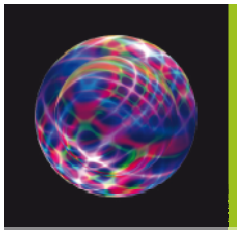
Josef Schefold, 21/09/17

# Hydrogen Production with Steam Electrolysis: A Glance at 15 Years of Durability Research in EIFER



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# Steam electrolysis with electrolyte supported solid oxide cell (SOC)

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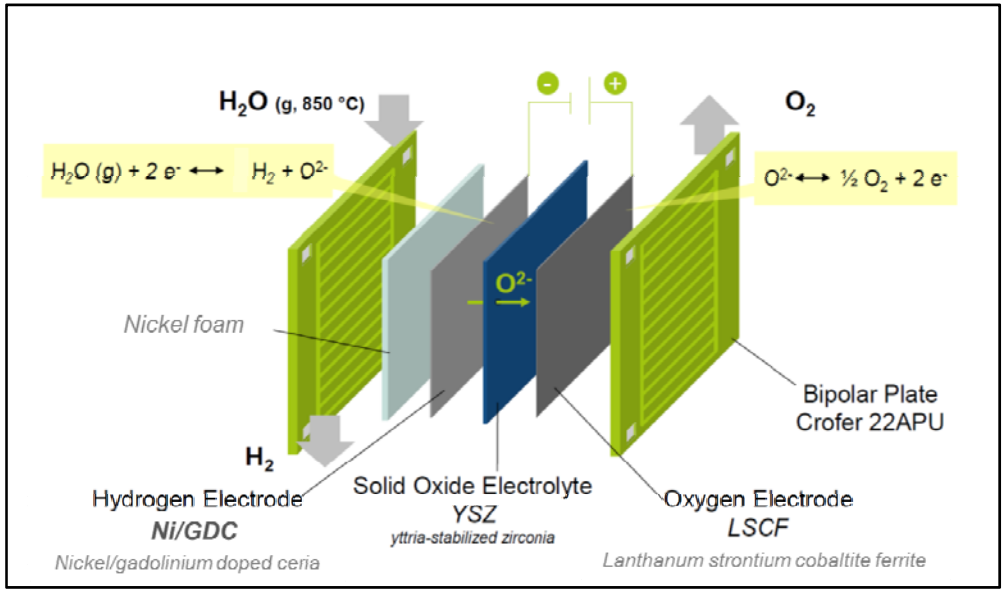
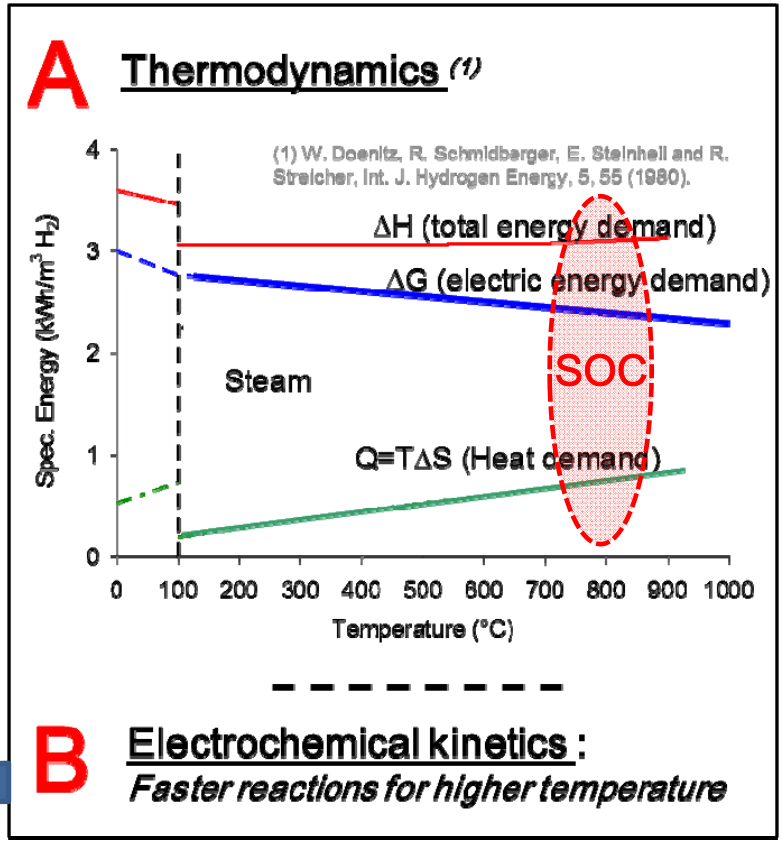
## Cell

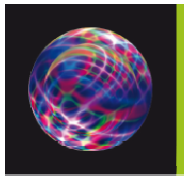



Source: adapted from GrInHy research project




- Highest efficiency
- No noble metal catalysts
- Co-electrolysis feasible ($H_2O/CO_2$)

# (Eifer-) History



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- Steam electrolysis done since the beginning (activites started in EDF in Les Renardières (F); context of European projects)
- Nobody left from the initial team
- Laboratories: → in Fraunhofer ICT and KIT
- Most urgent project work after lab creation: cell (& interconnect) testing
- Many follow-up projects…..

**<u>Goal</u>: Activities at interface *Applied Research* // *Development***

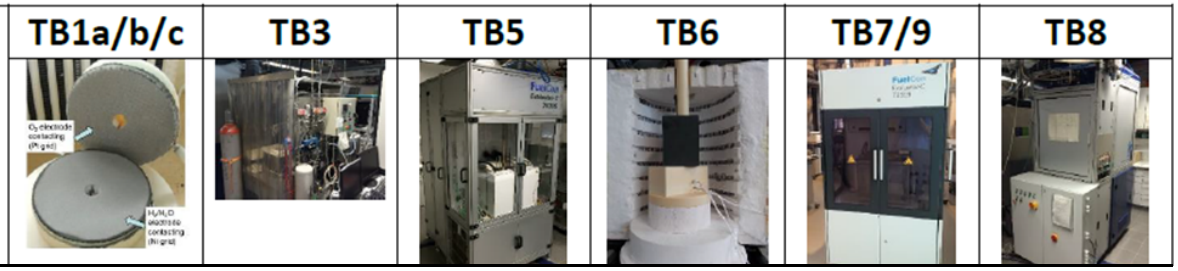
| | | |
|---|---|---|
| ***Scientific work***<br><br>***(→ Publishing)*** | ✚ | ***Work close to application (projects with the producers of cells, stacks & systems)*** |

# $H_2$ production with steam electroysis in Eifer

**Focus on (long-term) testing:**

- test benches for cells, short stacks (<1 kWel) and stacks (1-10 kWel)
- cells: (1): from different producers (DTU, FZ-Jülich, Ceramtec, Kerafol, Sunfire…)
  (2): reversible operation of existing fuel cells (SOFC)
- milestones & degradation analysis (impedance spectroscopy….)
- most critical bottleneck: no commercial testing equipment of sufficent reliability available

EIFER's SOC Test Facility at Fraunhofer ICT




**ScienceDirect:**

*Search in ''Internat. Journal of Hydrogen Energy'':*

High temperature water electrolysis in solid oxide cells Original Research Article
*International Journal of Hydrogen Energy, Volume 33, Issue 20, October 2008, Pages 5375-5382*
Annabelle Brisse, Josef Schefold, Mohsine Zahid
Abstract | PDF (792 K)

**10/2008: 170 h test**

23,000 h steam electrolysis with an electrolyte supported solid oxide cell Original Research Article
*International Journal of Hydrogen Energy, Volume 42, Issue 19, 11 May 2017, Pages 13415-13426*
Josef Schefold, Annabelle Brisse, Hendrik Poepke
Abstract | Graphical abstract | Research highlights | PDF (2613 K)

**5/2017: 23,000 h test**

# SOFC = SOEC = SOC ?

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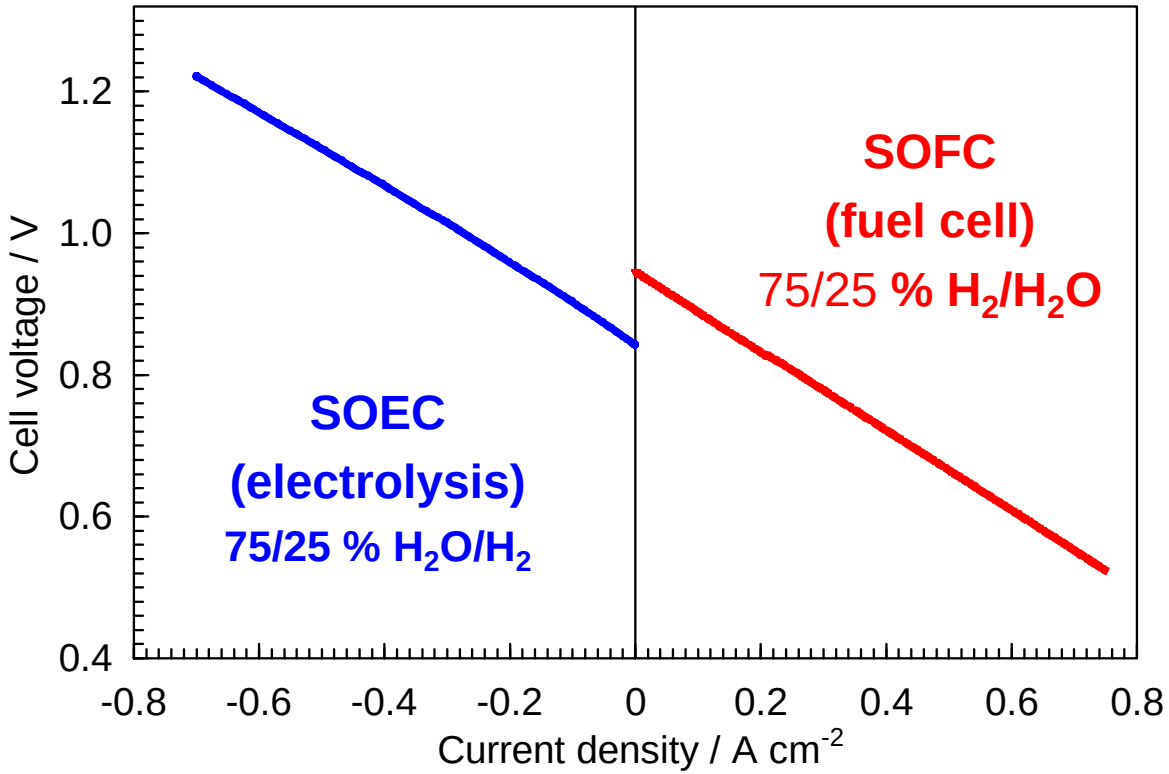
Reversible operation example (Sunfire cell; 850°C)




**Solid oxide cells at high temperature:**

- fast electrode kinetics → suitable for **reversible operation**

**Present:** fuel cells (SOFCs) usable for electrolysis

**Future:** increasing specific electrolysis-cell (SOEC) development

## SOEC Applications

- $H_2$ production
- Co-electrolysis ($H_2O/CO_2$)
- Power-to-gas
- Synfuel production
- Electricity grid stabilization
- Reversible operation (rSOCs)

***Issue for all*: Durability**

# SUNFIRE Project (2012-16): Power-to-Liquid with SOEC Technology (‘’Sector Coupling”)

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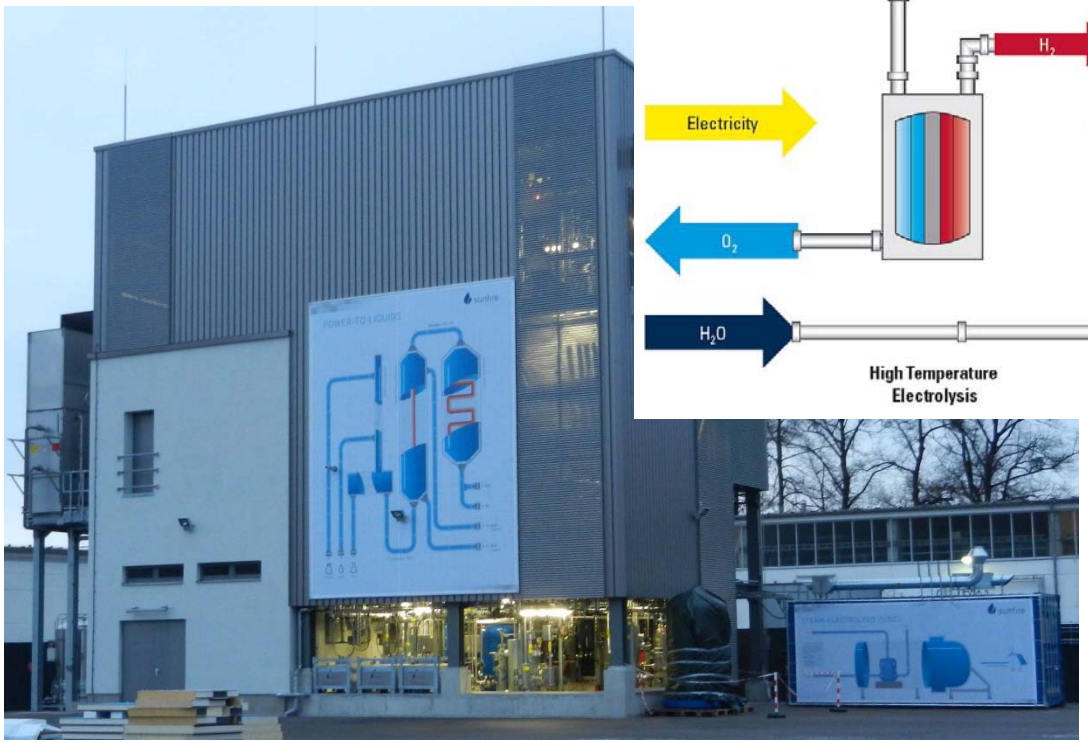

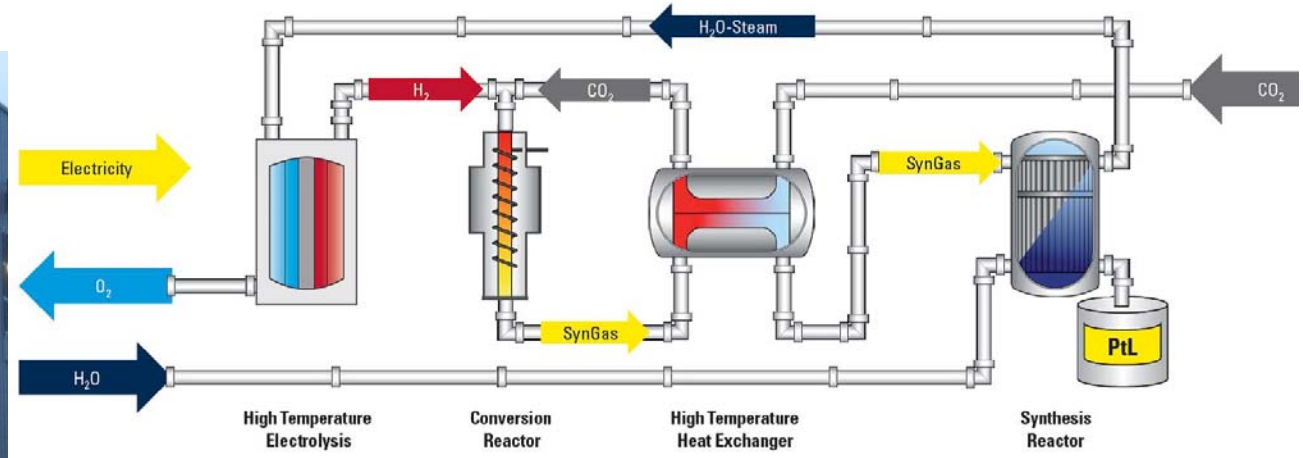


Source: <sunfire.de>

sponsored by the German Federal Ministry of Education and Research

**Demonstration project**

- production: 1 barrel petrol equivalent/day
- $H_2$ supply with SOEC (partial)

High temperature electrolyser, **10 kWel**

***EIFER: - cell/short stack testing (milestone 1000 h)***
***- ‘side result’: 23,000 h test***

# GrInHy Project of EU (2016-19) on Reversible SOC

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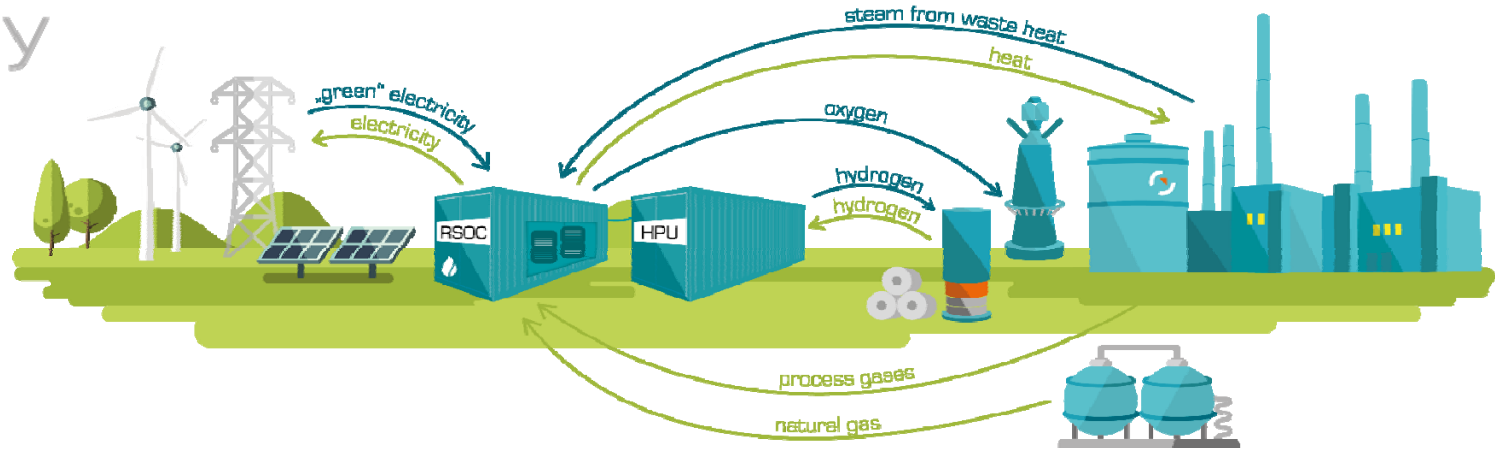
GrInHy
Green Industrial Hydrogen

http://www.green-industrial-hydrogen.com




***Cell/stack testing by EIFER***

| | |
|---|---|
| Efficiency | proof of reaching an overall electrical efficiency of at least 80 %LHV |
| Upscaling | SOEC unit to a DC power input (stack level) of 120 $kW_{el}$ |
| Operation | at least 7,000 h of operating the system |
| Lifetime | greater than 10,000 h with a degradation rate below 1 %/1,000 h |
| Reversible Operation | higher capacity utilization for stronger business cases |
| Costs | development of dependable data on system costs and cost reductions |
| Exploitation Roadmap | reversible high-temperature electrolyzer as a marketable product |

**SOEC:120 $kW_{el}$**

# GrInHy Reversible SOC Installation (06/2017)


GrInHy system in Salzgitter (D)


Container of the Reversible Solid Oxid Cells (RSOC) in Salzgitter

**SOEC: 120 $kW_{el}$**

**SOFC: 30 $kW_{el}$**



GrInHy Green Industrial Hydrogen

FCH FUEL CELLS AND HYDROGEN JOINT UNDERTAKING

# EIFER test 2010-2011: Electrode supported cell, 9,300 h @ -1.0 Acm$^{-2}$

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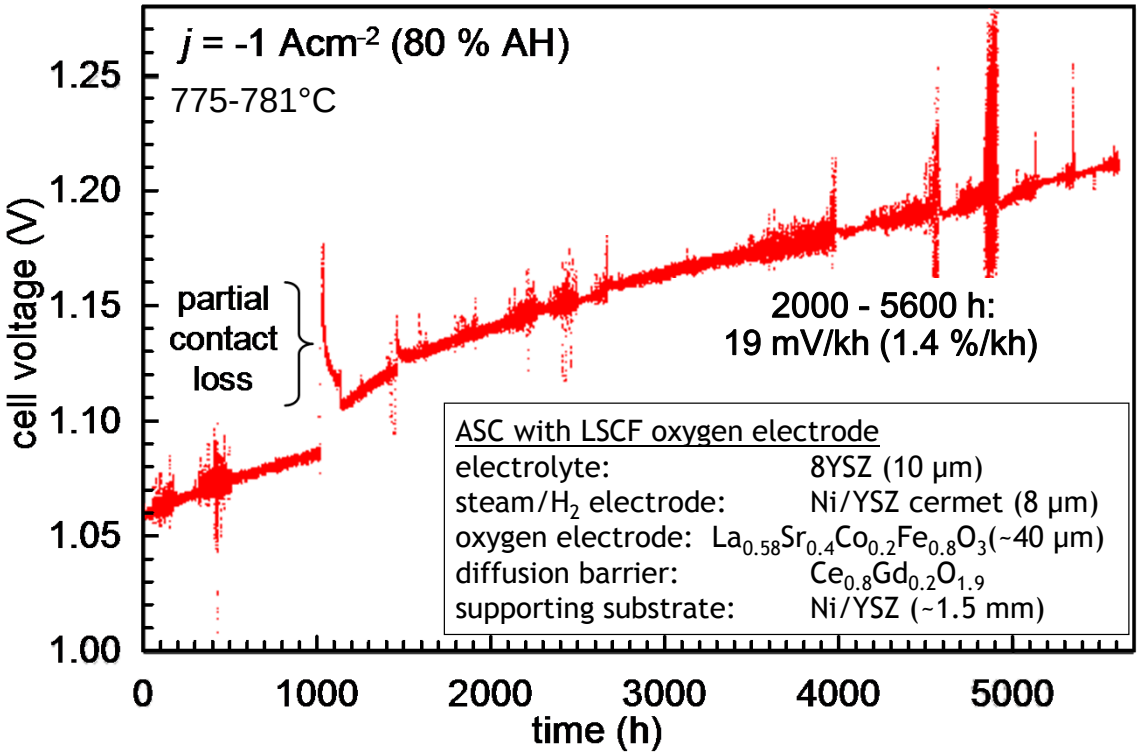
## Cell voltage vs. time (cell from FZ Jülich)




- **Longest reported test at that time**
- High current density
- Incidents & unstable steam supply
- Overall degradation
  40 mV/kh (3.1 % kh)
- **Degradation without incidents (2-5.6 kh): 19 mV/kh (1.4 %/kh)**

- **Further equipment improvement required**
- **Basis for HORIZONT project (BMWi 2011-2015)**


(a) J. Schefold, A. Brisse and F. Tietz, *J. Electrochem. Soc*. **159** (2), A137 (2012).
(b) F. Tietz, D. Sebold, J. Schefold, A. Brisse, *J. Power Sources*, **223**, 129 (2012).


Bundesministerium für Wirtschaft und Technologie

# EIFER test 2013-2016: Electrolyte supported cell; 20,000 h @ -0.9 Acm$^{-2}$ (SUNFIRE project)

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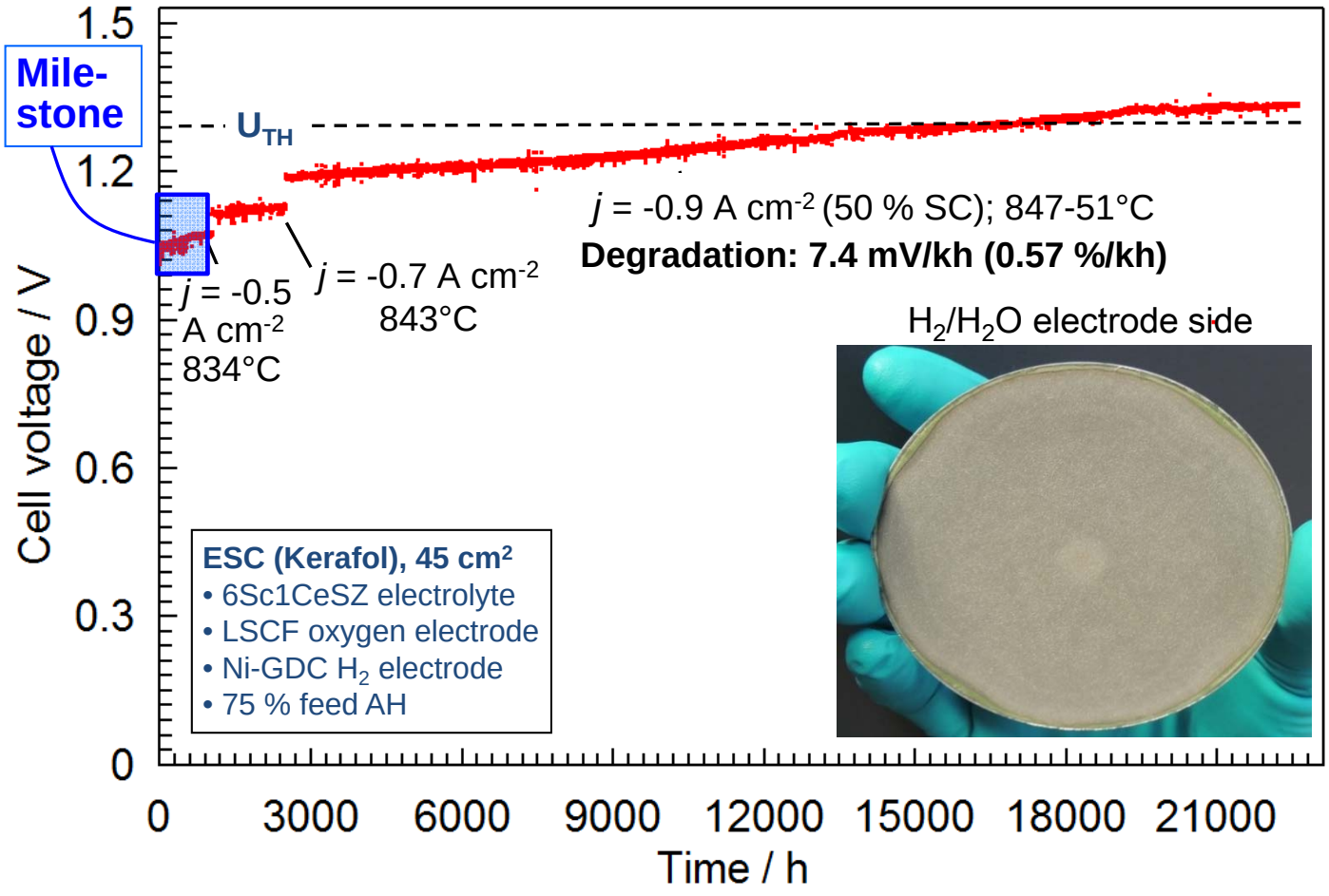
## Cell voltage vs. time




- longest reported test
- highest reported ESC current density

2 years: $U_{cell} < U_{th}$
$U_{th}$ : thermal neutral voltage → operation at theoretical efficiency

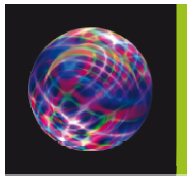
**Impedance spectroscopy:** mainly ohmic degradation (electrolyte, interlayers)
**Post-test:** Si pollution from water (Q. Fu (Eifer), M. Lorenzo, ICT))

Federal Ministry of Education and Research

From: J. Schefold, A. Brisse, H. Poepke, *Int. J. Hydrogen Energy* **42** (2017), 13415-26.

# Summary / Outlook

1. **Focus on long-term testing: Comparison of cells/stacks from different producers**
2. **<u>Today</u>: degradation puts upper current limit to electrode supported cells (~0.7 to 1 $Acm^{-2}$)**
3. **EIFER world record: 23,000 hours with 0.6 %/kh voltage degradation at 0.9 $Acm^{-2}$ current density (electrolyte supported cell from Kerafol)**
4. **Runnig work / Outlook**
   - ***testing of industrial cells (Sunfire….)***
   - *further reduction of degradation & increase in power density & steam conversion*
   - *power modulation*
   - ***co-electrolysis***
   - *stack & system testing up to 10 kW power range*
   - *Quality assurance/ test procedures (European SOCTESQA project)*



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# Thank you for your attention!



EDF KIT Karlsruhe Institute of Technology