

# **Contributions to Training and Education Made by Institutional Research**

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This document appeared in

Detlef Stolten, Thomas Grube (Eds.):

18th World Hydrogen Energy Conference 2010 - WHEC 2010

Parallel Sessions Book 5: Strategic Analyses / Safety Issues / Existing and Emerging Markets

Proceedings of the WHEC, May 16.-21. 2010, Essen

Schriften des Forschungszentrums Jülich / Energy & Environment, Vol. 78-5

Institute of Energy Research - Fuel Cells (IEF-3)

Forschungszentrum Jülich GmbH, Zentralbibliothek, Verlag, 2010

ISBN: 978-3-89336-655-2

## Contributions to Training and Education Made by Institutional Research

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In order to pave the way for the dissemination and success of hydrogen and fuel cell technologies, targeted training and further education is indispensable. This is the reason why this topic is also an important building block in current research, development and demonstration programmes. Today, the topic of hydrogen and fuel cells is already well established in training and education programmes in universities and third-level institutions, as well as in the education sector in general. Forschungszentrum Jülich has been active in this area for a number of years. Three research institutes are involved, each working in the area of their research and development expertise: IEF-1 focuses on materials synthesis and processing, IEF-2 on microstructure and the properties of materials, and IEF-3 on fuel cells. Work devoted to the solid oxide fuel cell (SOFC), high-temperature polymer electrolyte fuel cell (HT-PEFC) and the direct methanol fuel cell (DMFC) is supported by other project groups involved the areas of systems analysis (IEF-STE), project coordination (IEF-PBZ) and joining techniques and assembly (ZAT). A total of 160 people at Forschungszentrum Jülich are involved in the research and development of fuel cell technologies for specific applications. The most important contributions made by research at Jülich to training and further education addressing issues associated with future hydrogen and fuel cell technologies will be presented in the following sections.

### 1 University Education

In line with Jülich's guiding principles, scientists at Jülich are also involved in teaching activities at universities in parallel to their research and development work [1]. Within the framework of this so-called Jülich model, IEF boasts three such joint appointments with North Rhine-Westphalian universities. Prof. Dr.-Ing. Detlef Stolten and Prof. Dr.-Ing. Lorenz Singheiser each hold a chair at RWTH Aachen University. Prof. Dr. rer. nat. Detlev Stöver is head of department at Ruhr University Bochum. Two chairs at Aachen University of Applied Sciences, Division Jülich, are held by Prof. Dipl.-Ing. Ludger Blum and Prof. Dr.-Ing. Ralf Peters. Furthermore, PD Dr. rer. nat. Werner Lehnert lectures at the University of Ulm. Two other teaching positions at Aachen University of Applied Sciences, Division Jülich, are held by Dipl.-Ing, Dipl.-Wirt.Ing. Thomas Grube and Dr. Ir. Willem J. Quadackers.

The spectrum of topics taught ranges from the fundamentals of science and theoretical modelling and simulation methods to detailed technical knowledge and the characterization of technical applications. In total, ten lectures and four seminars are taught each semester, usually in the form of double periods. Lecturers also provide their students with additional material on the subjects taught. This comprehensive documentation containing illustrations, tables, and diagrams, for example, helps to prepare students for the compulsory

examinations. Table 1 provides an overview of the courses taught at universities by members of staff at IEF-3.

**Table 1: University courses taught by members of staff at IEF-3  
(V = lecture; Ü = seminar)**

Name	Topic	Type/hours semester		University
<b>Prof. L. Blum</b>	Brennstoffzellen – Die Zukunft der dezentralen Energieversorgung!?	V/2	WS	Aachen Univ. of Applied Sciences, Division Jülich
	Fuel Cells – The Future for Dispersed Power Supply!?	V/2	SS	
<b>Prof. Dr. R. Peters</b>	Basics and Applications of Chemical Reaction Theory – Simulation of Dynamic Processes in Energy Systems with Matlab/Simulink	V/2 Ü/2	WS	Aachen Univ. of Applied Sciences, Division Jülich
<b>Prof. Dr. L. Singheiser</b>	Werkstoffe der Energietechnik	V/1	WS SS	RWTH Aachen University
	Neue Werkstoffe für energietechnische Anlagen	V/1	WS SS	RWTH Aachen University
<b>Prof. Dr. D. Stöver</b>	Hochtemperatur-Brennstoffzelle – SOFC – Solid Oxide Fuel Cell	V/4	WS	Ruhr University Bochum
<b>Prof. Dr. D. Stolten</b>	Grundlagen und Technik der Brennstoffzellen	V/2 Ü/2	WS	RWTH Aachen University
<b>T. Grube</b>	Basics and Applications of Chemical Reaction Theory – Simulation of Dynamic Processes in Energy Systems with Matlab/Simulink	Ü/2	WS	Aachen Univ. of Applied Sciences, Division Jülich
<b>PD Dr. W. Lehnert</b>	Brennstoffzellen – von den Grundlagen bis zur Anwendung	V/2	SS	University of Ulm
	Elektrochemische Verfahrenstechnik	V/2	WS	
<b>Dr. W.J. Quadackers</b>	Werkstoffe in der Energietechnik	V/3	WS	Aachen Univ. of Applied Sciences, Division Jülich
	Materials in Energy Systems	Ü/3	SS	Aachen Univ. of Applied Sciences, Division Jülich

The number of students participating in the individual courses each semester varies between ten and fifty. The scientists working at the institutes concerned with fuel cell development also play an important role supervising term papers, diploma dissertations and PhD theses. On average, around nine diploma and master dissertations and seven PhD theses are completed every year on topics dealing with fuel cells.

## **2 Conferences and Workshops for Science and Industry**

Modelling experts at Jülich organized the international MUSIC Conference in March 2008, attracting participants from Canada, the United Kingdom and Germany to Forschungszentrum Jülich. MUSIC stands for “Multi-Scale Integrated Fuel Cell Model”. It focuses on the modelling of different types of fuel cells on various scales - from the stack right down to sub-cell components. The favoured tool for this task is the CFD software OpenFOAM, which is also used at Forschungszentrum Jülich. Within the framework of the conference, trainers from Wikki Ltd presented the software, showing participants the tool’s wide-ranging functionality. Compared to the other CFD tool used at Forschungszentrum Jülich - FLUENT - the open-source software OpenFOAM not only offers the user many of the most important features of FLUENT, but it also has good potential to be extensively expanded - a feature that is often essential in the field of fuel cells. Last but not least, OpenFOAM software promises compatibility for applications on supercomputers, which is of particular interest to scientists at Jülich.

For the fourth time, a representative of Forschungszentrum Jülich acted as chairperson of the German Hydrogen Congress when Professor Stolten took the chair for the fourth congress in 2008. The scientific and technical side of the conference was aimed at representatives from politics, industry and science, and included two one-day events with plenum and parallel sessions, company stands and poster presentations. In relation to the fields of energy, technology and industry, the conference took a detailed look at the path and role of hydrogen in the energy economy [2]. The overwhelmingly positive response to the last event and the encouragingly large number of participants confirmed the congress’s function as a scientific, technical and strategic discussion platform.

The coordination of the Lucerne Fuel Cell Forum rotates on an annual basis among well-established European scientists. Professor Stolten was responsible for the 2nd European PEFC Forum in 2003 [3], while Dr. Steinberger-Wilckens took over the chair for the 8th European SOFC Forum in 2008 [4]. The forum targets an international specialist audience and runs over the course of four days. It is accompanied by scientific and technical stands and poster presentations.

In cooperation with representatives from European research institutions, Jülich scientists have been organizing workshops since 2004 with the objective of sharing and discussing the latest findings in SOFC research and development. The topics change from event to event and range from materials science and modelling to cell tests and characterization as well as system components (BoP) and complete systems. In twenty-minute presentations, representatives from industrial organizations and institutional research report on the progress and current status of research and development.

### **3 Summer Schools and Tutorials**

For university students, the Energy Research Area at Forschungszentrum Jülich organizes occasional seminars and summers schools in cooperation with the universities. Depending on the type of cooperation, these events are held at the partner university or at Forschungszentrum Jülich. In autumn 2008, for example, a four-day master-class course was held on “Renewable Energies” at the University of Applied Sciences in Eberswalde. This course focused on climate change and possible measures to reduce climate-gas emissions. Jülich scientists gave presentations on topics such as the role of fuel cells as clean drive alternatives in the transport sector of the future. Two years previously Jülich scientists coordinated the Berlin autumn seminar 2006 on fuels and drives for the future in cooperation with university representatives from TU Berlin. Students and staff of the university in the field of automotive engineering participated in presentations and discussions on hybrid and hydrogen drive systems over the course of five days. The event also involved a technical excursion to the hydrogen filling station operated by the Clean Energy Partnership (CEP).

Jülich SOFC researchers together with representatives from other European research institutions have been organizing annual summer schools since 2004. These schools are usually held over the course of five days and are dedicated to specific R&D topics in the area of solid oxide fuel cells (SOFCs). The presentations and papers given by scientific experts are aimed at PhD students and young scientists. The synergy of presenting subjects in depth in an easy-to-understand manner provides those new to the field with an opportunity to get to grips with the basics of the R&D topic.

From 2001 to 2008, Professor Stolten held the Fuel Cell Tutorial in the run-up to the annual Fuel Cell Forum in Lucerne. As an internationally recognized fuel-cell expert, he introduced young scientists to the fascinating world of fuel cells and taught interested individuals working in scientific and technical fields the expert knowledge they were lacking. The tutorial simultaneously functioned as a specialist introduction to the conference week with papers on current findings from fuel cell research and development. In the relaxed atmosphere of a small working group, all of the questions raised by the participants were answered. Every participant received accompanying documentation for the tutorial including numerous useful illustrations, tables and diagrams. This documentation reflects the broad-based experience that Professor Stolten has in the field of solid oxide and polymer electrolyte fuel cells from the perspective of industry, research and science.

### **4 Work Experience for School Students**

The work experience programme aims to address the requirements and requests of each group of secondary-school students aged between 15 and 18, while simultaneously reflecting the scientific and technical resources of the supervising working group. Work experience lasts between one and two weeks. At the beginning of their work experience, school students are given an introduction to fuel cell technology, a tour of the laboratories and instructions on safety. The members of the group then spend around a day with each working group gaining insights into laboratory work. The tasks assigned to secondary-school students during work experience range from shadowing technical and scientific staff at the institute to supervised

independent work on selected practical projects. The school students learn the specific features of the different types of fuel cells and gain experience in job-related issues that arise when working in a scientific laboratory environment. On average every year, 12 to 15 school students take part in the work experience programme, which runs prior to the Easter and autumn holidays.

## 5 Information Events

The range of events organized in relation to further education and the provision of information is just as diverse as the needs of the groups themselves. In order to adequately meet the demands made on a particular research institute for training and information, a variety of different events are organized by Forschungszentrum Jülich.

### 5.1 Seminars for secondary-school students and teachers

Upon request, Forschungszentrum Jülich organizes introductory seminars for secondary-school students and teachers on the topics of hydrogen and fuel cells in order to provide participants with an intelligible overview. Seminars generally last between one and six school periods. When conducted at Forschungszentrum Jülich, they also include a one-hour laboratory tour. In the past few years, a number of seminars were held both at IEF-3 and in surrounding schools. On average, between 25 and 70 secondary-school students and teachers take advantage of the organized events each year.

Within the framework of the 4th German Hydrogen Congress in 2008, Jülich researchers organized a further education information day on the topic of “hydrogen and fuel cell technology” for secondary-school students, university students and teachers (see Figure 1). The day-long event held in Messe Essen provided the some 150 participants with interesting information on basic scientific and technical concepts as well as application-oriented systems. An overview of training opportunities and job descriptions in the area of “hydrogen and fuel cells” was also presented.



**Figure 1:** The further education information day in Essen, February 2008.

## 5.2 Information events for small and medium enterprises in the region

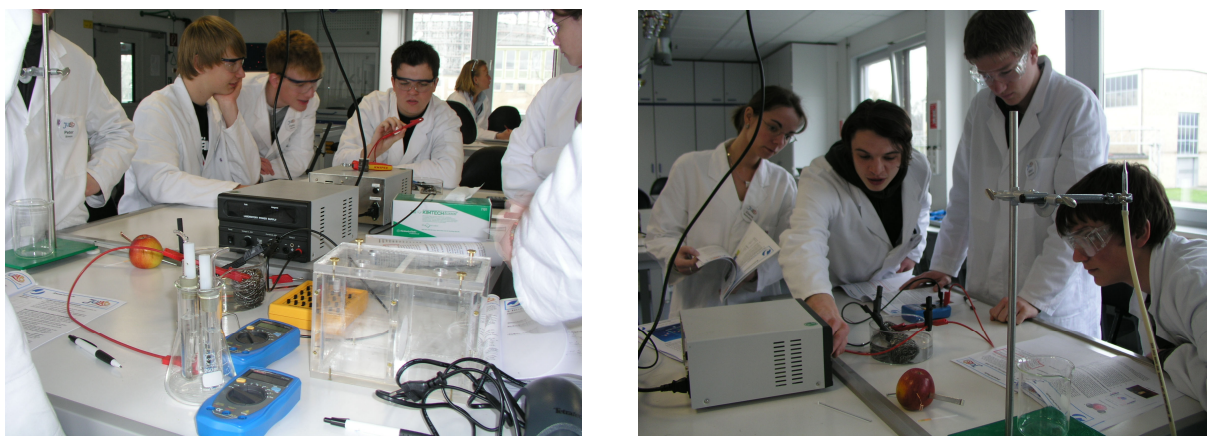
Over the last number of years, requests have often been received from companies in the region for information events on current issues in the field of energy technology. The organization and content of such events is targeted at the needs of the participants. In the past, for example, a number of round-table discussions, workshops and seminars have been held on the topics of hydrogen, fuel cells and electromobility with up to 100 participants.

## 5.3 Information events and visits to the institute for interested members of the general public

In order to promote a positive image of Jülich R&D activities in the public sphere, Forschungszentrum Jülich organizes information events and visits to the various institutes involved in the different R&D areas for interested members of the general public. Within the framework of such events, fuel cell technology has proven itself to be particularly popular. Each year a good 80 events are organized, and in 2008 around 1,400 participants learnt more about fuel cell technology. In general, the visit to IEF-3 is split into two parts: an introductory presentation by a competent young scientist, followed by a guided tour of the laboratory.

## 6 Schools Laboratory

The Jülich Schools Laboratory (JuLab) has set itself the task of introducing students to the world of hydrogen and fuel cells by encouraging them to conduct their own experiments [5]. Experiments have been developed for this purpose, and students perform them in order to find theoretical and practical solutions to technical tasks. Using an incomplete model vehicle with a fuel-cell drive system, school students work on properly completing the vehicle in JuLab, the Vocational Training Centre workshops and the Institute of Energy Research - Fuel Cells (IEF-3). Any components required are fabricated by the students themselves under supervision and tested for application. In performing this work, they gain insights into a variety of different jobs such as that of a scientist, laboratory assistant, mechanic and electronics engineer.



**Figure 2: School students conduct experiments in the Schools Laboratory on the topics of "hydrogen" and "fuel cells".**

Experiments are conducted under supervision in the well-equipped Schools Laboratory (see Figure 2). As students need to be familiar with conducting experiments from chemistry and physics classes, they must be aged 16 or over. The programme usually takes around one week.

## **7 Collaboration with External Organizations**

More and more attention is being devoted to designing, launching and implementing training and further education measures and qualification programmes on the topic of “fuel cell technology” both in the manufacturing industry and the relevant educational establishments. In order to cater for this demand, special initiatives have been launched. The combination of specialist technical knowledge and existing opportunities provide an excellent basis for collaboration. Forschungszentrum Jülich, for example, works very closely with the Fuel Cell Qualification Initiative, which aims to disseminate information on future fuel cell applications in order to pave the way for a smooth market introduction. This objective is accomplished by concrete involvement in development projects in terms of information provision and qualification measures.

Furthermore, Forschungszentrum Jülich collaborates with institutions in the training and further education sector. Jülich experts, in cooperation with the educational organization RAG Bildung and the entrepreneur centre Zukunftszentrum Herten, hold lectures for the Fuel Cell Education and Training Centre Ulm aimed at interested individuals working in the skilled trades, industry, research and education.

Together with the University of Bonn and Northwestern University Chicago, Forschungszentrum Jülich developed a summer school programme on “renewable energy”. The school is due to be held in 2010. In addition to topics from energy policy, the scientific and technical aspects addressed by Forschungszentrum Jülich are also on the agenda of courses for qualified students offered at American universities. Jülich experts are often invited to give guest lectures at participating American universities. Suggestions have been made that the programme should be expanded to include aspects such as work experience and internships.

## **8 Summary**

In order to pave the way for the dissemination and success of hydrogen and fuel cell technologies, targeted training and further education is indispensable. This is the reason why this topic is also an important building block in current research, development and demonstration programmes. Today, the topic of hydrogen and fuel cells is already well established in training and education programmes in universities and third-level institutions, as well as in the education sector in general. Forschungszentrum Jülich has been active in this area for a number of years.

Research scientists at Forschungszentrum Jülich teach and lecture in higher education institutions. One of the results of combining scientific and technical work with teaching activities is that comprehensive training material reflecting the current state of the art is made available. International comparison has shown the excellent position held by Jülich fuel cell

research. As a result, the scientists involved receive numerous invitations to chair and coordinate scientific conferences and tutorials. Furthermore, experts at Jülich are also involved in summer schools and other training and further education measures. Forschungszentrum Jülich offers secondary school students work experience and hands-on project-related experience at the Schools Laboratory. Both of these programmes are well received. Cooperation with external organizations in terms of information events and training and further education as well as the preparation and implementation of qualification projects rounds off activities at Jülich in the area of training and further education over the last few years.

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