Austrian Energy Agency

Das Implementing Agreement on „Advanced Fuel Cells (AFC)“

Dr. Günter R. Simader (AEA)
Univ.-Doz. Dr. Viktor Hacker (CD Labor, TU Graz)

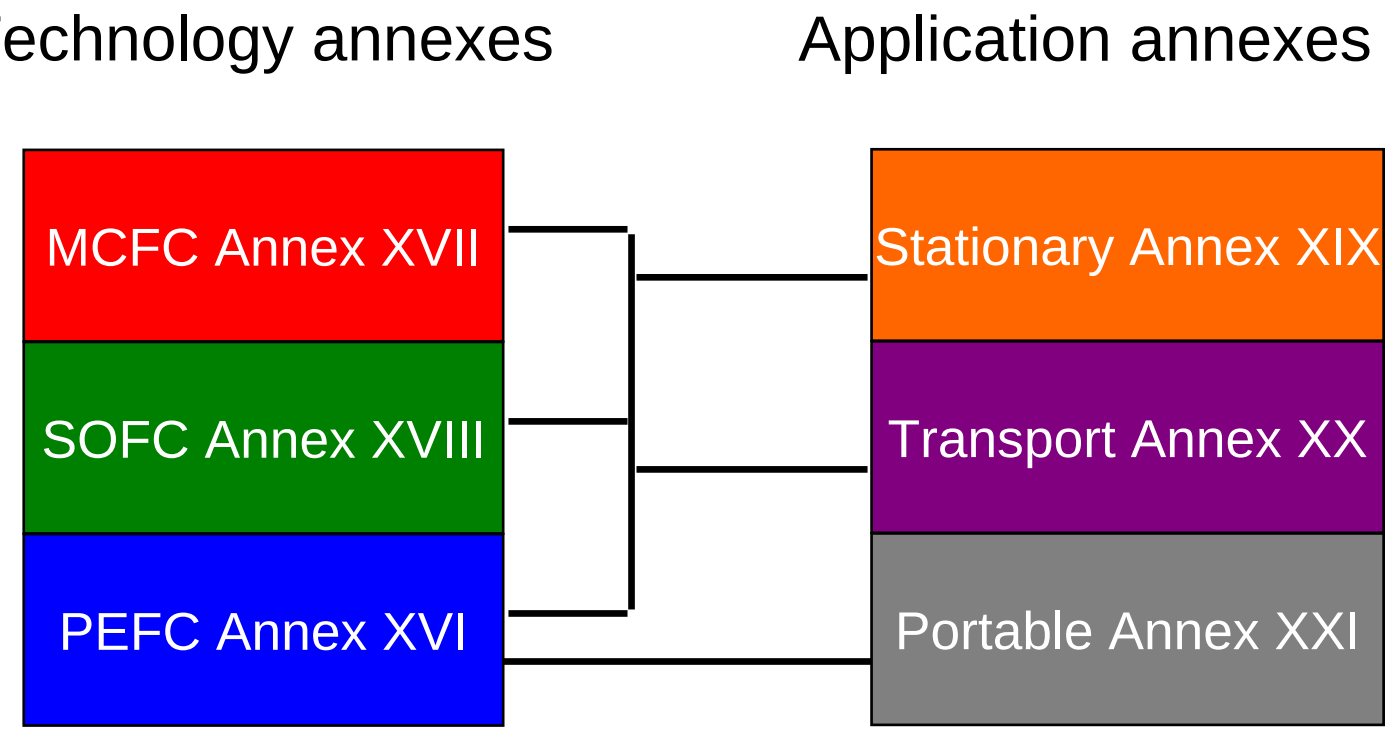
Inhalt

- Ziele, Inhalte und Arbeitsprogramm
- FTE Prioritäten bis zum Jahr 2008
- Die österreichischen Aktivitäten im IA AFC
- Schwerpunkte des Task XIX: Stationäre Applikationen (AEA)
- Schwerpunkte des Task XVI: PEFC (CD Labor)
- Schwerpunkte des Task XXI: Portable Applikationen (CD Labor)
- Zusammenfassung, Ausblick

Ziele, Inhalte, teilnehmende Länder

- Weiterentwicklung von fortgeschrittenen Brennstoffzellen-Systemen bis hin zur Markteinführung
- “Task shared” FTE Aktivitäten inklusive regelmäßigem Informationsaustausch
- Inhaltlich werden sowohl die verschiedenen BZ-Technologien als auch deren Anwendungen bearbeitet
- Laufende Arbeitsperiode: 2004 - 2008
- 17 teilnehmende Länder:
  - AT, AU, BE, CA, DE, DK, FI, FR, IT, JP, KR, NI, SE, CH, UK, US, TR, MX (pending)

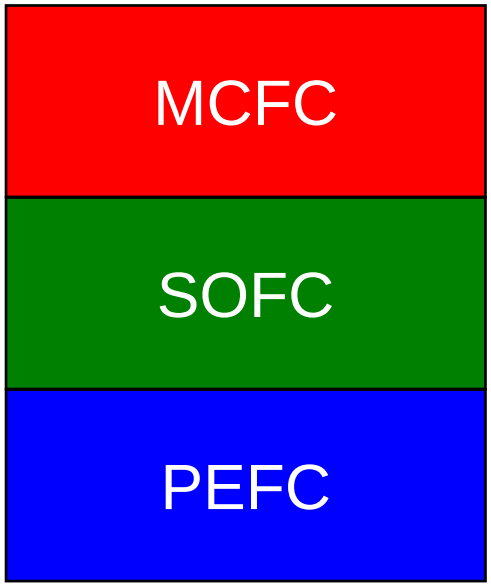
Struktur der Annexe



History - Tasks

	1996		1998		2000		2002		2004		2006		2008
MCFC	Annex VI				Annex XIV				**Annex XVII**				
SOFC	Annex VII			Annex XIII					**Annex XVIII**				
PEFC	Annex VIII			Annex XI					**Annex XVI**				
Stationary	Annex IX			Annex XII					**Annex XIX**				
Transportation		Annex X				Annex XV			**Annex XX**				
Portable									**Annex XXI (new)**				

FTE Prioritäten (2004 – 2008) - I



R&D activities

- Materials development (all)
- Component development (all)
- Stack & reformer testing (PEFC)
- Biomass fuelling (MCFC)

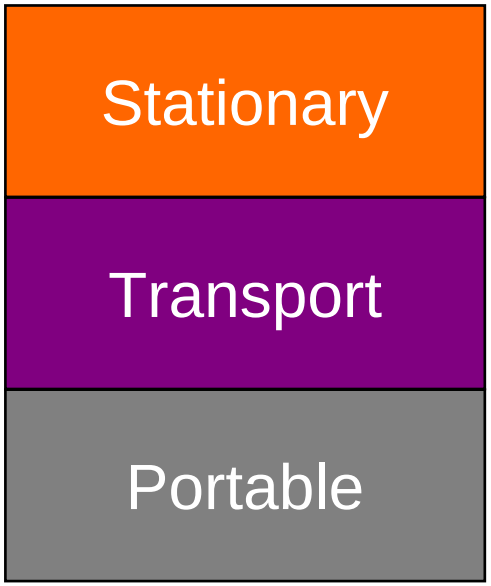
Demonstration activities

- Exchange of experience (MCFC. SOFC)

Supporting activities

- Raising industry awareness (PEFC)

FTE Prioritäten (2004 – 2008) - II



Demonstration activities

- Exchange of demonstration experience
- System studies

Commercialisation activities

- Market studies
- Well-to-wheel studies

Supporting activities

- Support to codes & standards authorities

+ ad-hoc workshops on materials, modelling, fuels for fuel cells and material costs and availability.

Österreichische Teilnahme

- seit Herbst 2004
- ExCo Vertretung: Österreichische Energieagentur und CD-Labor Brennstoffzellen
- Taskvertretungen:
  - Annex XIX - Stationary applications: Energie AG, österreichische Energieagentur
  - Annex XVI - PEFC: CD Labor für Brennstoffzellen
  - Annex XXI - Portable Power: CD Labor für Brennstoffzellen
- Einbindung von ö. Akteuren:
  - Direkt durch die Partner des CD Labors: AVL, OMV
    Mitarbeit der Energie AG am Annex XIX
  - Weitere Einbindung: Generell Plattform für interessierte Firmen/Institutionen;
    Bestmögliche Einbindung von öst. Akteuren in Form von Präsentationen (bei Annex-Meetings) bzw. in Form von Country Pictures (bei den Annex und ExCo Meetings im In- und Ausland)
- Österreichische Website:
  http://www.energyagency.at/projekte/iea_afc07-09.htm

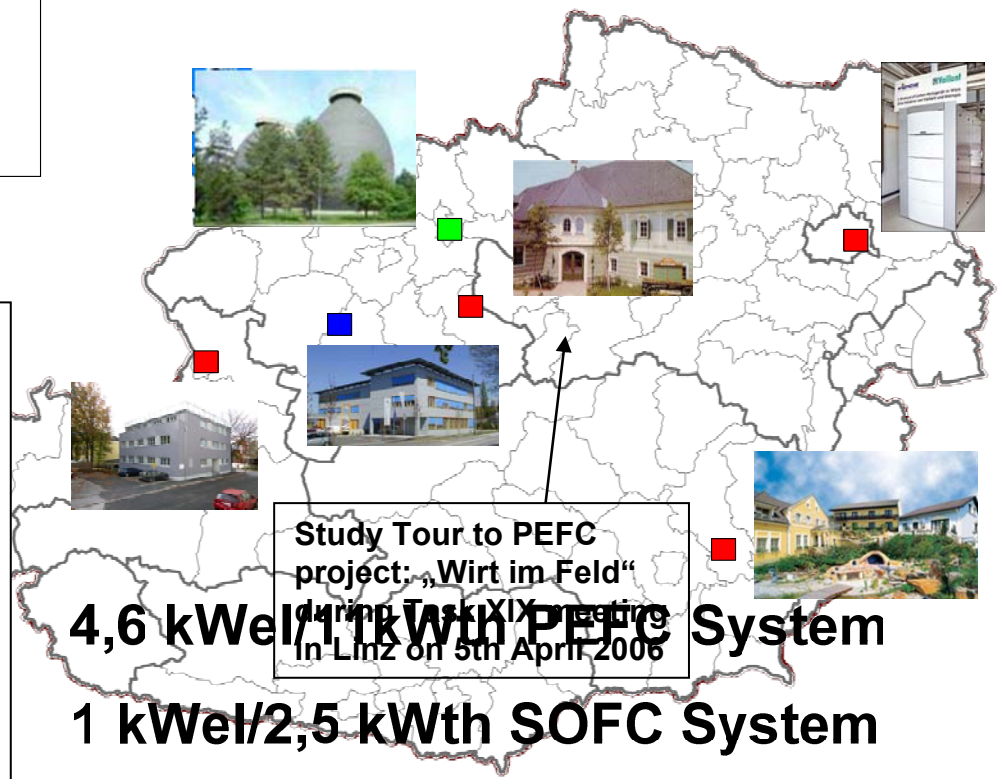
Zielsetzungen der österreichischen Beteiligung am AFC

- Integration österreichischer Spitzenforschung in internationale FTE Arbeitsschwerpunkte
- Transfer von internationalem Know-how nach (und in) Österreich
- Forcierung und Mobilisierung der österreichischen angewandten und Grundlagen FTE (durch gewonnenes IEA Know-how)
- Generell die Stärkung der Wettbewerbsfähigkeit und Internationalisierung der österreichischen Wirtschaft durch gesteigerte FTE-Leistungen.

Task XIX: Stationäre Brennstoffzellen – Aktivitäten

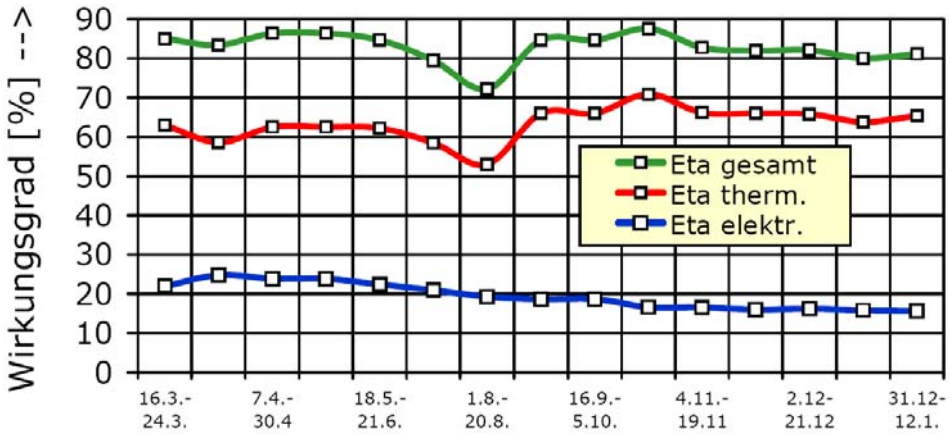
- Subtask 1: Market outlook
  (Subtask leader: Thoma & Renz, Switzerland)
- Subtask 2: The effect of a large number of fuel cells connected to the power grid
  (Subtask leader: NEDO, Japan)
- Subtask 3: Fuels for stationary fuel cells
  (Subtask leader: MTU-CFC, Germany)
- Subtask 4: Balance of plant for stationary fuel cells
  (Subtask leader: VTT, Finland)
- Subtask 5: Market and technology status for stationary fuel cells
  (Subtask leaders: EPRI, USA and Sydkraft, Sweden)
- End of Term Report: Per Ende 2008

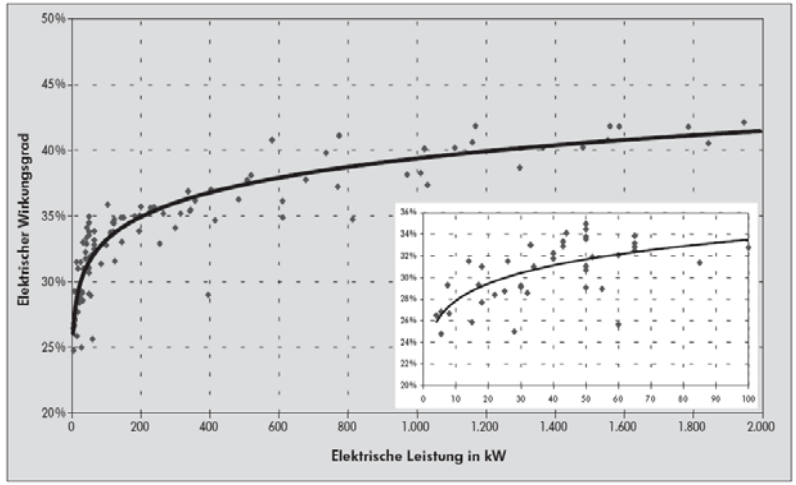
Highlights of the Austrian stationary residential fuel cell demonstration projects



- Market implementation – necessary challenges/-improvements:
  - Decrease investment-, O&M costs and generally complexity of system
  - Improvement of life time, reliability and efficiencies (decrease own consumption of electricity)
  - optimisation of controlling software and of conventional systems (incl. hydraulic connection)

Blitzlicht: Elektrische Wirkungsgrade vgl. mit Erdgas Systemen





- Quelle: H. Wilk, et.al., „50 Monate Betriebserfahrung der ARGE-Brennstoffzelle mit SOFC- und PEFC-Brennstoffzellen-Heizgeräte“ http://www.energyagency.at/projekte/iea_afc07-09.htm
- Quelle: ASUE, BHKW Kenndaten 2005

Experience: *hotmodule*® - Fuel Cells around the World

Fuel Cell Energy / USA

Coast Guard – CHP, barracks
Sheraton (2) – CHP, hotels
Ocean County College – CHP, university
Yale University – CHP, university
Zoot Enterprises (2) – reliability for critical load
Harrisburg Coal Mine – power from coal mine emissions
DFC/T (2) – Vision 21 combined cycle
Mercedes – power for general load
LADWP – power for office headquarters
LADWP – CHP, WWT
Grand Valley State University – CHP, university
Navy – land-based marine diesel application
AMP-Ohio – utility-scale grid support at substation
CAT Tech Centre – grid-connected, training for engineers & dealers

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MTU / Europa

University of Bielefeld – CHP, university
Rhoen-Clinic – CHP, hospital
RWE – CHP, energy park
IZAR – power, heavy industry
Deutsche Telecom – DC backup, telecom
Michelin, EnBW – electricity/steam, tire production
University Magdeburg – CHP, medical clinic
Pfalzwerke/Gruenstadt – CHP, medical clinic
Central-Clinic Bad Berka – CHP, hospital
Vattenval Europe, Bewag –2004 CHP, bi-fuel
FN Krefeld – 2004 CHP district heating
Ahlen – 2005 CHP, sewage gas
St. Ingbert – 2005, CHP, industrial
Leonberg – 2006, Biogas, municipal

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Marubeni / Japan

Kirin Brewery – CHP, industrial WWT
City of Fukuoka – CHP, municipal WWT
Nippon Metal – CHP, natural gas

3

mtu onsite energy

Demonstration of Residential PEFC Systems for Market Creation

Toshiba FCP

Sanyo

Ebara Ballard

Panasonic

Toyota

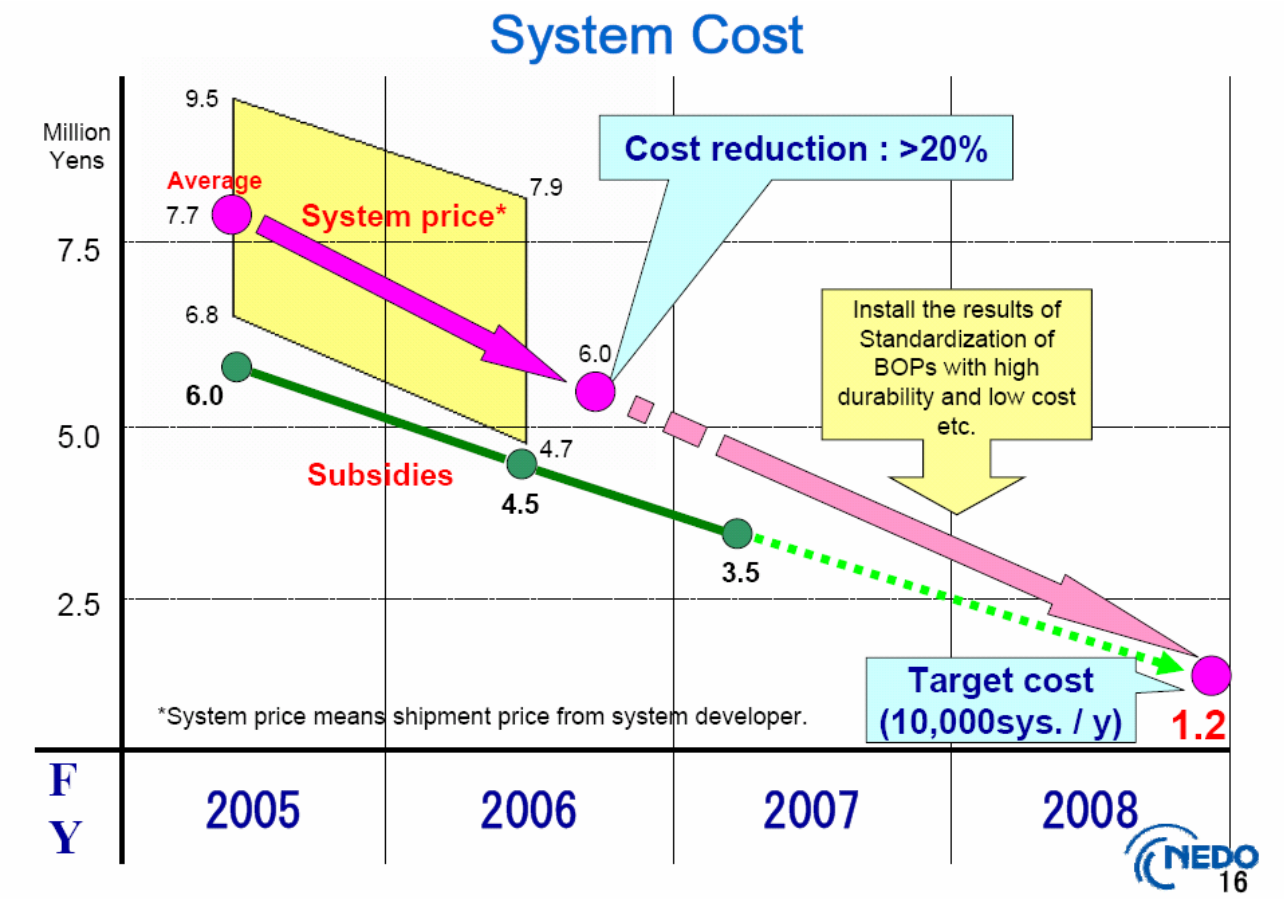
System Supplier

Supplier	Installed Number
Sanyo	445
Toshiba FCP	341
Ebara Ballard	285
Panasonic	162
Toyota	24
Total	1257

Fuel Class

Fuel	Installed Number
LPG	644
Town Gas	538
Kerosene	75
Total	1257

Problem: Hohe Systemkosten – erforderliche Degression für erfolgreiche Markteinführung in Japan



Quelle: NEDO

Summary: NEDO Programm

1. 1257 sites valuable field data is accumulated.
   [1257 sites = 480 sites (FY2005) + 777 sites (FY2006)]

2. Total power generation time : 2,904,853 hr
   Total power generation amount : 1,650,635 kWh
   [At the end of Dec. 2006]

3. Primary energy reduction rate : 15.3 % (26.7 % @ top pair site)
   CO_2 reduction rate : 28.0 % (40.5 % @ top pair site)
   [FY2005 1st term 175 sites average : Oct. 2005 - Sep. 2006]

4. Good Energy-saving effect and environmental friendliness of residential PEFC systems were shown.

5. Based on various field data, the improvement of the performance and reliability, etc. is advancing in parallel with cost reduction.

Annex XVI: Polymer Electrolyte Fuel Cells (OA - Argonne National Laboratory, U.S.A.)

- **Participants**
  - Austria
  - Belgium
  - Canada
  - Denmark
  - Finland
  - France
  - Germany
  - Italy
  - Japan
  - Korea
  - Mexico
  - Netherlands
  - Norway
  - Sweden
  - Turkey
  - United Kingdom
  - United States

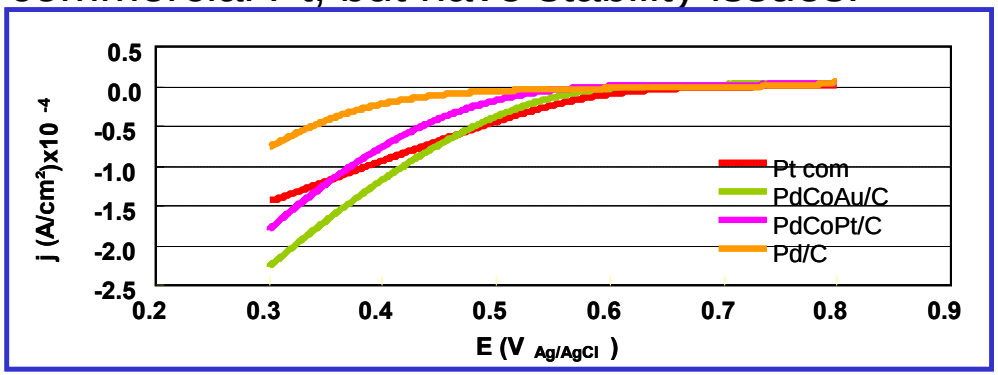
Recent Technical Highlights
Subtask 1: New Stack Materials

Italy, ENEA:

Developing electrodeposition technique for fabricating high utilization Pt/carbon powder and Pt/carbon nanotube electrocatalysts

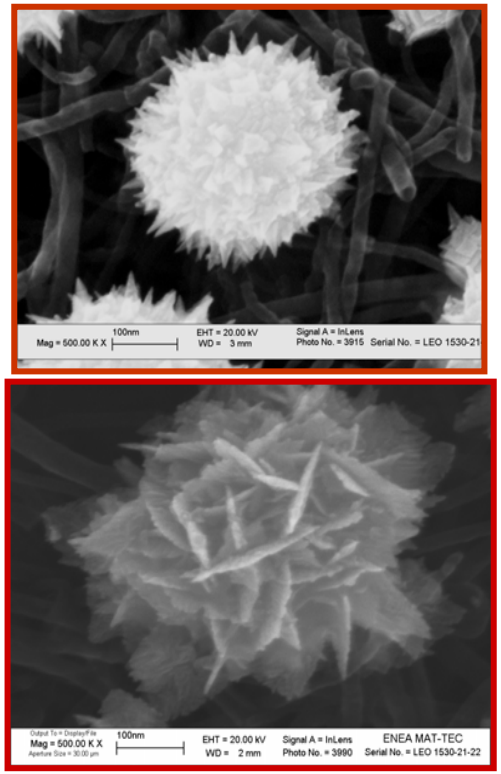
United Kingdom, Newcastle University:

Developing palladium alloy catalysts for the oxygen reduction reaction. Found PdCoAu/C and PdCoPt/C (7:2:3) have acceptable activity compared with commercial Pt, but have stability issues.



Oxygen reduction activity of Pd alloy electrocatalysts compared with commercial Pt

G. Fernández Álvarez, Newcastle U., United Kingdom



Pt nanoparticles formed by electrodeposition under various deposition conditions

A. Cemmi, ENEA, Italy

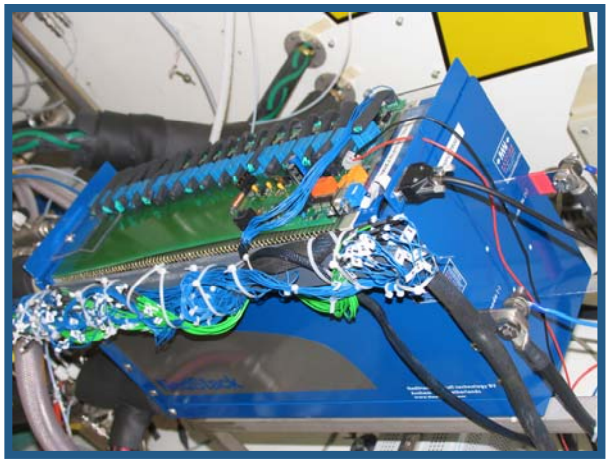
Recent Technical Highlights
Subtask 2: System and Balance-of-Plant

Austria, TUGraz:

Studying the degradation of PEMFCs under hydrogen starvation conditions using reference electrodes and off-gas analysis. High cathode potentials (>1.1 V) reached during purge of anode cause carbon corrosion.

Belgium, VITO:

Completed ammonia-PEMFC project (ACCEPT), further developed stack voltage-current monitoring system, and testing several PEMFC stacks



Stack fitted with VITO's Cell Voltage Monitoring System

P. Coenen, VITO, Belgium

Single cell test apparatus fitted with four reference electrodes

W. Baumgartner, TUGraz, Austria

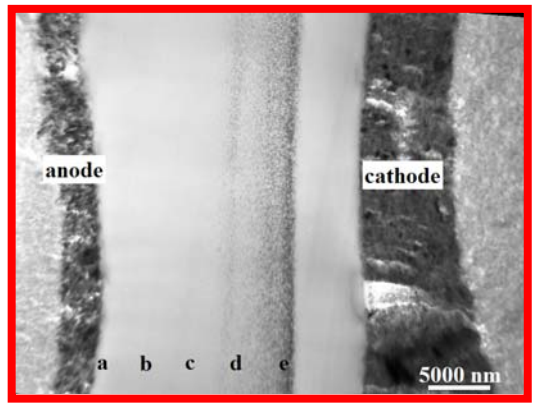
Recent Technical Highlights
Subtask 2: System and Balance-of-Plant

Denmark, IRD:

Determined that the performance degradation of reformate-fueled cells is due to membrane pinholes, PTFE erosion of the cathode GDLs, catalyst particle growth, and Pt/Ru migration from the anode

Finland, VTT:

Developed fuel cell stacks, stack components, and auxiliary devices for stationary CHP (0.5 to 2 kW), back-up power, and industrial specialty vehicles.



Cross-section of aged MEA (2,000 hrs) showing catalyst component deposition in membrane

S. Yde-Andersen, IRD, Denmark

1.4 kW PEM Power Pack

T. Keränen, VTT, Finland

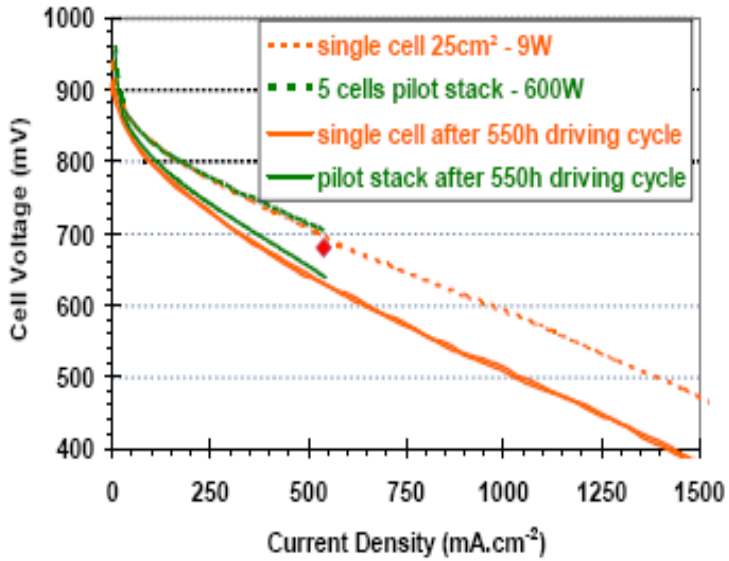
Recent Technical Highlights
Subtask 2: System and Balance-of-Plant

France, CEA:

Developing an 80 kW_e system for transportation applications and determining durability (30,000 hrs). Developing electron microscopy techniques to understand the link between micro and nanostructure and MEA performance

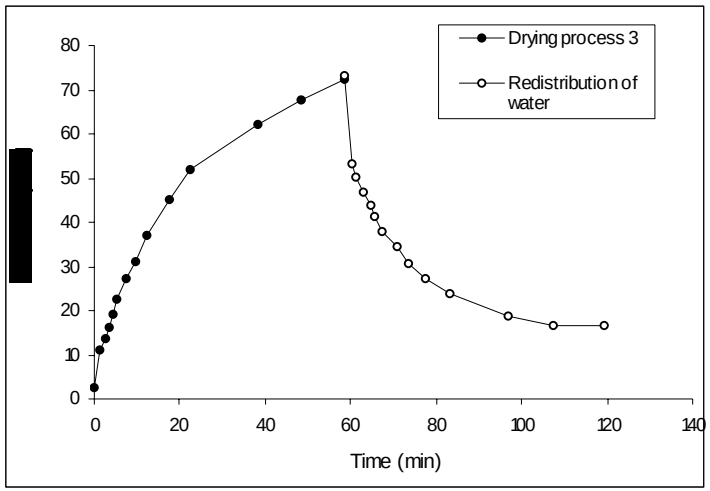
Mexico, Electricity Research Institute:

Studying water transport in MEAs and developing a stack simulator



Initial performance of individual cells in 9 W and 600 W stacks and performance after 550h driving cycle

N. Bardi, CEA, France



Water uptake of an MEA with time upon changing relative humidity conditions

R. Flores, Electricity Research Institute, Mexico

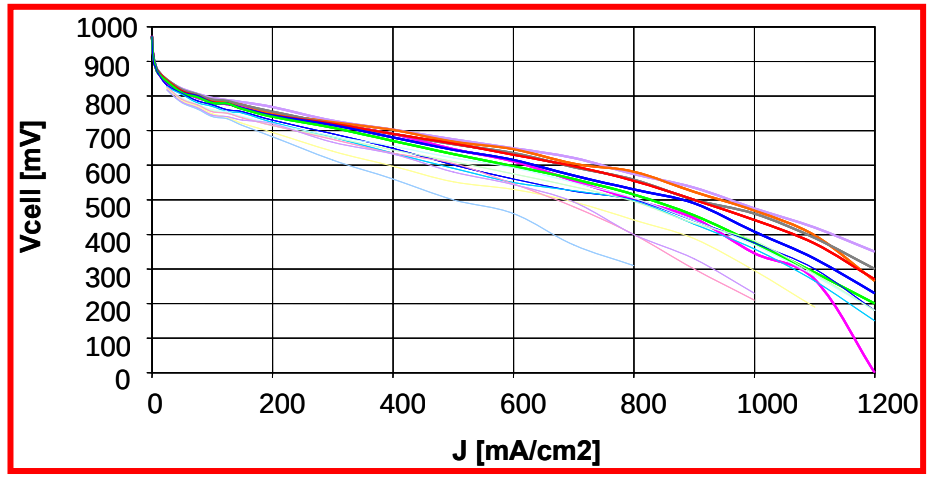
Recent Technical Highlights
Subtask 2: System and Balance-of-Plant

Netherlands, ECN:

Studying the causes of performance degradation with freeze/thaw and cool down/start-up cycling. Freeze/thaw cycling increases ohmic and mass transport resistances.

Turkey, TÜBİTAK MRC:

Integrating systems and developing components for PEFCs



Loss of MEA performance with 52 freeze/thaw cycles

R. Makkus, ECN, Netherlands

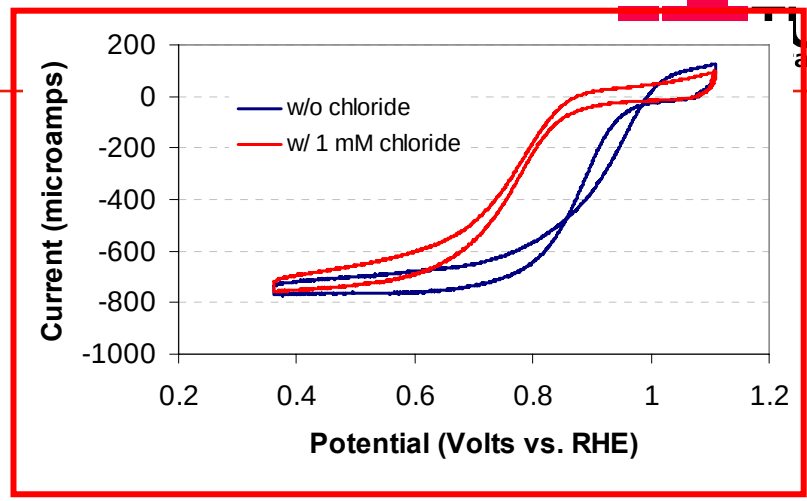
Bipolar plates with various flow field patterns

İ. BİCAN, Tübitak Marmara Research Center, Turkey

Recent Technical Highlights
Subtask 2: System and Balance-of-Plant

United States, ANL:

Determined the effect of air impurities on the performance of MEA components. Chloride poisons the oxygen reduction reaction on Pt_3Co, methylene chloride does not.

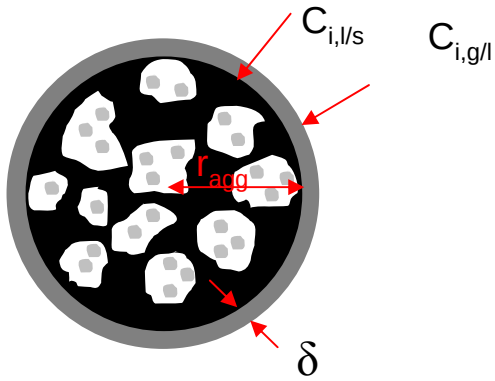


Voltammetry showing chloride poisoning of oxygen reduction reaction (by 100 mV),

D. Myers, Argonne National Laboratory, United States

United Kingdom, Newcastle Univ.:

Modeling the performance of high-temperature membrane PEFCs. Found GDL convective transport and thin ionomer film around catalyst agglomerate to be important.



Representation of agglomerate thin film model of electrode layer

T. Sousa, Newcastle Univ., U.K.

Recent Technical Highlights
Subtask 3: Direct Fuel Polymer Electrolyte Fuel Cells

Germany, Jülich:

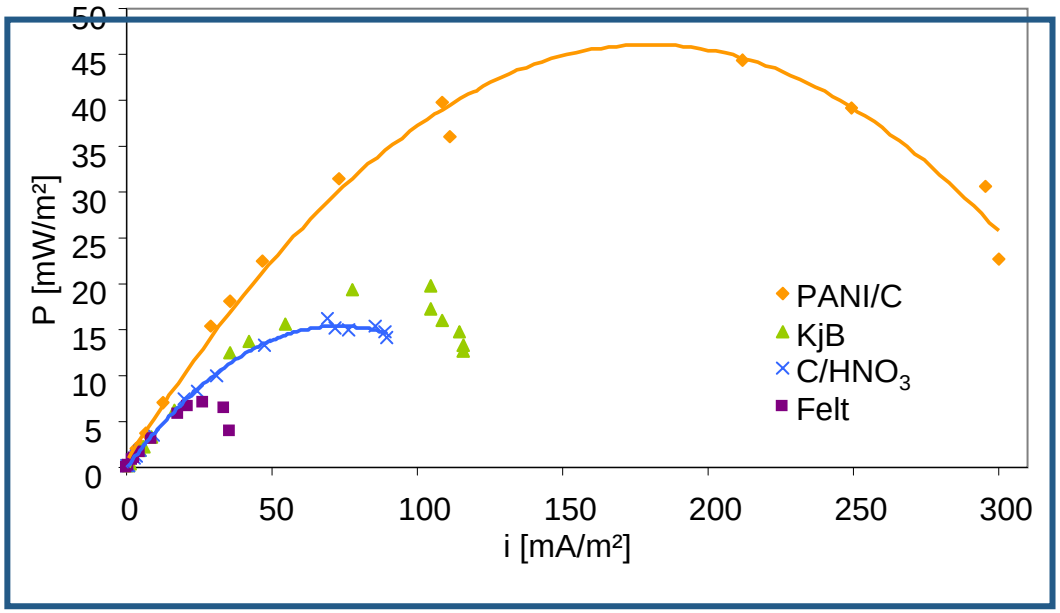
Investigating aging effects in the DMFC stacks used in their fuel cell-powered scooter (JuMOVe)

JuMOVe2 which showed stack degradation of 1800 W to 600 W over 500 operating hours

J. Mergel, Forschungszentrum Jülich GmbH, Germany

United Kingdom, Newcastle University:

Developing anode materials for microbial fuel cells running on wastewater fuel



Power output of microbial fuel cell utilizing various anode catalysts

B. Christgen, Newcastle Univ., U.K.

Recent Progress, Annex XVI

- **The eighth meeting of the Annex XVI Working Group was hosted by Graz Technical University, Graz, Austria on Nov. 22-23, 2007.**

19 participants from 13 countries

Annex XXI: Fuel Cells for Portable Applications (FZ Jülich, Germany)

- **Participants**
  - Austria (TU Graz)
  - Canada (DRDC Atlantic)
  - Finland (VTT)
  - Germany (FZ Jülich, DLR Stuttgart)
  - Italy (ITAE Messina)
  - Japan (NEDO, AIST)
  - Korea (KIER)

Highlights

- Development of air breathing fuel cells
- Fuel cell systems
- Development and testing procedures

DMFC for portable and small mobile applications

- **portable**

  ≤ 50 W
  Replacement of
  Li battery

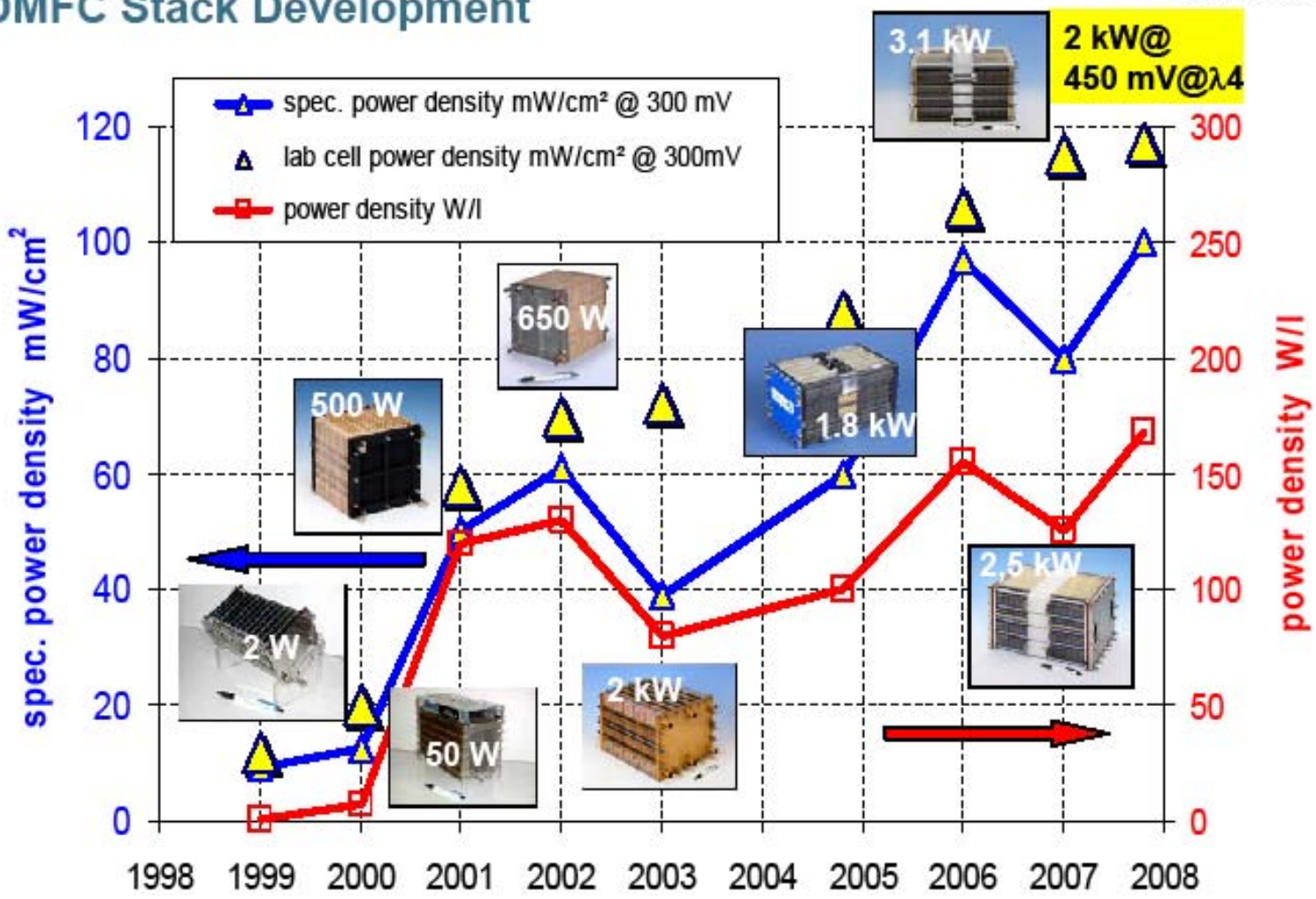
- **transportable**

  50 W - 1 kW
  Replacement of
  Diesel generator

- **mobile**

  0.5 – 2.5 kW
  Replacement of
  Pb Battery

DMFC Stack Development



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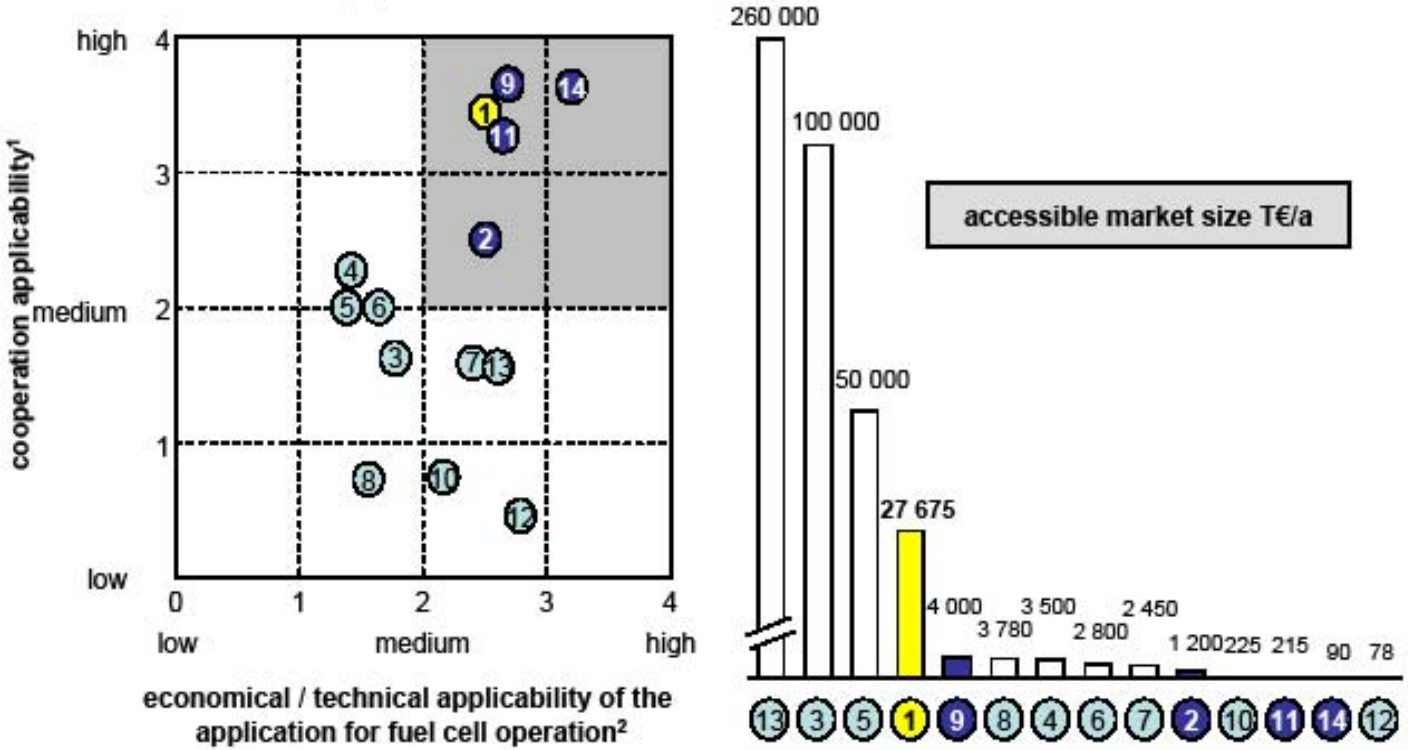
DMFC Stack: progress in stack development

Pt/PtRu-loading	pressure loss	air stoich.	spec. power	lifetime
mg/cm²/cell	mbar	λ	W/kg	h
8	300	10-20	28	< 100
optimized electrodes	optimized flow fields	optimized cathode	use of expanded graphite	material stack/system
4	2-4	4-8	90	stat. 2000 dyn. 20
n. m.	n. m.	optimized cathode	increased MEA performance	- material - mode of operation
5	2	4	125	dyn. 650

n. m. = no modification

Market Survey DMFC-Systems

- Benchmark of Applications / Partners and Accessible Market Size

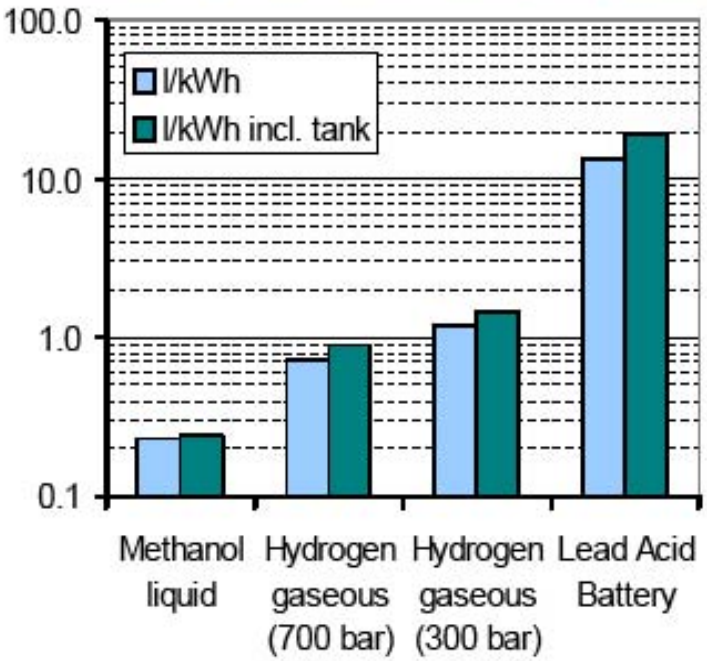


1 Horizontal order picker
2 Industrial vacuum cleaners
3 Fork lift truck
4 Vacuum cleaner
5 Scooter
6 Wheel chair
7 Wheel chair
8 Power mower
9 Power mower
10 APU
11 Yacht
12 Full size glider
13 APU
14 Special uses

1) according to cooperation will and competence
2) according to technical needs and costs

Comparison of Different Energy Sources

- Methanol versus Hydrogen and Lead Acid Batteries



advantages of liquid fuel:

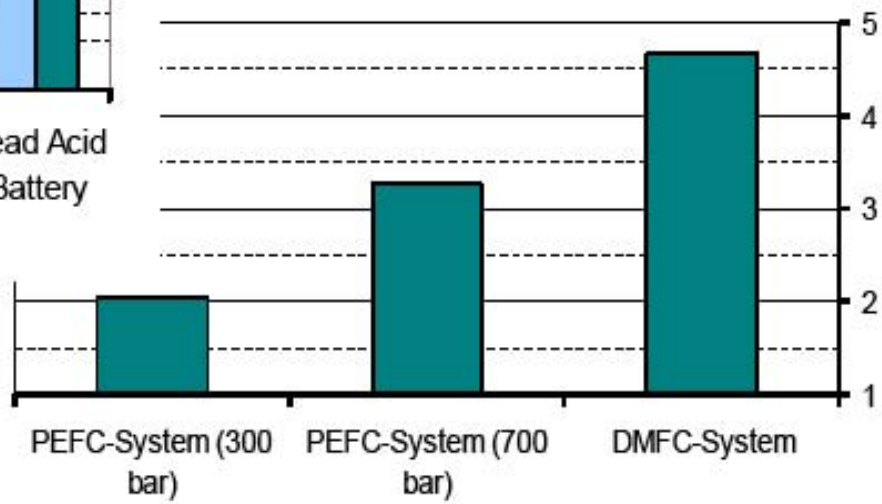
→ use of conventional storage systems

→ no high pressure tanks

→ no gas monitoring system

→ quick refilling

Time of operation without refueling in relation to conventional battery systems



Develop and demonstrate high volume/low-cost manufacturing techniques

- Continuous machine fabrication will cut manufacture costs and improve quality

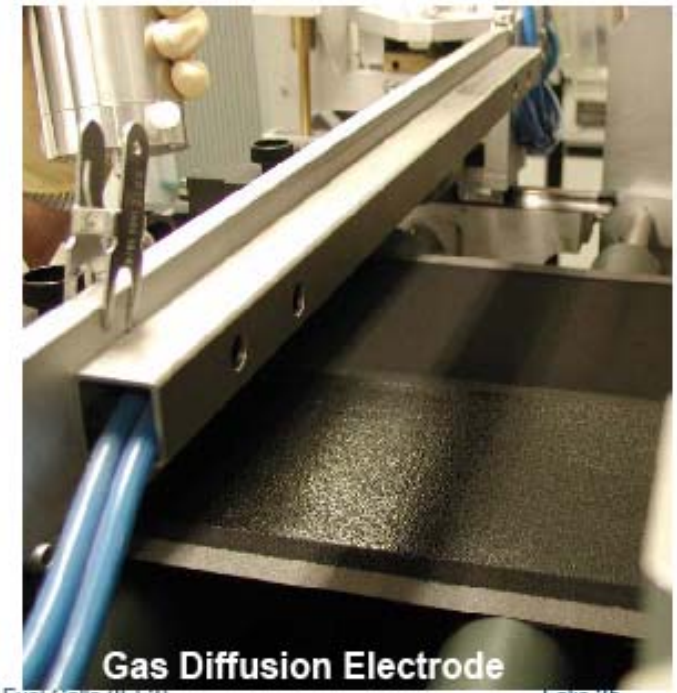
Continuous coating techniques

- Knife over role
- Slot coating
- Screen-printing

Requirements

- Suitable viscosity
- Stable catalyst inks

Deskcoater



Gas Diffusion Electrode

Summer School TU Graz

Registration

Mag. Carmen Gehrer
Christian Doppler-Laboratory for Fuel Cell Systems
Institute for Chemistry and Technology of
Inorganic Material

Graz University of Technology
Steyrergasse 21
8010 Graz, Austria

Tel. +43 (0)316 873 8781
Fax +43 (0)316 873 8782
carmen.gehrer@tugraz.at
www.fuelcells.tugraz.at

Deadline for registration:
July 15th, 2008 (limited number of participants!)

No fee for students in natural science or technology (undergraduate, graduate, PhD).

Accommodation

Students have the possibility to stay in fully equipped rooms of a foreign student house in a flat-sharing community incl. TV, internet, and kitchen:
www.housing.oead.ac.at
Please contact Ms Carmen Gehrer for further information.

Contact Information

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E-mail: viktor.hacker@tugraz.at

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Prof. Shigenori Mitsushima
Department of Energy and Safety Engineering
Yokohama National University
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E-mail: mitsushi@ynu.ac.jp

International **Summer School** on Advanced Studies of Polymer Electrolyte Fuel Cells

Graz University of Technology, Austria

August 25th-29th, 2008

Christian Doppler Laboratory for Fuel Cell Systems
Graz University of Technology, Austria

Department of Energy and Safety Engineering
Yokohama National University, Japan

General Information

Fuel cells are recognised as the most promising clean power sources for future transportation and stationary applications. Low temperature fuel cells, especially the Polymer Electrolyte Fuel Cells (PEFCs), have demonstrated high efficient power production with low emissions in thousands of prototypes worldwide.

The International Summer School on Advanced Studies of PEFC is organized in co-operation between **Graz University of Technology, Austria** and the **Yokohama National University, Japan** with internationally recognised experts in the field of fuel cell research.

The lectures include fundamental studies and advanced aspects of PEFCs. Practical training and a social program complete this week.

- One week intensive course, 6 to 8 hours of lectures and practice per day.
- Certificate of Attendance (without exam) 5 ECTS credits (with exam).
- Lecturers from Austria, Germany, Italy and Japan provide an introduction and represent the state-of-the-art of this emerging technology.
- The attendees get the possibility to improve their communication skills by studying in a multicultural work environment.

Lectures*

PEFC Principals and Applications
Prof. K. Ota
(Yokohama National University, Japan)
Prof. V. Hacker
(TU Graz, Austria)

Heat and Mass Transport in the PEFC
Prof. T. Araki
(Yokohama National University, Japan)

Modelling of Fuel Cells – Principles and Applications
Dr. U. Reimer
(Research Centre Juelich, Germany)

Electrochemical Characterisation Methods
Prof. S. Mitsushima
(Yokohama National University, Japan)

Fundamental Aspects of Electrode Processes
Prof. B. Gollas
(TU Graz, Austria)

PEFC Electrode Preparation and MEA/GDL Assembling
Dr. G. Squadrito
(CNR-ITAE, Italy)

Single Cell Characterisation / Measurement Techniques
Dr. W. Baumgartner, Prof. V. Hacker
(TU Graz, Austria)

Gas Purification
Prof. M. Siebenhofer
(TU Graz, Austria)

PEFC & Hydrogen as Fuel – Fundamentals
Prof. K. Ota
(Yokohama National University, Japan)
Dr. M. Klell
(HyCentA Research GmbH; Austria)

Laboratory Tutorial
Prof. V. Hacker, E. Wallnöfer M.Sc.
(TU Graz, Austria)

*subject to alterations

Zusammenfassung, Ausblick

- Österreichische IEA Teilnahme (seit 2004) zeigt ein positives Bild hinsichtlich verstärkten Kooperationen (Vernetzung) mit den ausländischen Partnern (Beitrag zur weiteren Internationalisierung der österreichischen Forschung)
- Die österreichischen Projekte konnten durch die IEA Teilnahmen qualitativ verbessert werden (know-how Transfer nach Österreich)
- Die IEA Teilnahme bietet sehr vielen Firmen eine Plattform sich bei den ausländischen Partnern darzustellen (unter Berücksichtigung der nationalen Referenzprojekte, die derzeit im Rahmen der nationalen Programme aufgebaut werden)
- Die zukünftigen IEA AFC Aktivitäten sehen verstärkte Disseminationsaktivitäten – im Rahmen der Projektmöglichkeiten – vor (Website, periodische Artikel, Präsentationen, Workshop(s))

Relevante Websites

- Internationale Energieagentur: http://www.iea.org
- Implementing Agreement on Advanced Fuel Cells: http://www.ieafuelcell.com/ http://www.energyagency.at/Advanced_Fuel_Cells
- CD Labor Brennstoffzellen: http://www.fuelcells.tugraz.at/
- Österreich in der IEA: http://www.energytech.at/iea/