Simader, Energieverwertungsagentur, Vienna
(on commission of the bmvit and supported by the Division Energy and Environment Technologies, DI Theodor Zillner)

"Österreichisches Strategiepapier: Brennstoffzellenforschung, -entwicklung und -vermarktung in der mobilen Anwendung"
Author: Dr. Herbert Wancura et. al., INTEMA Consult GmbH, Graz
(on commission by the bmvit and supported by the Subdivision for Transportation Technology, Logistics, and Environment, Dr. Andreas Dorda)

INFORMATION PUBLICATIONS

The summary of the strategy paper on mobile applications is available at: www.bmvit.gv.at/tech/a3.htm

The report on stationary energy systems has been published in the BMVIT series "Reports on Energy and Environment Research", 2/2002 and is available from:

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