HEXIS Exzellente Brennstoffzellen-Technik

Fuel cell system development at HEXIS

Technological Status and Economic Potential of Fuel Cell Technology

Outreach Event of the IEA Advanced Fuel Cell Implementing Agreement

23rd April 2015 | Andreas Mai

Introduction on the company

HEXIS Exzellente Brennstoffzellen-Technik

- Business: Development, manufacturing and bringing to market of SOFC-based micro-CHPs
- Hexis fuel cell activities started in the 90^{th} at Sulzer, more than 20 years of experience on SOFC systems & components
- Hexis AG (Winterthur (CH), Headquarter) and Hexis GmbH (Konstanz (D), subsidiary)
- Owners: 50 % Swiss foundation **since 10 / 2012: 50 % Viessmann Group**
- **40 employees**

VIESSMANN climate of innovation

Concept of Galileo

Fuel Cell Heating Appliance Galileo 1000 N
Focus on Matching Customer's Energy Demand

Tailored development for single family houses and small apartment buildings

Electricity demand
~4500 kWh/a

Heat demand
15'000–25'000 kWh/a

Electricity supply
Fuel cell: ~4000–5500 kWh/a

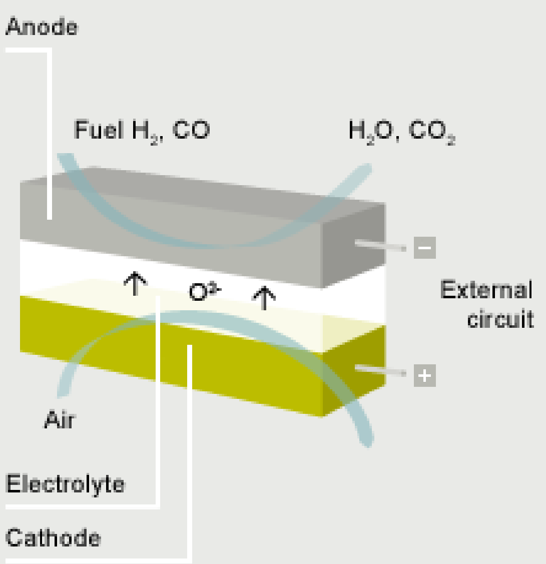
Heat supply
Fuel cell: 8000–11'000 kWh/a
Additional burner: rest

Energy demand of building
Example:
Single family home, 4 people,
building stock (140 kWh/m² a),
central DHW

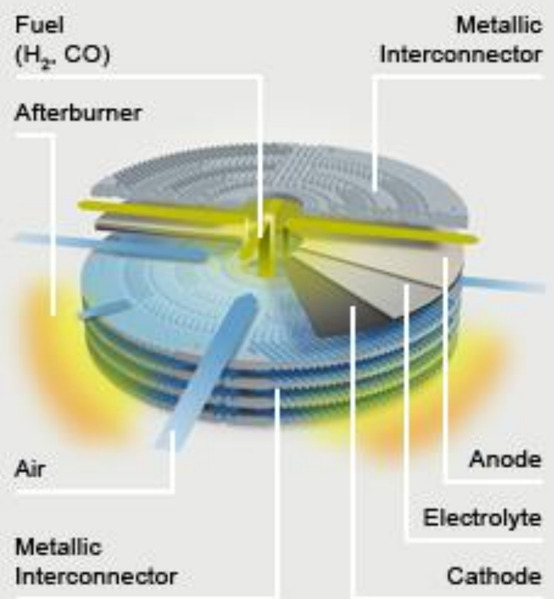
Energy supply trough device
Example:
Fuel cell system
Galileo 1000 N, 4500–6000 h/a,
Storage tank 500 l

Fuel Cell Heating Appliance Galileo 1000 N
HEXIS-SOFC Principle

Electrochemical process of a solid oxide fuel cell



Operating mode of a fuel cell



Fuel cell module

Micro-CHP Galileo 1000 N
Specifications

Fuel cell

Electrical output	1 kWel (AC, net)
Thermal output	1.8 kWth
Electrical efficiency	35 % (AC, net)
Overall efficiency	95 % (LHV, T_{Return} = 30 °C)

Back-up burner included

Dimensions	620 x 580 x 1640 mm
Weight	210 kg

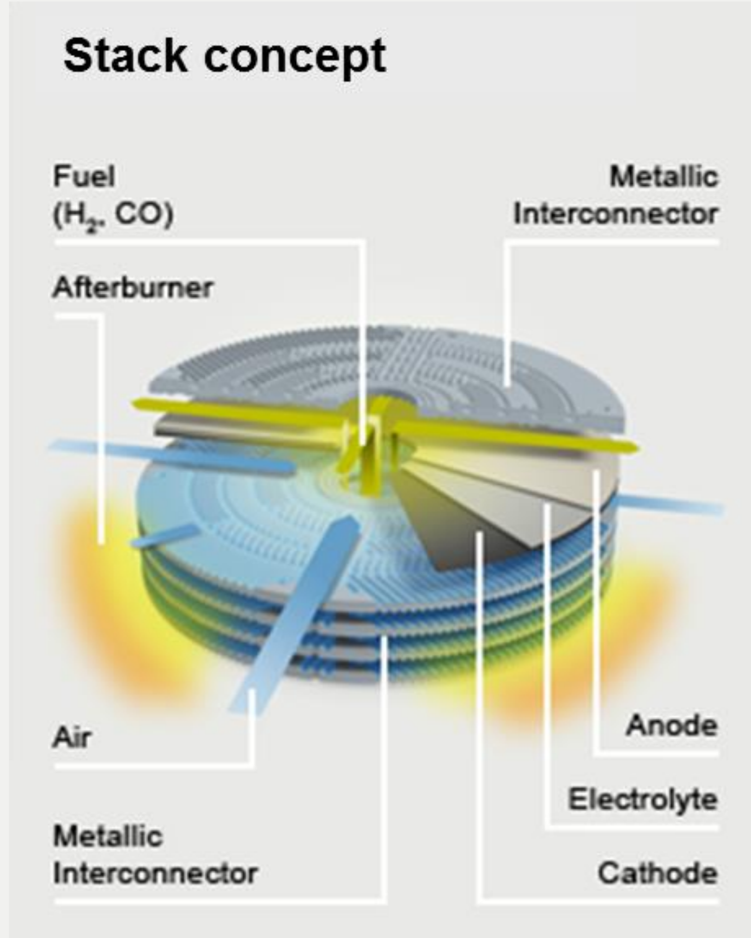
→ Designed to fit to single family and similar houses

Stack concept

Open, radial system

- Post-combustion zone surrounds the stack
  → Electrolyte supported cells for redox stability
- Operation temperature 800 - 900°C
- 100 cm² active area
- Low pressure drop between gas and air
  → low requirements on sealings
  → No distinctive sealings
- Highly integrated with heat exchanger
- Interconnects: powder metallurgical CFY
- easy assembly

→ Keep it as simple as possible.



Micro-CHP Galileo 1000 N
Features

Environment

- Lowest emissions of pollutants, **very quiet**

Ressources

- Highly efficient fuel utilisation, high overall efficiency – demonstrating high-end CHP

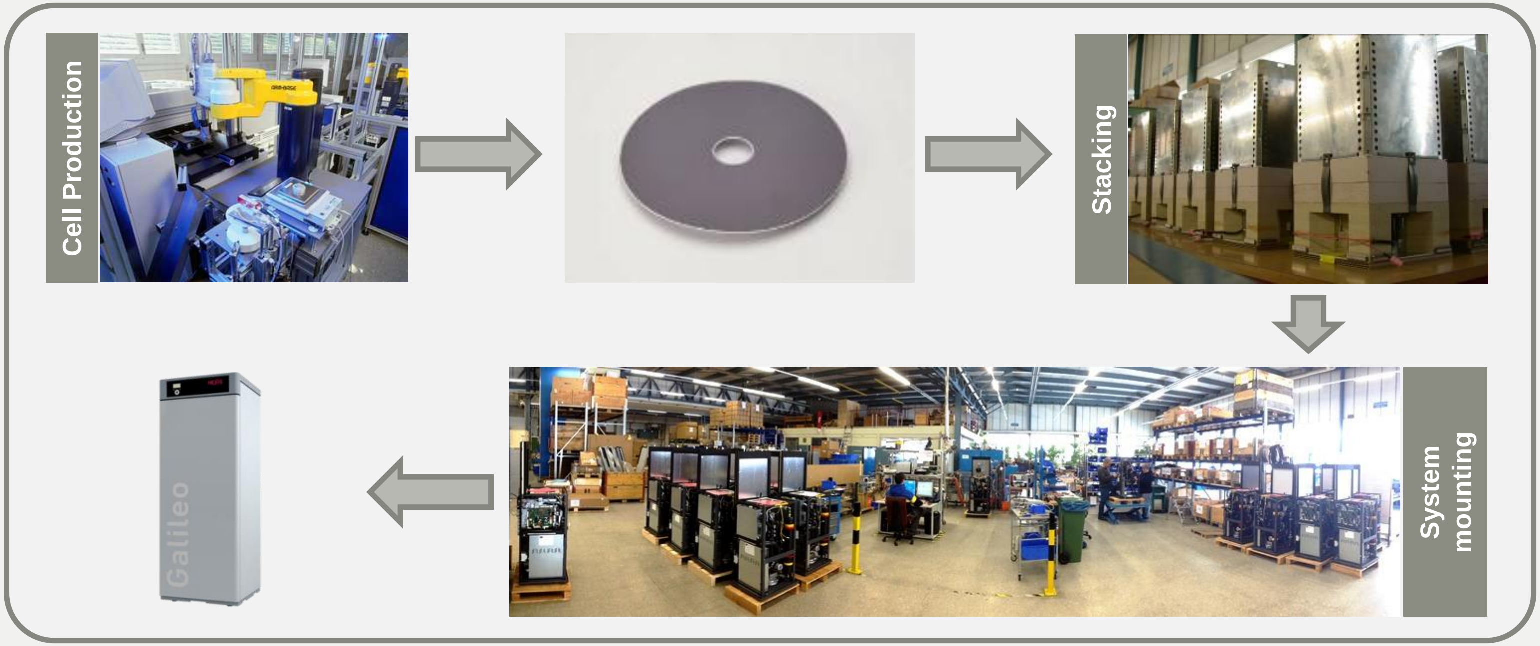
Customer demands

- Customer tailored supply of electricity and heat
- **Coverage of heat demand, even at blackouts**
- Easy installation in already existing house infrastructure
- **Web-based services for end-customers and installers:** heating control, maintenance support
- **7-years all-inclusive warranty sold with the system**

Targeted system lifetime: 20 years

Targeted stack lifetime: 7-8 years

Production Infrastructure



Cell production ► stack assembly ► Pilot manufactory for entire fuel cell system

Cells: Capacity for up to 100‘000 cells/year (→ 2 MW, for more than **1000 systems** per year)

Stacks: Capacity for approx. 5-8 stacks and fuel cell modules/day (> **1000 modules** per year)

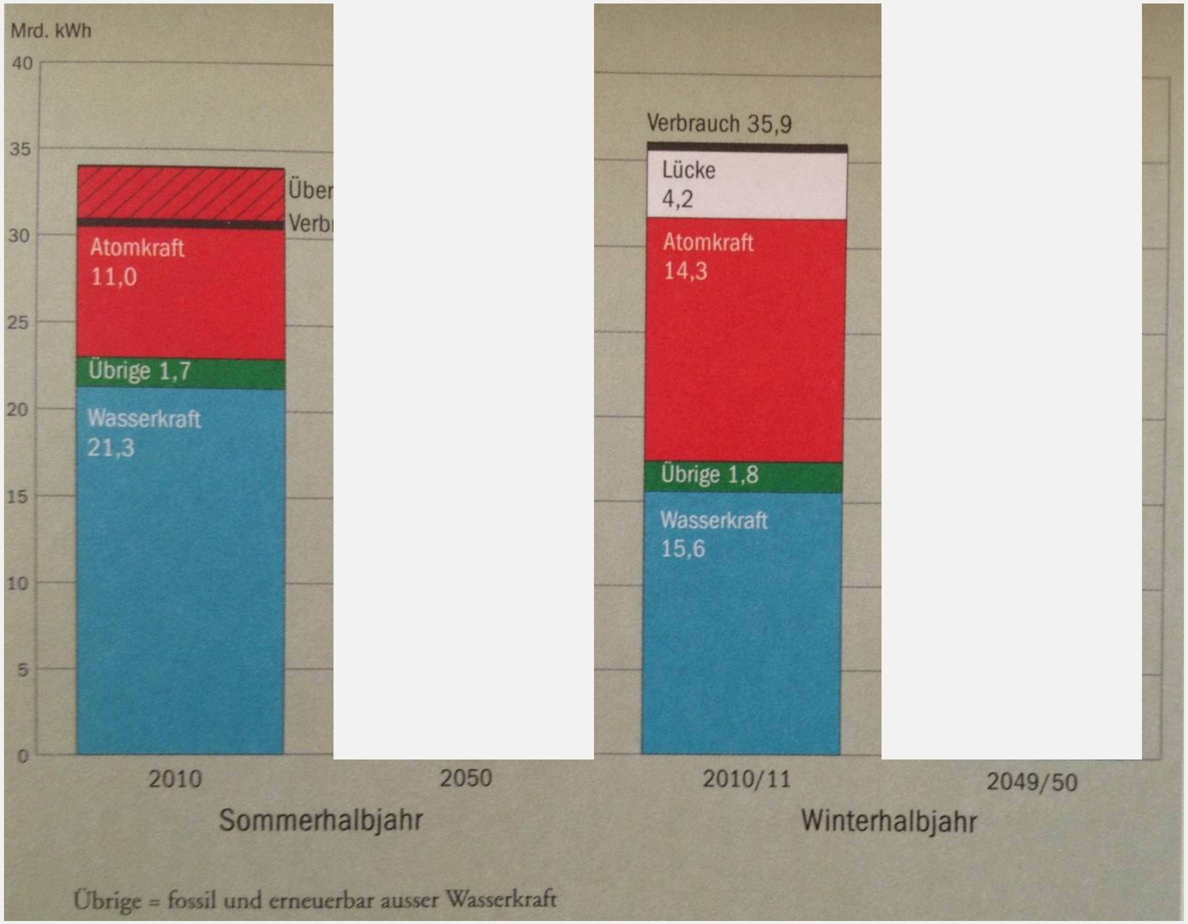
Systems: Capacity for 2-3 systems/day (approx. **500 systems** per year)

CE certified assembly and end control

Customer ready fuel cell system to be delivered

Energy scenarios in Switzerland

Production and consumption of electricity 2010 and 2050



[Quelle: BFE-Statistik, BFE-Szenario «Neue E-Politik», Berechnungen Hanspeter Guggenbühl in die «Energiewende»]

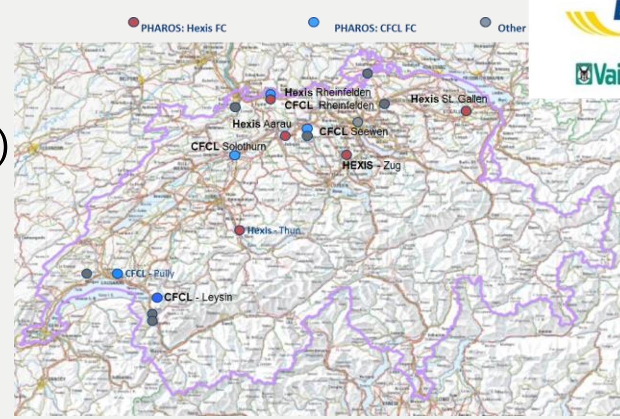
Demonstration projects and “real-life” systems

callux
Praxistest Brennstoffzelle fürs Eigenheim

- Preparation of the market launch of fuel cell micro-CHPs
  220 systems (in 3 Generations) delivered by Hexis in the project
- Average operating time per year (SFH): approx. 5000 h
- Longest fuel cell lifetime up to now: >15’000 h (w/o service), many stacks with 5’000 – 10’000 h
- Availability in SOFC-operation: 98% to > 99%
- Reduction of CO_2-emissions per household by 1 to 1.5 t p.a. (german energy mix)

PHAROS: Swiss project, 5 Galileo installed

Closest Galileo here in Zürich (approx. 1 km away)
today (14:22): 1195 W DC



Marketing Galileo 1000 N
European Joint Project ene.field

- Europe-wide demonstration test funded by European Commission (E.C.), where HEXIS intends to deliver and to support 100 micro FC-CHP systems

- Basic idea
  - Test project to install and test ~1’000 micro FC-CHP in European countries from 2012-2017
  - Increase number of fc system production, prepare and develop local markets

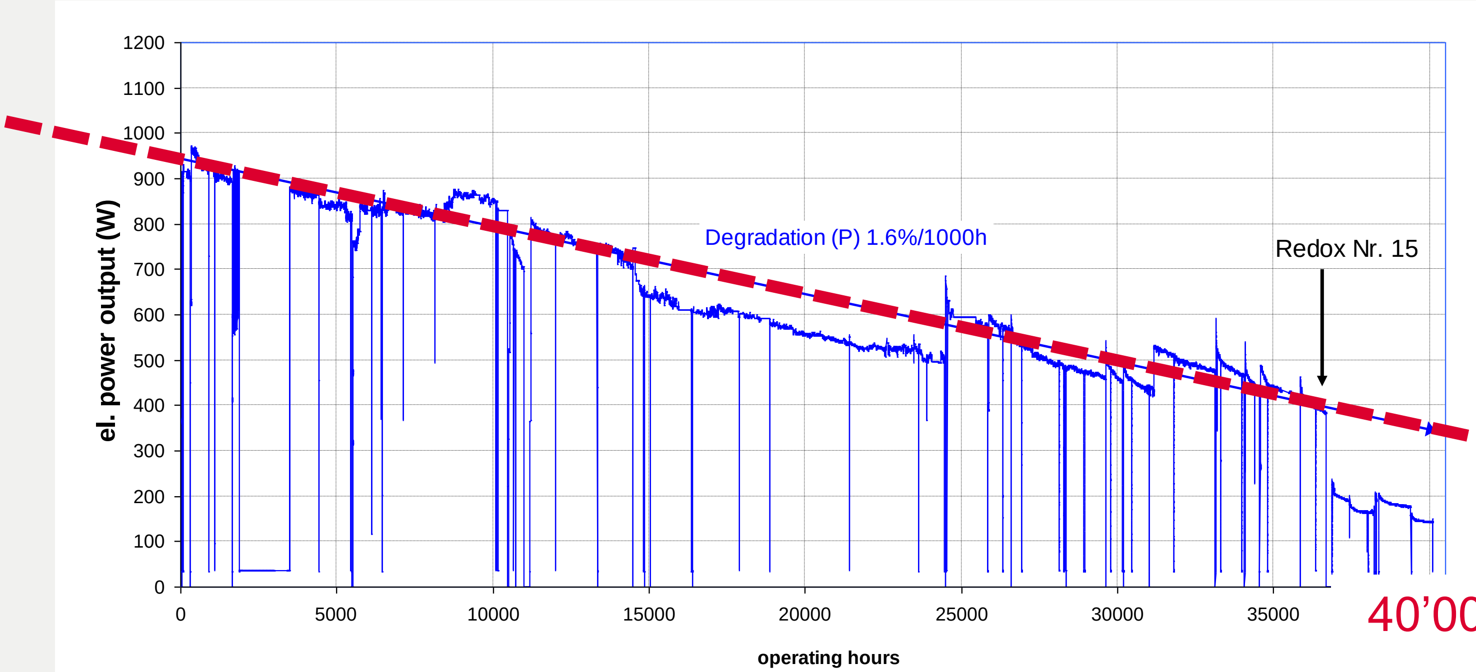
- HEXIS deals with the E.C., i.e. no effort for customer (ESCo and installer) as well as end customer.

- HEXIS has delivered 15 systems, yet.

→ **More Information on www.enefield.eu**

Results from testing Galileo

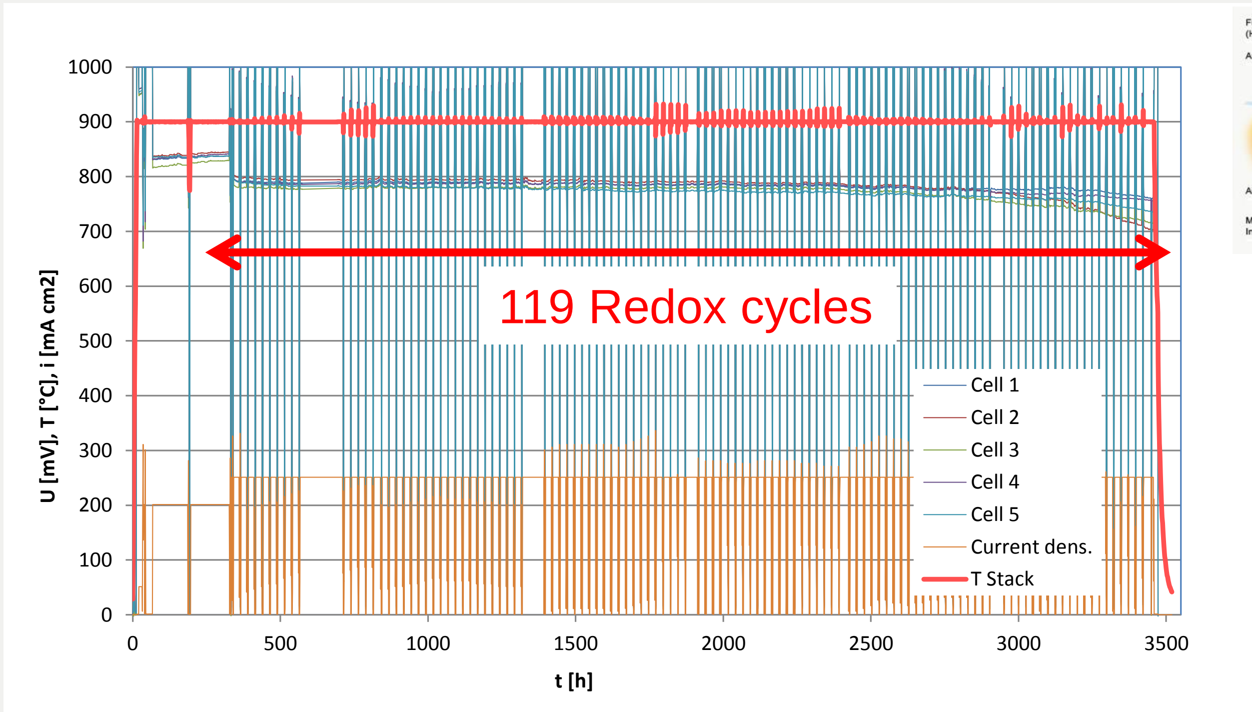
Lifetime: steady-state degradation
Test on Galileo system

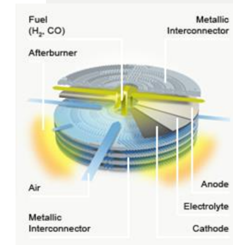


- No progressive degradation till 37000 h → **some extrapolation for newer stacks**
- Stack operation stopped in May 2012

Life time: stability against cycles
Results of a 5-cell stack

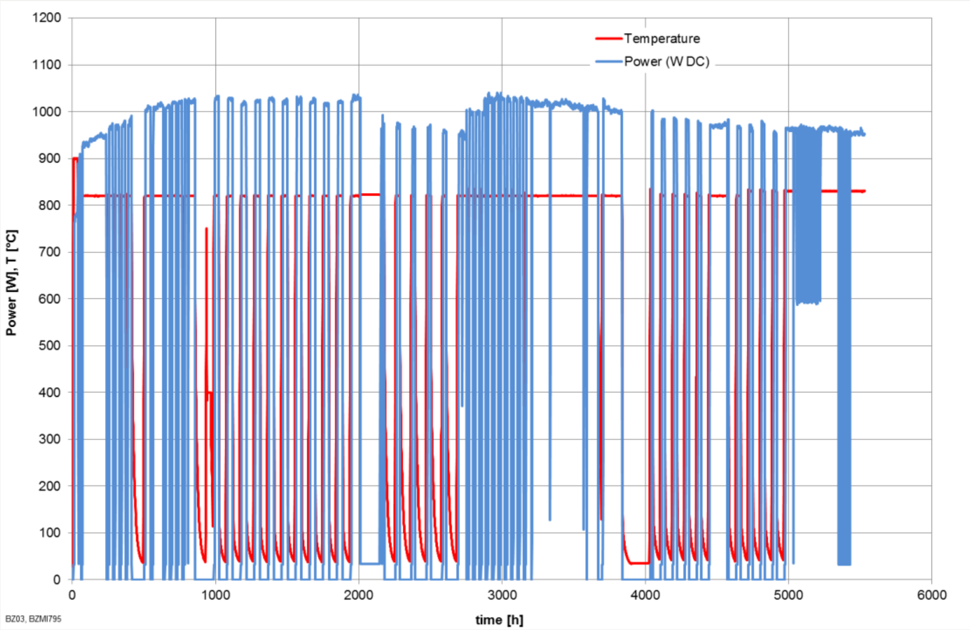
operated with natural gas (4 g/h per cell), 900°C

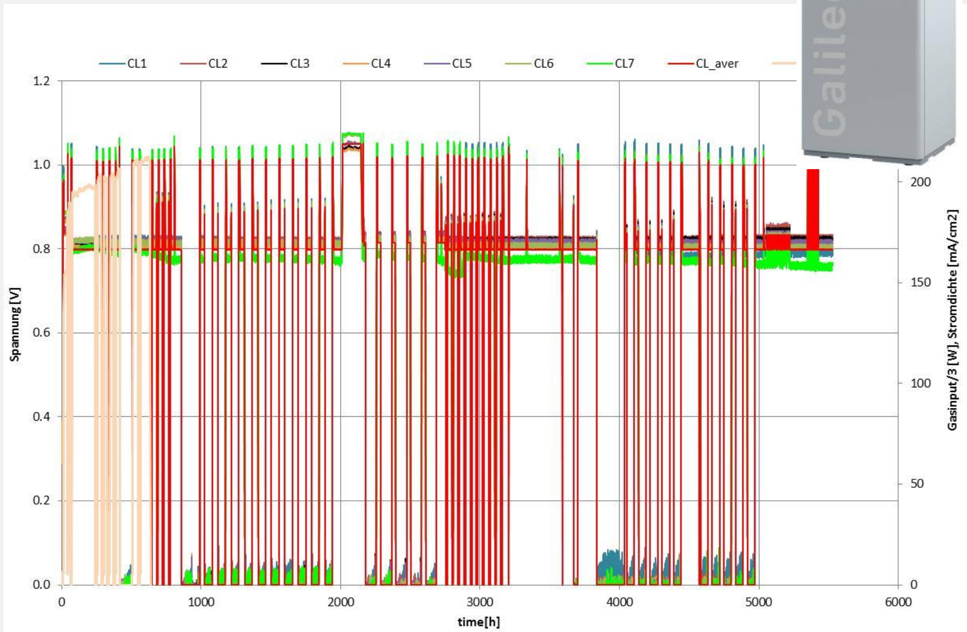




- No measureable degradation due to 100 full redox-cycles (1 h re-oxidation, voltage < 10 mV)
- After 105th cycle, degradation sets in
- Redox Cycling stability much more than sufficient for 8 years of stack operation

Life time: stability against cycles
Test on system level



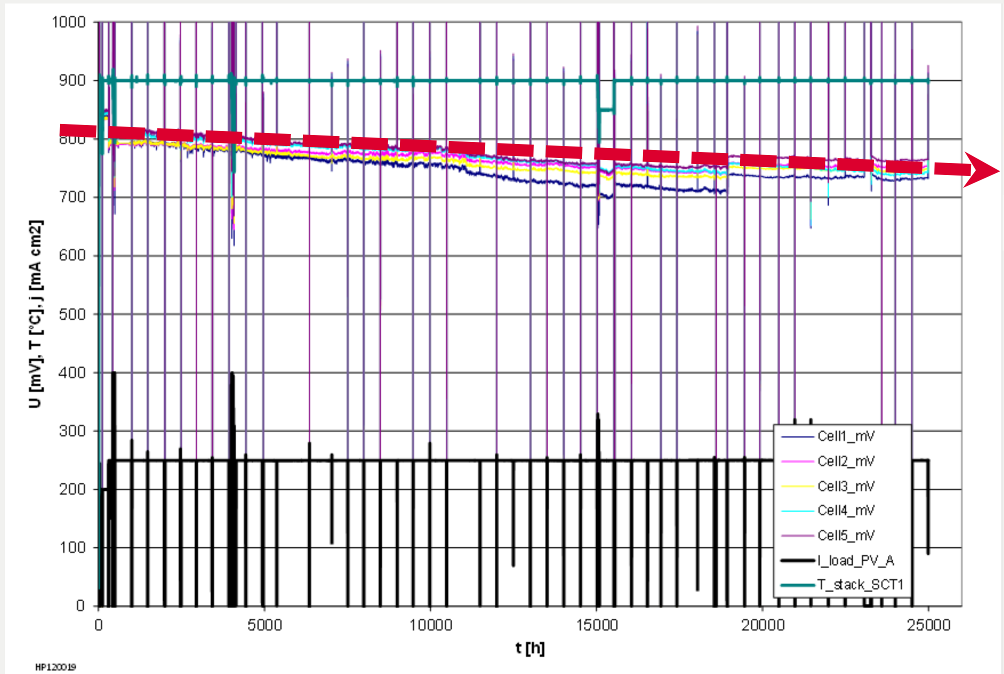


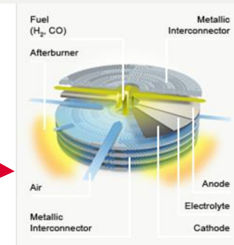
- No visible degradation due **to 50 complete on-off cycles, 20 modulations and 20 inverter disruptions**
- Simulation of "planned" and "unplanned" on-off cycles, to different ending temperatures
- "Unplanned": simulation of e.g. gas interruption or component failure
- Should be OK for 8 years stack lifetime
- **No signs of accelerated degradation of end-layers, repeated with similar behaviour**

Lifetime: steady-state degradation

Test on 5-cell stack

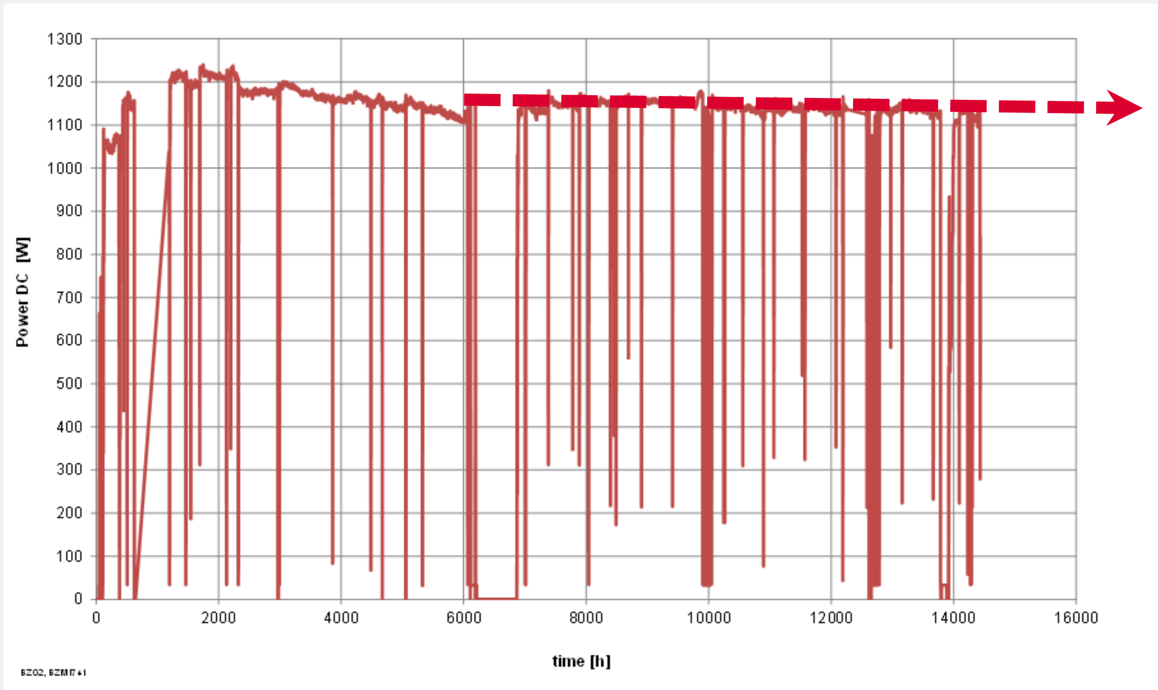
operated with natural gas (4 g/h per cell), 900°C





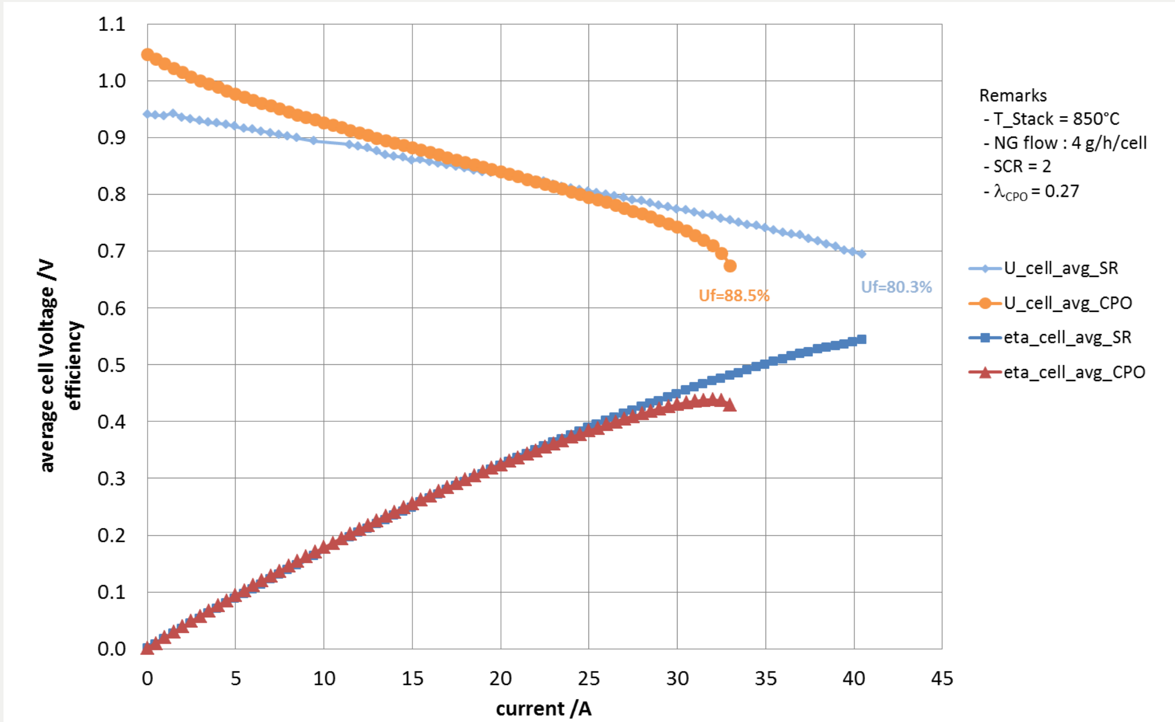
- Power density approx. 0.2 W/cm²; electrical efficiency approx. 39 % DC
- Voltage Degradation 0.5 % / 1000 h over 25000 h
- Fits well to the data measured on system level
- If degradation stays like this, stack lifetime of 40000 h can be achieved

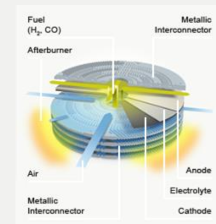
Lifetime: steady-state degradation
Lab-test on Galileo system



- Electrical efficiency 35 % AC, netto
- Degradation approx. 10 W/1000 h → approx. 0.8 % / kh
- Other tests with similar behaviour
- International and national collaborations have been very important for the understanding of degradation effects and implementation of improvements, e.g. the Swiss project *SOF-CH ESC* supported by SFOE

Increasing electrical efficiency: STR instead of CPO
Results of a 5-cell stack





- CPOx: electrical efficiency approx. 45 % (DC) with ≈230 mW/cm²
- STR: electrical efficiency approx. 55% (DC) with ≈280 mW/cm²

→ Reforming is the major parameter to increase the electrical efficiency in the Hexis system

→ But negative effects on complexity, robustness, reliability and costs can result

→ **Funded project supported by SFOE with the aim to implement STR as an alternative on system level a has just started**

Résumé and future

Résumé
Technical status & market

- Technical targets achieved on a statistical basis
- More than 250 Galileo systems built and operated (lab, field, market)
- Far more than 2 Mio. hours of operation experiences
- For SOFC very good cycling stability shown (also «unplanned»)
- Further important improvements on lifetime, reliability, robustness, etc.
- Simple installation verified by installers, broad application spectrum
- Challenges: cost; demonstration of predicted / extrapolated lifetimes

➔ **Technical readiness for pilot market entry achieved**

➔ **Market introduction started 2013**
(German-speaking part of Switzerland, selected partners in Germany)

Fuel cell heating appliance Galileo 1000 N
Future

- Expected / predicted / extrapolated lifetimes have to be demonstrated
- Besides further increase of lifetime and performance,
  cost reduction is the important current task
- Next system generation will include know-how & components from Viessmann and will be sold via the normal Viessmann distribution channels
- Steam reforming and higher efficiencies will be further topics for the future

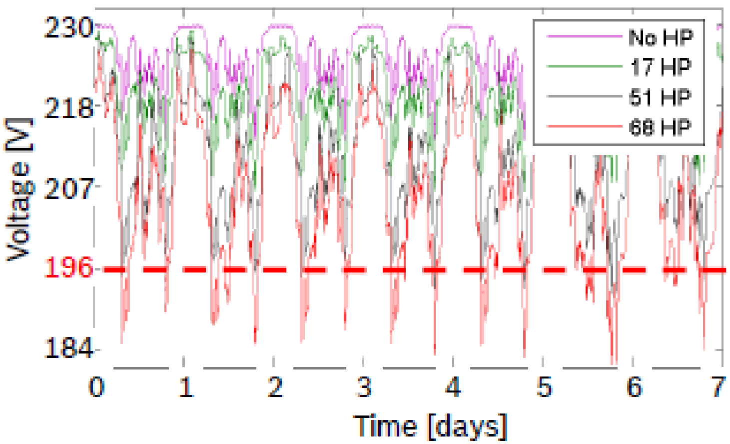
Thank you for listening!

Dr. Andreas Mai, HEXIS AG
Zum Park 5 | 8404 Winterthur | Switzerland
T +41 52 262 63 12 | F +41 52 262 63 33
andreas.mai@hexis.com | www.hexis.com

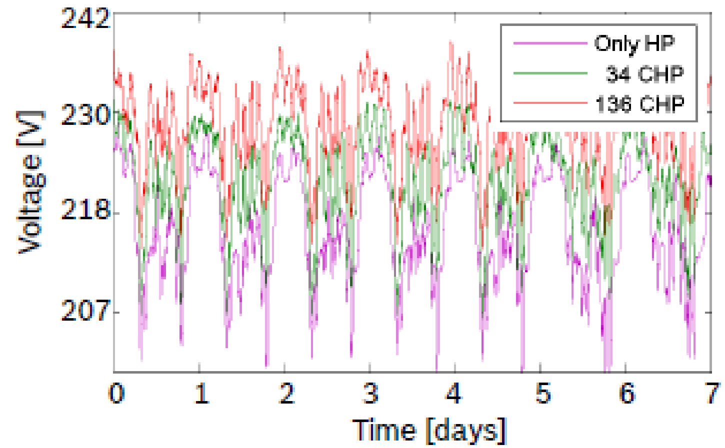
Fuel Cell Heating Appliance Galileo 1000 N
Voltage Profile mCHP and HP in a Grid

(existing suburban grid with 170 houses)

Penetrations with Heat Pumps



Penetrations with CHP (34 Heat Pumps)



- → 30% (51/170 houses) Heat Pumps in exemplary suburban grid cause under-voltage outside EN 50160 regulations.
- → In a grid with 20% Heat Pumps, a similar number of CHPs reduce under-voltage issues significantly.

Voltage issues due to 30% penetration with Heat Pump can be solved with CHP.
Rough Guide: 1 kW_{el} Fuel Cell CHP per 1 kW_{el} Heat Pump

[Quelle. BBT, 2013]