



OTTO VON GUERICKE
UNIVERSITÄT
MAGDEBURG

FAKULTÄT FÜR
ELEKTROTECHNIK UND
INFORMATIONSTECHNIK

Institut für Elektrische Energiesysteme

Diagnostic of a Stationary PEM Fuel Cell System for Residential Energy Supply

Dipl.-Ing. Maik Heuer

2nd PhD and Young Researcher Seminar

Agenda



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- **Fuel Cell and Storage Lab at LENA**
- **Function of a Fuel Cell**
- **Diagnostic of a PEM Fuel Cell**
- **Requirements for Residential Use**

Fuel Cell Lab - Equipment



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- research in **PEM** Fuel Cell Systems (FCS)
- five stationary FCS ($P_{el}=300-5000W$)
- two autonomous FCS – *auxiliary power units* (APU)
- student FCS for internships
- electrolyser for hydrogen production
- developed measurement electronic for FC controlling



Fuel Cell Lab- Stat.& APU



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research for automotive
APU applications

control
strategies

reformate
gas

long term
measurements



5000W FCS for APU

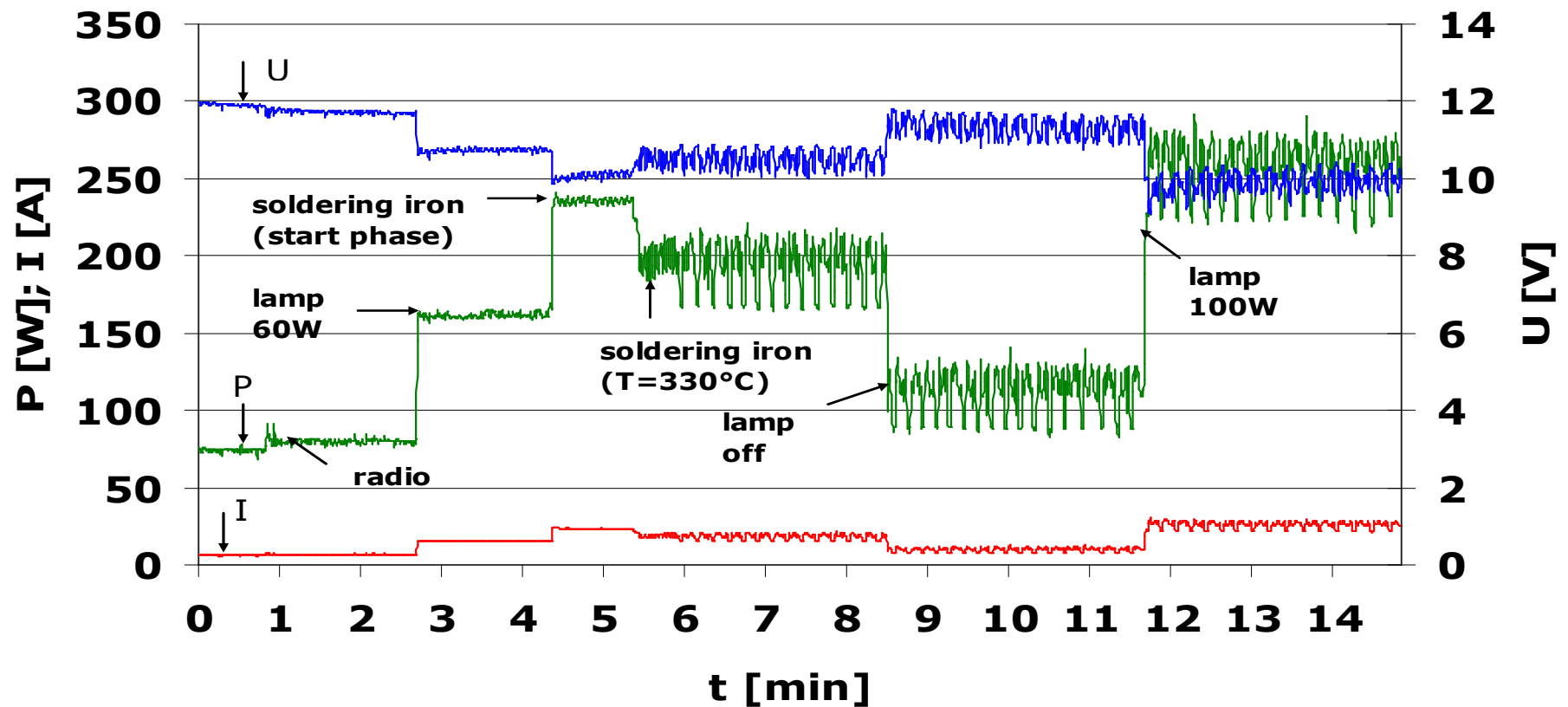
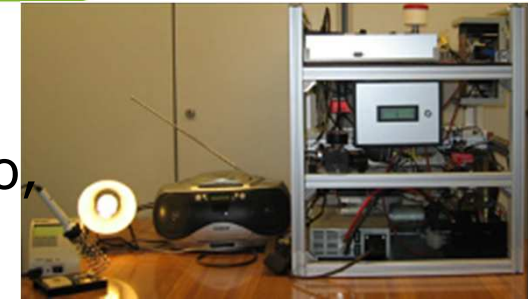


350W FCS for different research areas

Fuel Cell Lab- Autonomous

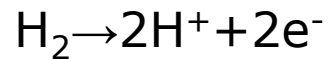


behaviour of FC voltage (U), power (P) and current (I) supplying a load of a radio a lamp and a soldering iron

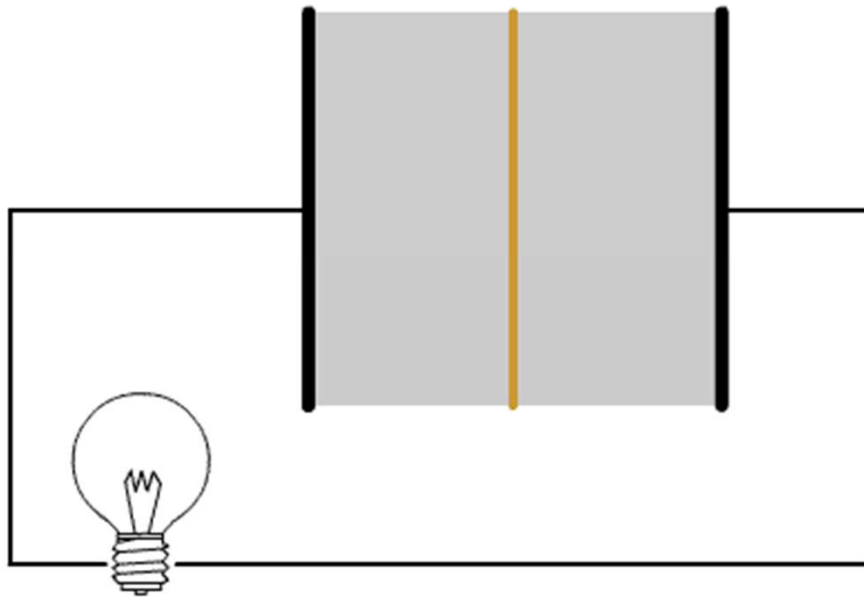
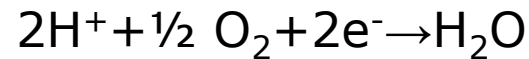


Function of a Fuel Cell

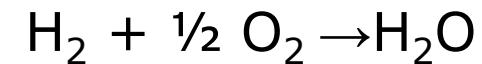
Anode:



Cathode:



Total reaction:



Efficiency:

40-70% (single cell),
load-dependent

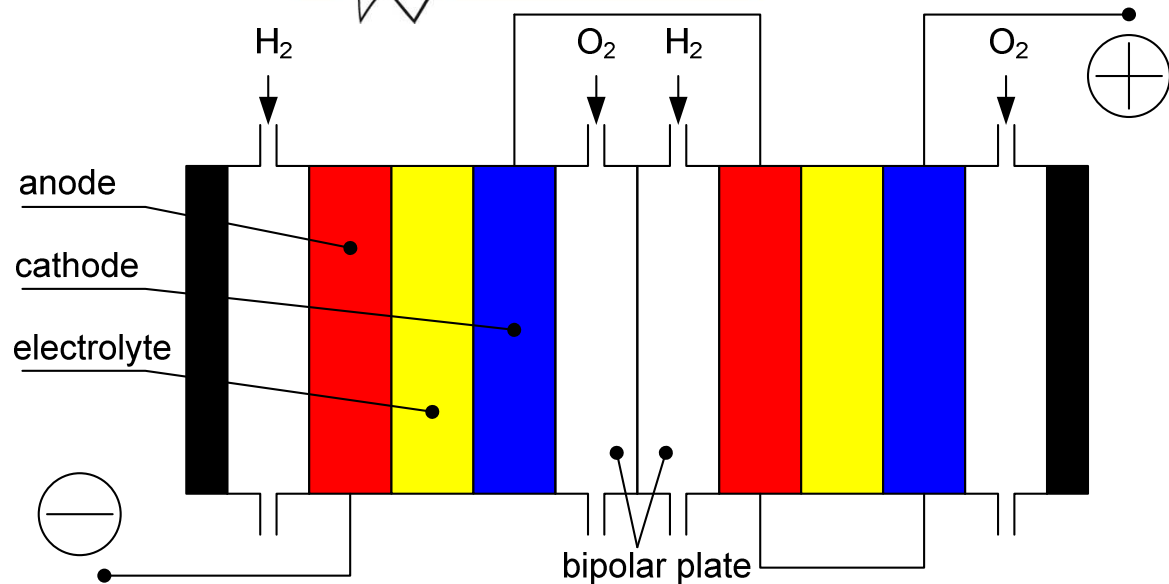
- directly conversion of chemical energy into electrical
- reaction products are only water, heat and power
- no CO_x , NO_x emissions

Function of a Fuel Cell



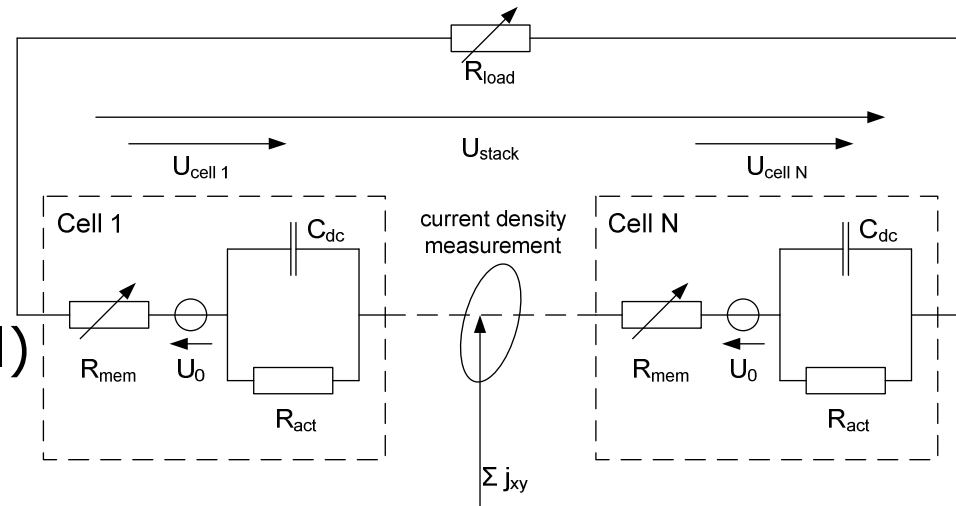
construction of a stack

serial connection of cells
addition of cell voltages



electric circuit of a stack

R_{mem} membrane resistance
 C_{dc} double layer capacity
 R_{act} activation resistance
 U_0 idle voltage (1V per cell)



Diagnostic of a PEM Fuel Cell



cell voltage decay leads to a reduced output power of the FC by

mechanical

pressure difference



membrane damage

thermal

gradients in current density



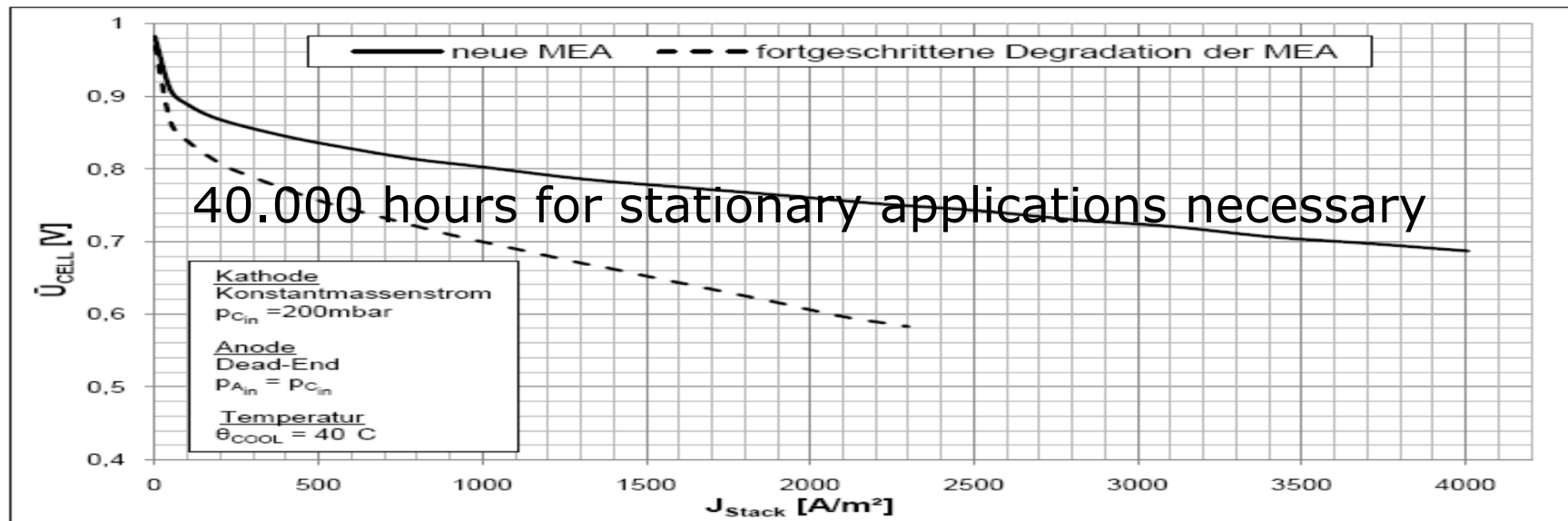
local overheating

physical/chemical

reduction of catalyst



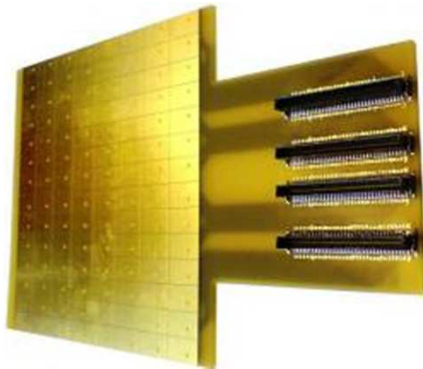
reduced output power



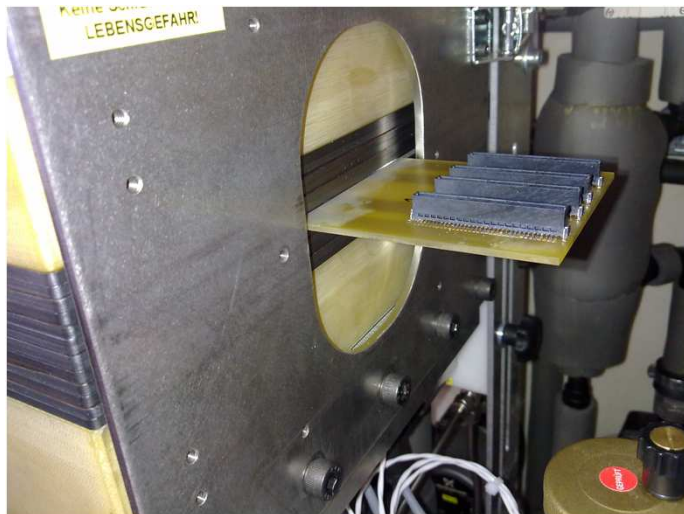
voltage and current density curve of new and an "old" FC-Stack

Diagnostic of a PEM Fuel Cell

one solution: current density measurement (CDM)



integration of a shunt board
between two cells of a stack



shunt board within the stack

measuring the current density
distribution at 112 segments
on the membrane surface

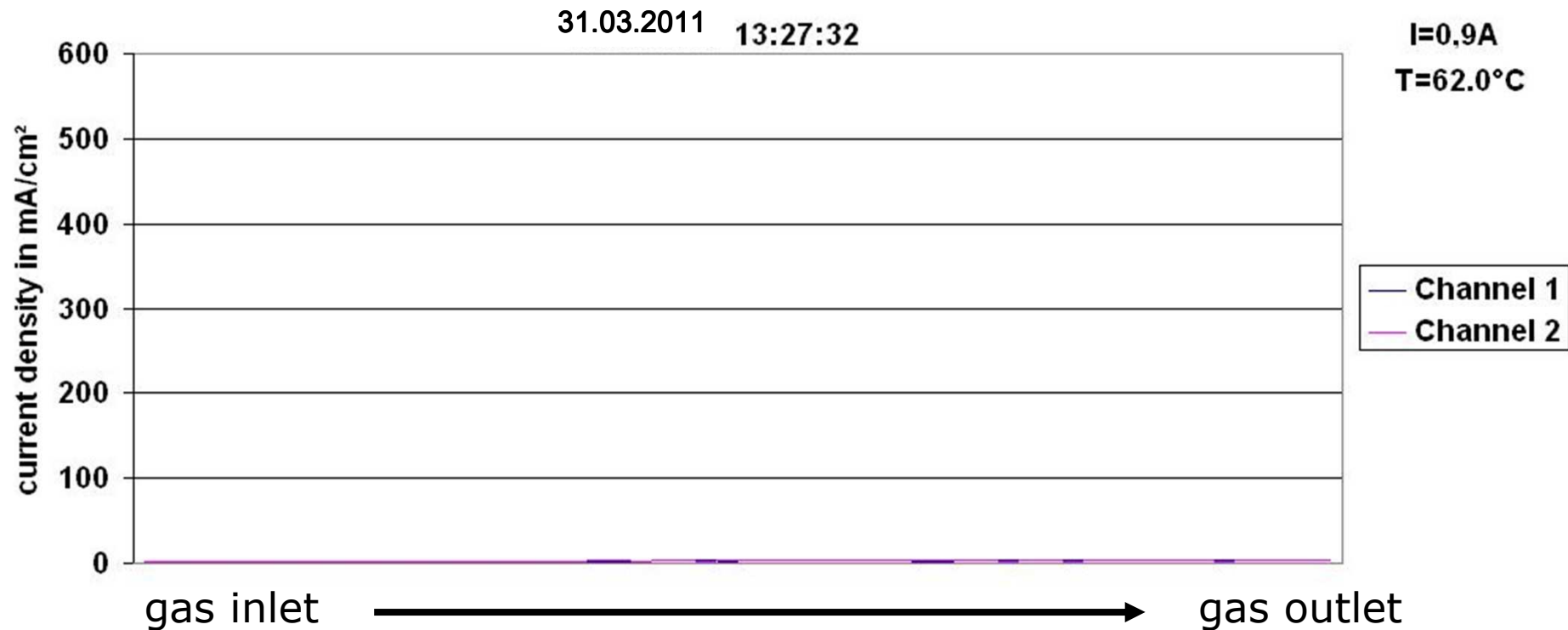


view in the FC
information about FC behaviour

Diagnostic of a PEM Fuel Cell



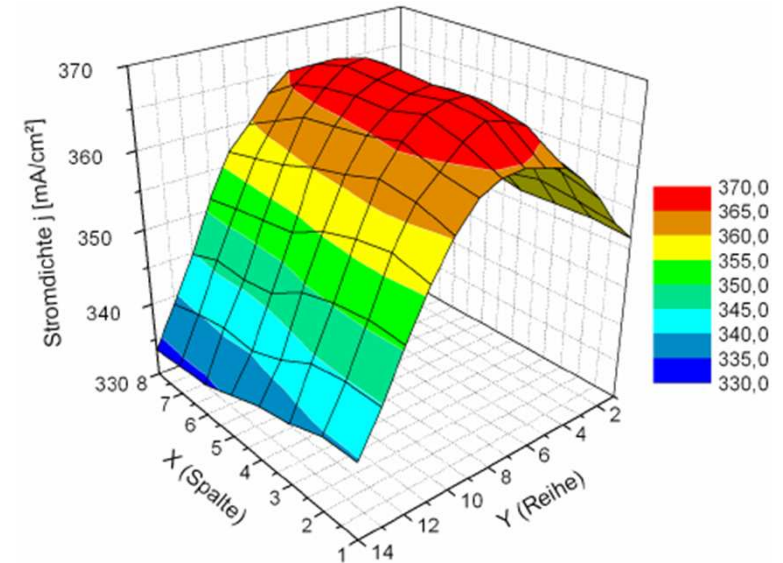
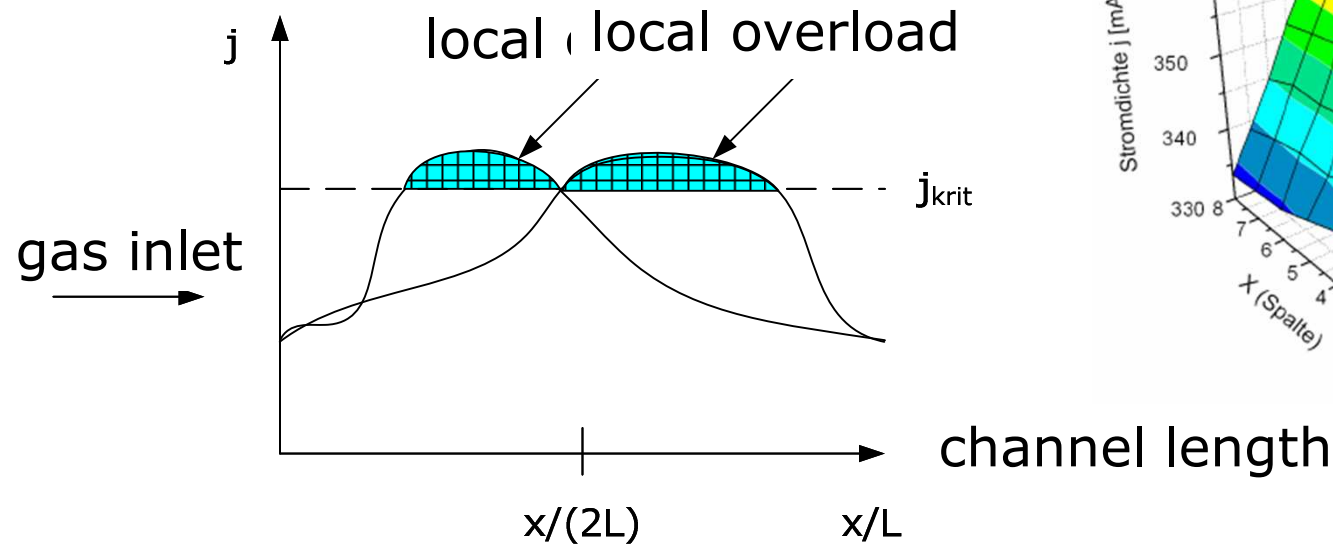
CDM gives information about the FC process



current density distribution along two gas channels during start up, constant and shut down phase of a FCS

Diagnostic of a PEM Fuel Cell

$j_{nom} > j_{krit}?$



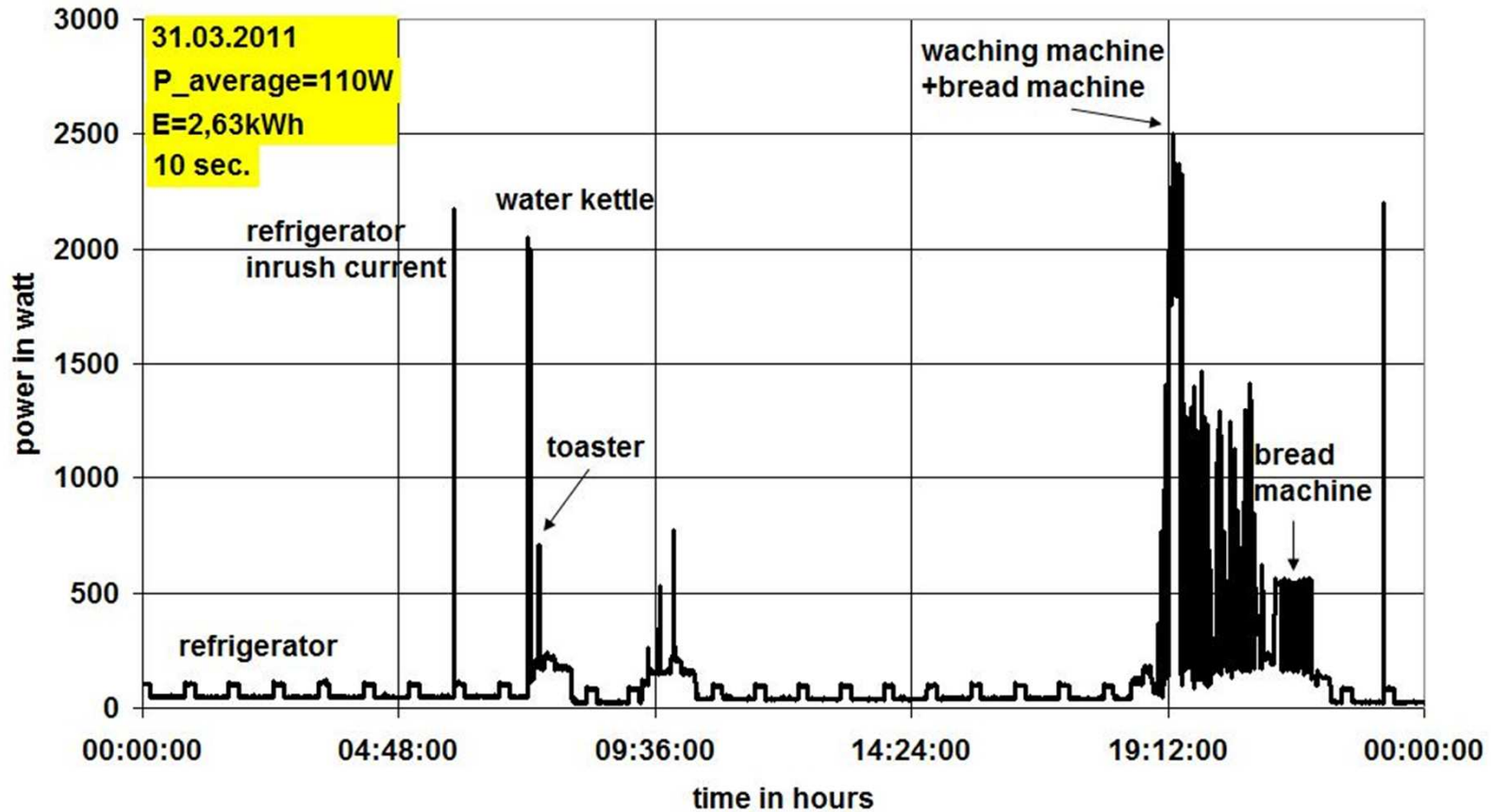
- reasons: $R_{mem} \uparrow$ \longrightarrow unbalanced water distribution at the membrane
 T \longrightarrow lower temperature at the gas inlet
 D \longrightarrow high gas velocity leads to lower H_2 diffusion

FC diagnostic necessary for an optimized operation

Requirements for Residential Use



two person household with energy-saving household appliances
annual energy consumption of 963kWh

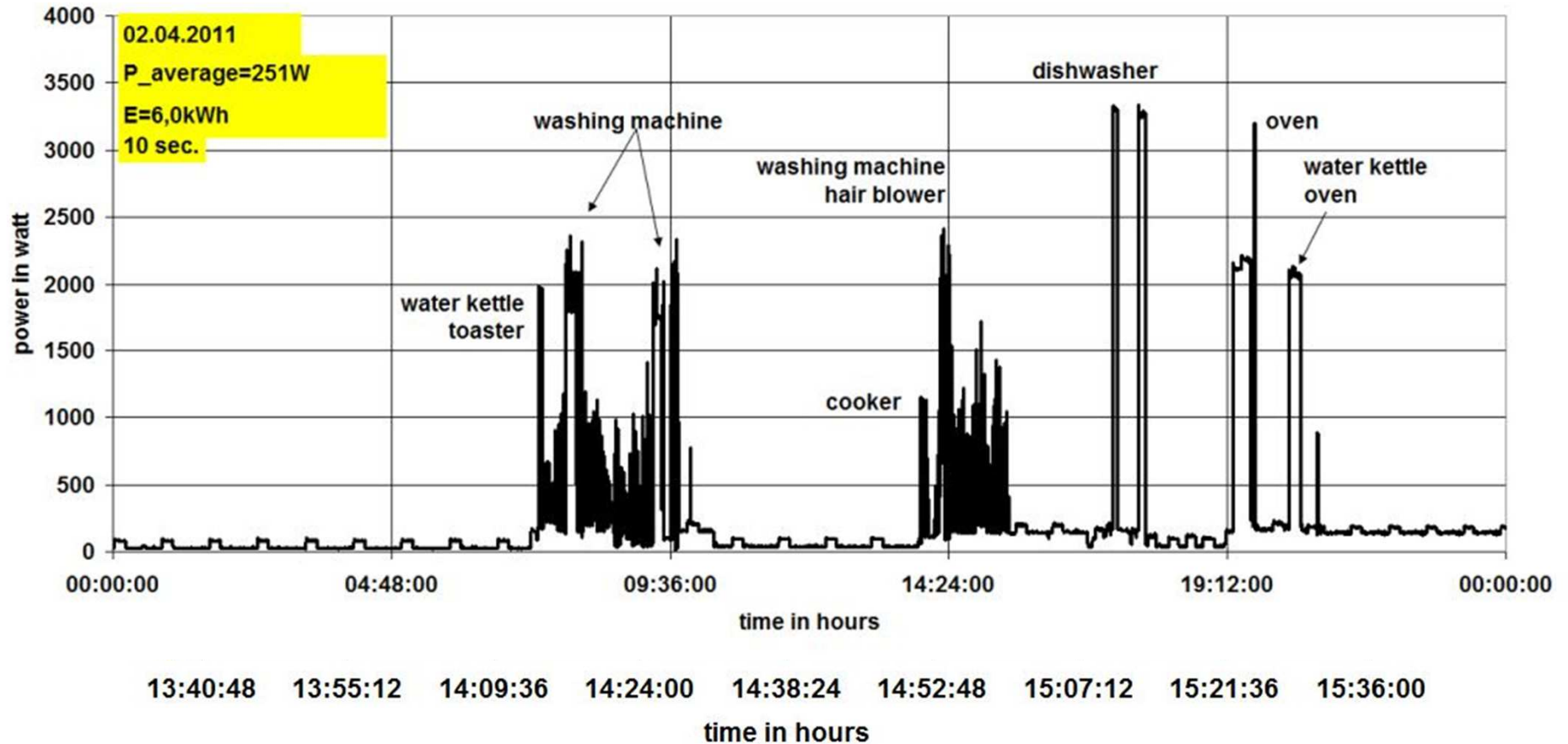


measured load profile of a work day

Requirements for Residential Use



permanent load changes up to 3500W

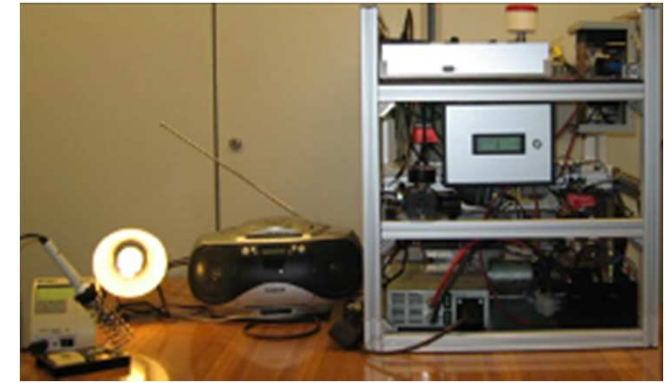


measured load profile at the weekend in detail

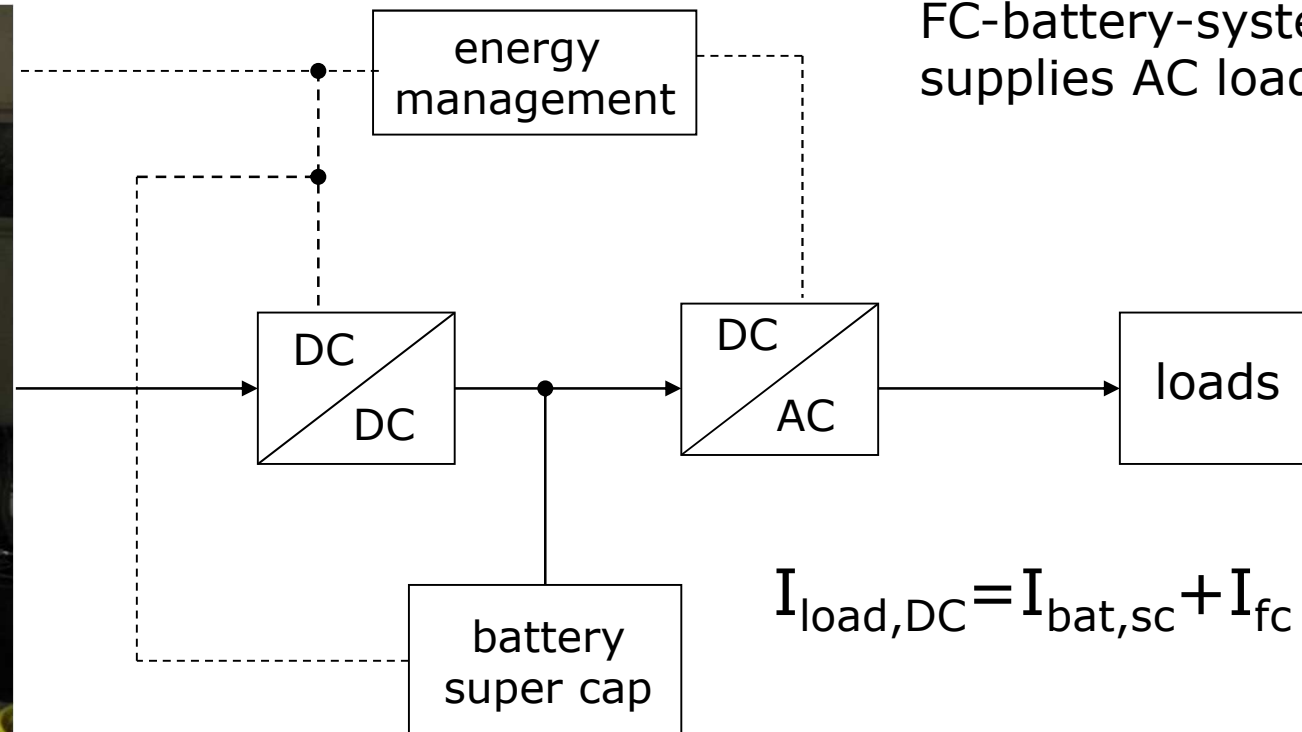
Requirements for Residential Use



- high load peaks in households
- coupling FCS with super cap and a "small" battery to avoid very high power gradients of the stack
- FC provides thermal energy for heating



FC-battery-system
supplies AC loads



Thank you for your attention



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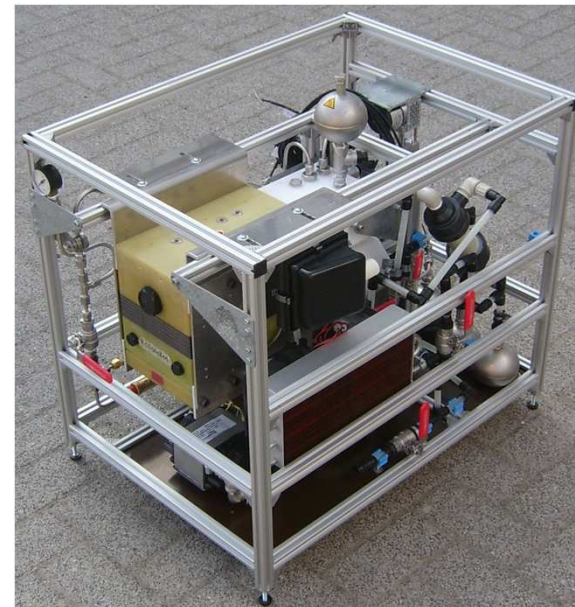
contact:
maik.heuer@ovgu.de

stand-alone FC Systems

supply AC or DC loads up to 300W
30% electric efficiency
4 hours operating at nominal power

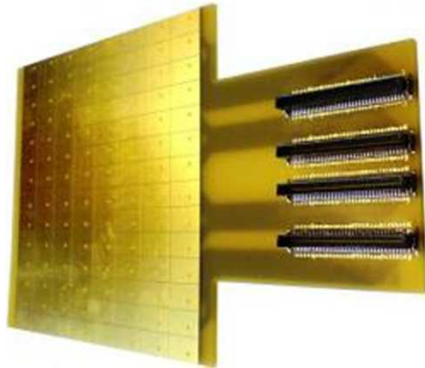


500W FCS

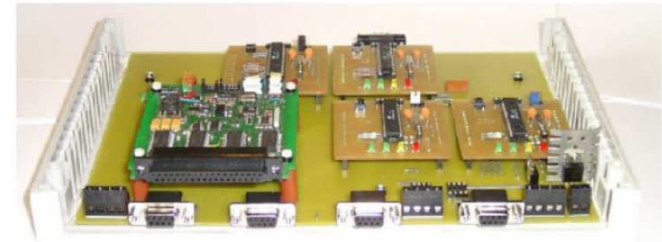


350W FCS

Fuel Cell Lab- Equipment



FC current density board



control unit for FCS



humidity test bench
for sensor check



FC single cell voltage
measurement device



500W DC/DC converter
12-22V/24V

Fuel Cell Lab- H₂ & Storage



production	1.000 l/h
efficiency	60-66%
FC energy (gross)	1,45 kWh
FC energy (net)	1 kWh

compressed	200bar
purity	99,999%
mass	9 kg
volume	106.800 l
FC energy (gross)	152 kWh
FC energy (net)	112 kWh



electrolyser



hydrogen tank