

Highlights der Brennstoffzellenentwicklung AFC Annex 31 und Annex 35

Viktor Hacker

Fuel Cell Group, Institut für Chemische Verfahrenstechnik und
Umwelttechnik, NAWI Graz, Technische Universität Graz
Inffeldgasse 25/C, 8010 Graz

IEA Vernetzungstreffen - Aktuelle Entwicklungen, Modul Wien, 29. Oktober 2015

Content

- Introduction to IA AFC
- Members and Meetings Annex 31
- Members and Meetings Annex 35
- Contribution TU Graz to Annex Meetings
- Dissemination

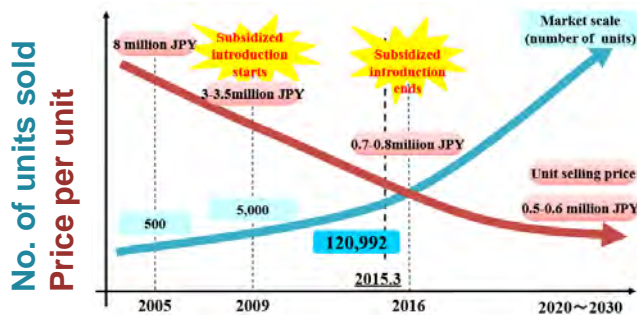
The Advanced Fuel Cells Implementing Agreement



Toyota Mirai \$57,500 (MSRP in CA)



Hyundai ix35 Fuel Cell \$499/month (Free Fuel and Maintenance in CA)



800 000 JPY = approx. 6 000 EUR

The Advanced Fuel Cells Implementing Agreement has eight active Annexes

Technologies

Polymer Electrolyte Fuel Cells

To reduce the cost and improve the performance of PEFCs, DMFCs and corresponding fuel cell systems.

Solid Oxide Fuel Cells

To assist, through international co-operation, the development of SOFC technologies.

Electrolysis

To share information and learning on electrolyser technologies and their applications.

Applications

Fuel Cells for Stationary Applications

To understand better how stationary fuel cell systems may be deployed in energy systems.

Fuel Cells for Transportation

To understand better how fuel cells may be deployed in transportation applications.

Fuel Cells for Portable Applications

To assist, through international co-operation, the development and commercialisation of portable fuel cells.

Systems Analysis

To assist the development of fuel cells through analysis work to enable a better interpretation of the current status, and the future potential, of the technology. This work will provide a competent and factual information base for technical and economic studies.

Modelling of Fuel Cell Systems

To further develop the open source modelling approaches and knowledge base to facilitate the development of fuel cell technology.

<http://www.ieafuelcell.com/links.php>

Advanced Fuel Cells Implementing Agreement Map



Annex 30: Electrolysis

Annex 31: Polymer Electrolyte Fuel Cells

Annex 32: Solid Oxide Fuel Cells

Annex 33: Fuel Cells for Stationary Applications

Annex 34: Fuel Cells for Transportation

Annex 35: Fuel Cells for Portable Applications

Annex 36: Systems Analysis

Annex 37: Modelling of Fuel Cells Systems

<http://www.ieafuelcell.com/links.php>

Annex 31: Polymer Electrolyte Fuel Cells

NAME	COUNTRY	COMPANY
Viktor Hacker	Austria	Graz University of Technology
Shanna Knights	Canada	Ballard
Steven Holdcroft	Canada	Simon Fraser University and NRC Canada
Steen Yde-Anderson	Denmark	IRD Fuel Cell A/S
Hans Aage Hjuler	Denmark	Danish Power Systems
Jari Ihonen	Finland	VTT
Henri Karimäki	Finland	VTT
Thierry Priem	France	Commissariat à l'Energie Atomique (CEA)
Werner Lehnert	Germany	Forschungszentrum Jülich
Carsten Cremers	Germany	ICT Fraunhofer
Alex Schechter	Israel	Ariel University
Alessandra Carbone	Italy	CNR-ITAE
Akimasa Daimaru	Japan	Daido University
Gu-Gon Park	South Korea	Korea Institute of Energy Research
EunAe Cho	South Korea	Korea Advanced Institute of Science and Technology (KAIST)
Ulises Cano	Mexico	Instituto de Investigaciones Eléctricas (IIE)
Göran Lindbergh	Sweden	KTH – Royal Institute of Technology
Rakel Wreland Lindström	Sweden	KTH – Royal Institute of Technology
Lars Petterson	Sweden	KTH – Royal Institute of Technology
Di-Jia Liu	USA	Argonne National Laboratory

- R&D oriented
- Identification and development of techniques and materials
- Cost reduction
- Improve the performance and durability
 - Polymer electrolyte fuel cells (PEFC)
 - Direct fuel polymer electrolyte fuel cells (DF-PEFC)
 - Corresponding fuel cell systems
- Major applications are
 - Automotive
 - Portable power
 - Auxiliary power units (APU)
 - Stationary power (residential, commercial)
 - Combined heat-and-power (CHP) sectors

Contribution Fuel Cell Group TU Graz

- **PEFC**
 - Investigation of degradation phenomena
 - Identification of critical operation parameters
 - Optimisation operation parameter
 - Characterisation methods
- **HT-PEFC**
 - Catalyst research
 - Lifetime improvement
 - Cost reduction
- **DMFC/DEFC**
 - Catalyst research
 - Membrane
- **Catalyst research & MEA development**



Annex 31: Polymer Electrolyte Fuel Cells

Meeting Seoul, Korea

- 13.-14. June 2014
- Contribution TU Graz
 - Advanced Fuel Cell Diagnostics
- Participants from:
 - Austria
 - France
 - Germany
 - Italy
 - Japan
 - Mexico
 - Sweden
 - Switzerland
 - USA
 - Korea
 - Canada and China (guests)



Meeting Pfinztal, Germany

- 6.-7. July 2015
- Contribution TU Graz
 - Development of Fuel Cell Equivalent Circuits taking into Account Non-linear Effects

Participants from:

- Austria
- Denmark
- Germany
- Italy
- Japan
- South Korea
- Mexico
- Sweden
- USA

Annex 35: Fuel Cells for Portable Applications

NAME	COUNTRY	COMPANY
Victor Hacker	Austria	Technische Universität Graz
Christina Bock	Canada	Department of National Defence
Ed Andrukaitis	Canada	NRC
Per Balslev	Denmark	Dantherm Power A/S
Carsten Cremers	Germany	Fraunhofer Institut Chemische Technologien
Alexander Dyck	Germany	NEXT ENERGY
Martin Müller	Germany	Forschungszentrum Jülich GmbH
Fabio Matera	Italy	CNR-ITAE
Akiteru Maruta	Japan	AIST
Sang-Kyung Kim	Korea	KIER
Maria Wesselmark	Sweden	Intertek

- Focus & Application
 - Handheld FC systems
 - Portable FC systems
 - Light traction FC systems (e.g. forklift)
- Objectives
 - Information exchange
 - Starts from **catalyst** research to **MEA** development to **FC stacks** to complete **systems**
 - FC types
 - Low-temperature PEMFC
 - DMFC/DEFC
 - DBFC (only TU Graz)
 - Hydrogen storage systems for portable FC applications

Contribution Fuel Cell Group TU Graz

- **Hydrogen storage system based on Ionic Liquids**
 - Research on storage system and hydrogen release from chemical carrier
 - System with PEMFC
 - DBFC R&D
- **DMFC/DEFC**
 - Catalyst research
 - Membrane
- **Catalyst research & MEA development**



Annex 35: Fuel Cells for Portable Applications

Meeting Messina 2014

- Participants from:
 - AT, DE, IT
- Topics
 - Standardization of FC testing procedures
 - To make results from different labs comparable
 - DMFC research
 - Degradation studies
 - Applications with long stand-still time
 - Portable hydrogen storage
 - Pressurized
 - Metal hydride
 - Ionic liquid storage system

Meeting Oldenburg 2015

- Participants from:
 - AT, DE, IT, KR
- Topics
 - DMFC catalyst development
 - Cheaper and stable catalysts
 - DMFC MEA design and development
 - Overcome degradation
 - Nafion content in membrane and air humidification

DMFC as a backup power system for telecom applications (Martin Müller, FZ Jülich)

MEA Design and operation strategies can help to reach market and customer demands (A. Glüsen, FZ Jülich)

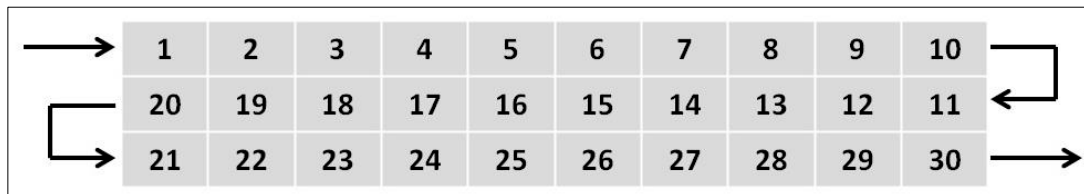
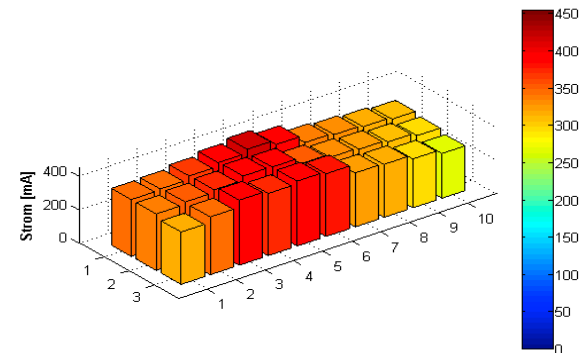
Contribution TU Graz

SecondAct (Annex 31)

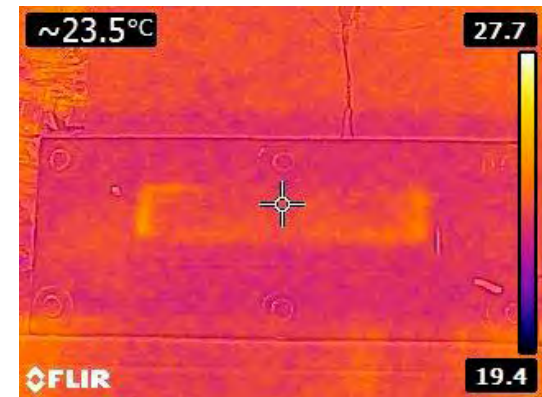
Simulation, Statistics and Experiments Coupled to develop Optimized aNd Durable μ CHP systems using Accelerated Tests

- In-situ characterisation
 - Polarisation measurements (IV)
 - Electrochemical impedance spectroscopy (EIS)
 - Cyclic voltammetry (CV)
 - Hydrogen diffusion measurements

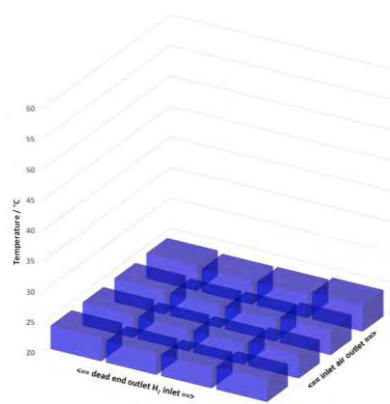
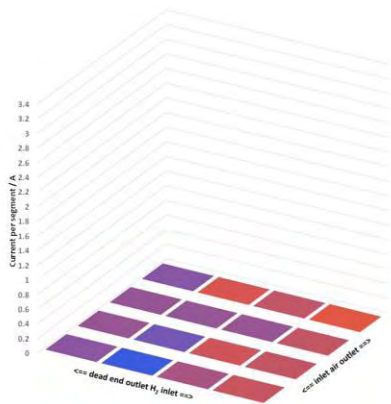
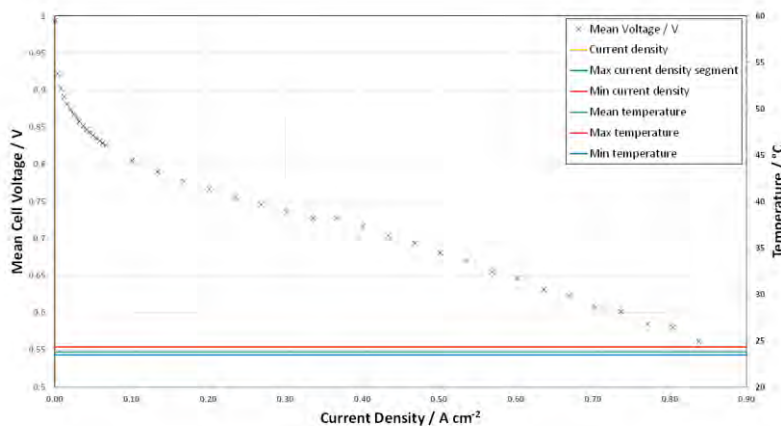
Segmented cell: local defects can be detected via spatial resolution of the current density during characterisation



- Ex-situ characterisation
 - Detection of membrane thinning and pinholes by infrared thermography (destructive method, only EOL)



Advanced 3D fuel cell analysis and condition diagnostics (Annex 31)

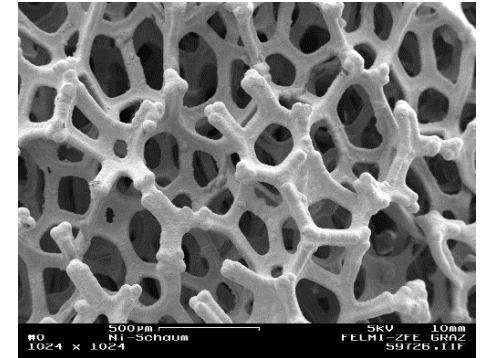


Goals

- 3 dimensional fuel cell stack diagnostics
 - Real time data analysis
 - Optimised efficiency due to higher fuel utilisation
 - Higher lifetime by avoiding critical states
-
- ➔ The theory of harmonic distortions has been put into Equivalent Circuits predicting the received spectra
 - ➔ Optimised frequencies and amplitudes to improve differentiation of critical states
 - ➔ A new hardware has been developed and is capable to measure harmonic distortions (at 4 frequencies at multiple cells)
 - ➔ Current and Temperature distributions have been presented
 - ➔ More efficient control concepts still avoiding critical states are possible
 - ➔ Multipole Equivalent Circuits enabling 3-dimensional analysis with the same number of shunt sensor plates

Hydrogen Storage in Ionic Liquids (Annex 35)

- Storage medium conditions
 - Aqueous solutions
- Hydrogen release
 - $\text{IL-BH}_4 + 4\text{H}_2\text{O} \rightarrow \text{IL-B(OH)}_4 + 4\text{H}_2$
 - Catalytic
 - Heterogeneous metal catalysts
- Characterization
 - SEM, EDX
 - Benchmark tests of H_2 release
- Properties
 - Pressureless at ambient temperatures
 - No hydrogen release without catalyst
 - Simple handling



Dissemination

Dissemination - Publication

Vorträge

- Friedrich, T.; Grimmer, C.; Hacker, V.:
CEET research Activities on Portable FC Applications. - in: IEA AFC Implementing Agreement Annex 35 Meeting. Oldenburg am: 16.09.2015
- Friedrich, T.; Grimmer, C.; Hacker, V.:
CEET Research Activities on Portable Applications - Borohydride H₂ Storage System. - in: IEA AFC Annex 27 Meeting. Messina am: 11.09.2014
- Hacker, V.; Weinberger, S.; Bodner, M.:
Advanced Fuel Cell Diagnostics. - in: IEA AFC, Annex 22 Meeting. Seoul am: 13.06.2014
- Hacker, V.:
Development of Fuel Cell Equivalent Circuits taking into account Nonlinear Effects. - in: IEA AFC Annex 31 meeting. Pfanztal am: 06.07.2015

Journals

- Grimmer, C.; Grandi, M.; Zacharias, R.; Cermenek, B.; Weber, H.; Morais, C.; Napporn, T. W.; Weinberger, S.; Schenk, A.; Hacker, V.:
The electrooxidation of borohydride: a mechanistic study on palladium (Pd/C) applying RRDE, ¹¹B-NMR and FTIR. - in: Applied catalysis / B 180 (2016) , S. 614 - 621
- Grimmer, C.; Nestl, S.; Senn, J.; Hacker, V.:
Selective real-time quantification of hydrogen within mixtures of gases via an electrochemical method. - in: International journal of hydrogen energy 40 (2015) 4 , S. 2055 - 2061
- Schenk, A.; Grimmer, C.; Perchthaler, M.; Weinberger, S.; Pichler, B. E.; Heinzl, C.; Scheu, C.; Mautner, F.-A.; Bitschnau, B.; Hacker, V.:
Platinum-Cobalt Catalysts for the Oxygen Reduction Reaction in High Temperature Proton Exchange Membrane Fuel Cells – Long Term Behavior Under Ex-situ and In-situ Conditions. - in: Journal of power sources 266 (2014) , S. 313 - 322

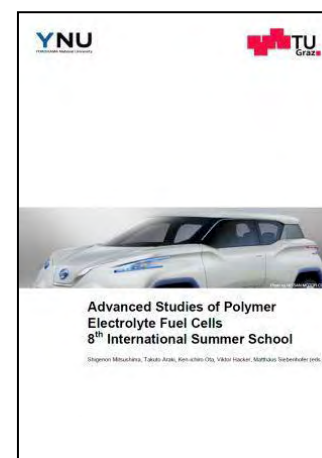
Abstracts / Poster

- Cermenek, B.; Zacharias, R.; Grandi, M.; Grimmer, C.; Schenk, A.; Hacker, V.:
Palladium based electrocatalysts for ethanol oxidation reaction in alkaline medium. - in: 8th International Summer School on Advanced Studies of Polymer Electrolyte Fuel Cells. Yokohama am: 02.09.2015
- Kaltenböck, I.; Schenk, A.; Grimmer, C.; Pichler, B. E.; Hacker, V.:
Active and stable oxygen reduction catalysts for the high temperature Polymer electrolyte fuel cell. - in: 8th International Summer School on Advanced Studies of Polymer Electrolyte Fuel Cells. Yokohama am: 30.08.2015
- Grandi, M.; Grimmer, C.; Zacharias, R.; Senn, J.; Hacker, V.:
Synthesis and Characterisation of carbon supported bimetallic platinum-gold-nanoparticles for borohydride direct oxidation. - in: 8th International Summer School on Advanced Studies of Polymer Electrolyte Fuel Cells. Yokohama am: 30.08.2015
- Senn, J.; Grimmer, C.; Nestl, S.; Hacker, V.:
Real-time quantification method for Hydrogen . - in: 8th International Summer School on Advanced Studies of Polymer Electrolyte Fuel Cells. Yokohama am: 30.08.2015
- Zacharias, R.; Grimmer, C.; Grandi, M.; Senn, J.; Hacker, V.:
Hydrolysis in direct borohydride fuel cells -. - in: 8th International Summer School on Advanced Studies of Polymer Electrolyte Fuel Cells. Yokohama am: 30.08.2015
- Grimmer, C.; Zacharias, R.; Grandi, M.; Hacker, V.:
The benefits of a mixed electrolyte approach for direct borohydride fuel cells-. - in: 8th International Summer School on Advanced Studies of Polymer Electrolyte Fuel Cells. Yokohama am: 30.08.2015
- Malli, K.; Nestl, S.; Voitic, G.; Hacker, V.:
The influence of two different synthesis routes on the performance of alumina supported iron oxygen carrier for the steam iron process . - in: 8th International Summer School on Advanced Studies of Polymer Electrolyte Fuel Cells. Yokohama am: 30.08.2015

Dissemination – Summer Academy

Eine „International Summer School“ zum Thema Brennstoffzellen wird in Kooperation mit der Yokohama National University jährlich geplant und alternierend in Yokohama, Japan und Graz, Österreich durchgeführt.

- 8th FC Summer School 2015**
 Yokohama National University, Japan
 August 31st - September 5th, 2015
- 9th FC Summer School 2016**
 Graz University of Technology
 August 29th – September 3rd, 2015



www.tugraz.at/fcsummerschool

Dissemination – Internet

- TU Graz CEET
www.tugraz.at/institute/ceet/forschung/brennstoffzellenentwicklung/
- IEA AFC
www.ieafuelcell.com/
- BMVIT: Nachhaltig Wirtschaften
www.nachhaltigwirtschaften.at/iea/results.html/id3378
- A3PS
<http://www.a3ps.at/site/de/links-0>

TU Graz CEET

www.tugraz.at/institute/ceet/forschung/brennstoffzellenentwicklung

Institut für Chemische Verf... x +

www.tugraz.at/institute/ceet/forschung/brennstoffzellenentwicklung/

Suchen

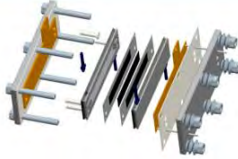
erstrecken sich von mobilen Anwendungen in Fahrzeugen über die dezentrale Stromerzeugung bis hin zu portablen Geräten. Die Forschungs- und Entwicklungsarbeiten am Institut für Chemische Verfahrenstechnik und Umwelttechnik konzentrieren sich auf die Verbesserung der Leistungsfähigkeit und der Lebensdauer der Brennstoffzellen. Untersucht werden Brennstoffzellen im Dauerbetrieb, unter realen Betriebsbedingungen und unter stark schädigenden Betriebsbedingungen (Accelerated Stressing Test AST).

Die in-situ Analyse der Schädigungsmechanismen von Polymerelektrolytmembran-Brennstoffzellen (PEFC) erfolgt anhand von Stromdichte-Spannungskennlinien, Zyklovoltammetrie, elektro-chemischer Impedanzspektroskopie, Wasserstoffdiffusionsmessungen, Gasanalyse und über die Fluoridionenfreisetzung der Membran mittels der Analyse der Elektrodenkondensate. Die Potentialverteilung in der Zelle wird mit Hilfe von Referenz-elektroden bestimmt. Zur Untersuchung der Stromdichteverteilung im realen Betrieb werden segmentierte Testzellen eingesetzt. Extreme Betriebspunkte wie die Unterversorgung mit Wasserstoff oder der Froststart bei bis zu -20°C werden untersucht.

Gaskonditionierung für Brennstoffzellen

Niedertemperatur-Brennstoffzellen nutzen zum Großteil Wasserstoff als Brennstoff. Die kommerziellen Verfahren zur Wasserstoffherstellung und Feinreinigung, wie sie zum Beispiel in Erdölraffinerien zum Einsatz kommen, sind für den kleineren Leistungsbereich nicht anwendbar. Es bedarf daher auf dem Gebiet der Brennstoffkonditionierung innovativer Technologien, um die Bedürfnisse dieser neuen Energiesysteme zu erfüllen.

Ein Forschungsschwerpunkt liegt dabei in der Entwicklung des Reformer Sponge Iron Cycle (RESC), welcher als Festbett-Versuchsreaktor im Labor betrieben wird. Ein weiteres Arbeitsgebiet des Moduls bildet die Mikro-Verfahrenstechnik zur Reformierung von flüssigen Kohlenwasserstoffen in Mikro-Strukturapparaten für den Einsatz in mobilen Brennstoffzellensystemen. Den wesentlichen Vorteil dieser Technologie bildet der optimierte



Assoc.Prof. Viktor Hacker
Inffeldgasse 25 C
8010 Graz
viktor.hacker@tugraz.at

**FORSCHUNGS-
BERICHTE**

DuraPEM - Stabilisierte aktive Platin-Übergangsmetallkatalysatoren für die Sauerstoffreduktion in Hochtemperatur-PEM-Brennstoffzellen



ePolycat - Pt-freie Katalysatorsysteme und ethanolbeständige Polysaccharid-Membranen für die alkalische DEFC

Flex-Fuel Reformer for Fuel Cell Systems

INFORMATIONSPLATTFORMEN

IEA Advanced Fuel Cells

Nachhaltig Wirtschaften

© 2015 TUGRAZ

Impressum

DE 17:27
27.10.2015

IEA AFC www.ieafuelcell.com

Home - IEA Advanced Fuel Cells x +

www.ieafuelcell.com

Suchen

Members Area Login

Username

[Website cookies policy](#)

[Get help logging in](#)

HOME FUEL CELLS ANNEXES PUBLICATIONS NEWSLETTERS MEETINGS JOIN CONTACT LINKS

Advanced Fuel Cells
Implementing Agreement

Implementing Agreement for a Programme of Research, Development and Demonstration on Advanced Fuel Cells

Welcome to the website of the Implementing Agreement for a Programme of Research, Development and Demonstration on Advanced Fuel Cells (Advanced Fuel Cells Implementing Agreement, AFCIA).

The Implementing Agreement for a Programme of Research, Development and Demonstration on Advanced Fuel Cells began in 1990, and currently has 13 member countries: Austria, Denmark, Finland, France, Germany, Israel, Italy, Japan, Korea, Mexico, Sweden, Switzerland, and USA. Our aim is to advance the state of understanding of all members in the field of advanced fuel cells.

The focus of our work is the eight active Annexes (groups): members of which meet regularly to share technology and policy developments in their countries, companies and research institutions, for the benefit of everyone involved:

- Fuel Cells for Transportation
- Fuel Cells for Stationary Applications
- Fuel Cells for Portable Applications
- Polymer Electrolyte Fuel Cells
- Solid Oxide Fuel Cells
- Systems Analysis
- Modelling of Fuel Cell Systems
- Electrolysis

The Advanced Fuel Cells Implementing Agreement is overseen by the Executive Committee, who meet twice a year to oversee the Agreement, to share the results generated within the

Advanced Fuel Cells
Implementing Agreement
Map

The map provides details of members and institutions that contribute to the Implementing Agreement for Advanced Fuel Cells.

[View the map >](#)

Latest Publications

17:32
27.10.2015

BMVIT: Nachhaltig Wirtschaften

www.nachhaltigwirtschaften.at/iea/results.html/id3378

IEA Implementing Agreement: ... x +

www.nachhaltigwirtschaften.at/iea/results.html/id3378

IEA FORSCHUNGS KOOPERATION

SITEMAP NEWSLETTER KONTAKT Suchen ...

Ein Service des **bm**

Implementing Agreement: Fortschrittliche Brennstoffzellen (AFC)

Das Hauptziel dieses Implementing Agreements ist die forcierte Technologieentwicklung von Schlüsselkomponenten und -systemen von Brennstoffzellen. Analysen des Marktumfelds und die Unterstützung bei der Marktimplementierung durch die Entwicklung der hierfür erforderlichen politischen Rahmenbedingungen und Instrumente bzw. dem Abbau existierender Implementierungsbarrieren stellen ebenfalls wesentliche Projektziele dar.

Title and Synopsis

Implementing Agreement: Advanced Fuel Cells (AFC)

The aim of the IEA Advanced Fuel Cells programme is to enhance the state of technology of key components and -systems of fuel cells. Furthermore, the activities of this implementing agreement should contribute to the market implementation of fuel cells by a better understanding of the necessary market frame work and instruments and by removing of existing market barriers.

Beschreibung

Auf nationaler bzw. internationaler Ebene sollen Analysen/Berichte/-Medieninformationen erarbeitet werden und der IEA, nationalen/internationalen Entscheidungsträgern, umsetzungsorientierten Unternehmen/Institutionen bzw. der breiten Öffentlichkeit (inkl. Medien) zur Verfügung gestellt werden.

Geplanten Aktivitäten

- Das Durchführen und Monitoring von F&E Aktivitäten (inkl. der Analyse der Kosten für Zellen, Stacks und Systeme)
- System und Marktanalysen (inkl. technologischer, ökonomischer und ökologischer Aspekte)
- Analyse von Markt- bzw. Umsetzungsbarrieren
- Verstärkte Disseminations- und Verbreitungsaktivitäten (inkl. Newsletter, Annual Reports, Workshops, spezifische Reports zu aktuellen Themen, etc.)

Struktur

Das Programm strukturiert sich in drei technologisch-typenorientierte Annexe, in drei applikations-orientierte Annexe und einem Annex in dem systemanalytische Arbeiten durchgeführt werden. Diese sind:

- Annex 30: Electrolysis

Inhaltsverzeichnis

- ↓ Title and Synopsis
- ↓ Beschreibung
- ↓ Teilnehmende Staaten
- ↓ Status
- ↓ Publikationen
- ↓ Kontaktadresse

Kontext Links

- Website des IEA Advanced Fuel Cells (AFC) Programme
- Annex 31: Polymerelektrolytmembran-Brennstoffzellen
- Annex 33: Stationäre Applikationen
- Annex 35: Brennstoffzellen für portable Anwendungen

ZIELE & INHALTE

AUSSCHREIBUNGEN

VERANSTALTUNGEN

TECHNOLOGIE-INITIATIVEN

PUBLIKATIONEN

ÜBER DIE IEA

PROGRAMME

- Stadt der Zukunft
- Haus der Zukunft
- Energiesysteme der Zukunft
- IEA Forschungs-kooperation

STRATEGIE

- Strategieprozess Energie 2050

NACHHALTIGwirtschaften

17:35 27.10.2015

A3PS <http://www.a3ps.at/site/de/links-0>

The screenshot shows a web browser window displaying the A3PS website. The browser's address bar shows the URL www.a3ps.at/site/de/links-0. The website header features the A3PS logo and the tagline "Rethinking Propulsion". Below the header, there is a navigation menu on the left with items: Home, About, A3PS Conferences, Documents, News, Downloads, Links (highlighted in red), Contact, Login, and Events. A search bar with a "Suche" button is located below the menu. To the right of the menu, there are sections for "Internationale Plattformen:" and "Partnerinstitutionen:". The "Internationale Plattformen:" section lists links to the German Federal Ministry of Transport, International Partnership for Hydrogen and Fuel Cells in the Economy, and IEA - Advanced Fuel Cells Implementing Agreement (AFC). The "Partnerinstitutionen:" section lists links to FFG, KLIEN, and Umweltbundesamt. At the bottom of the page, there is a footer with links for HOME, IMPRESSUM, and KONTAKT. The Windows taskbar at the bottom of the screenshot shows the time as 17:31 on 27.10.2015.

Dissemination – Workshop TU Graz

2nd International Workshop on Hydrogen and Fuel Cells

Die Veranstaltung wird in Kooperation mit der Yokohama National University und in enger Abstimmung mit BMVIT und FFG geplant und durchgeführt.

TU Graz, 31. August 2016



Vielen Dank!

IEA Vernetzungstreffen - Aktuelle Entwicklungen, Modul Wien, 29. Oktober 2015