Field Test Experience with Areva's PEM Electrolysis Systems

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Content

AREVA in Germany short information

Smart Grid Solar Project – AREVA Scope - The hydrogen chain

Close up: The AREVA PEM electrolyser used in the project

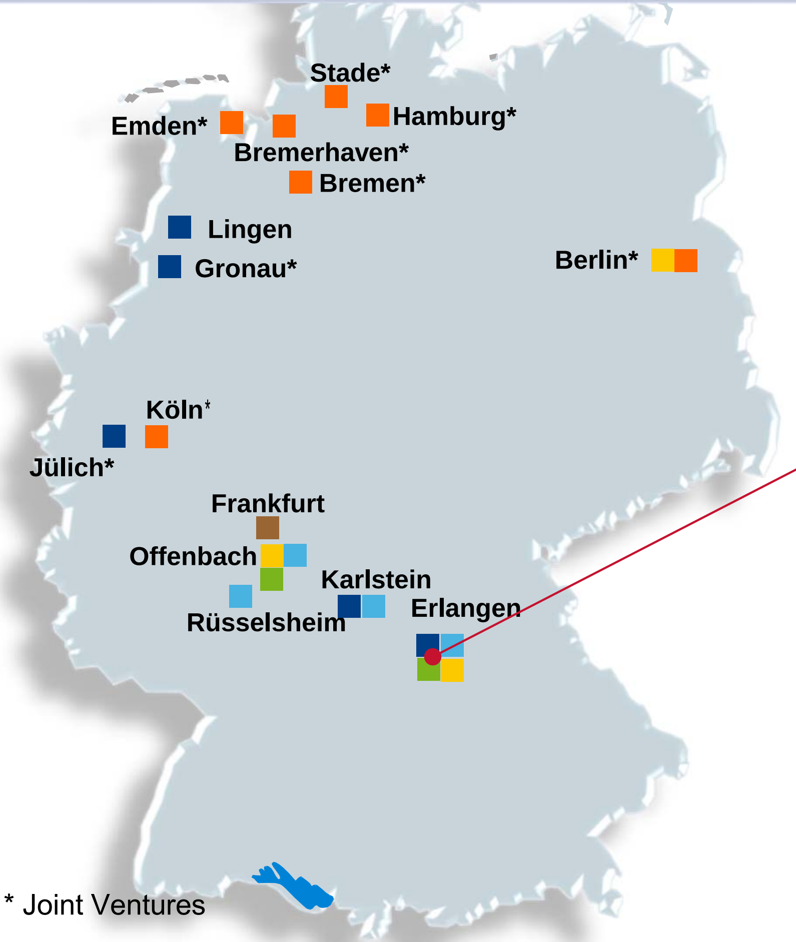
The PEM elektrolyseur in the field – measurements from the testfield Arzberg

AREVA in Germany

4.100 AREVA-Employees in Germany (41.000 worldwide)

Sales in Germany (2014)*: 1,1 B€
(Germany 29%, Export 71%) (8,3 B€ worldwide)

* IFRS



* Joint Ventures

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- 100% **AREVA Renewables**
  - 40 % **AREVA H2 Gen**
- 100% **AREVA NP**
  - 100% **AREVA GmbH**
- 100% **AREVA NC**
- 100% **AREVA Mining**

Mining | Front End | Reactors and Services | Back End | Engineering & Projects | Renewable Energy

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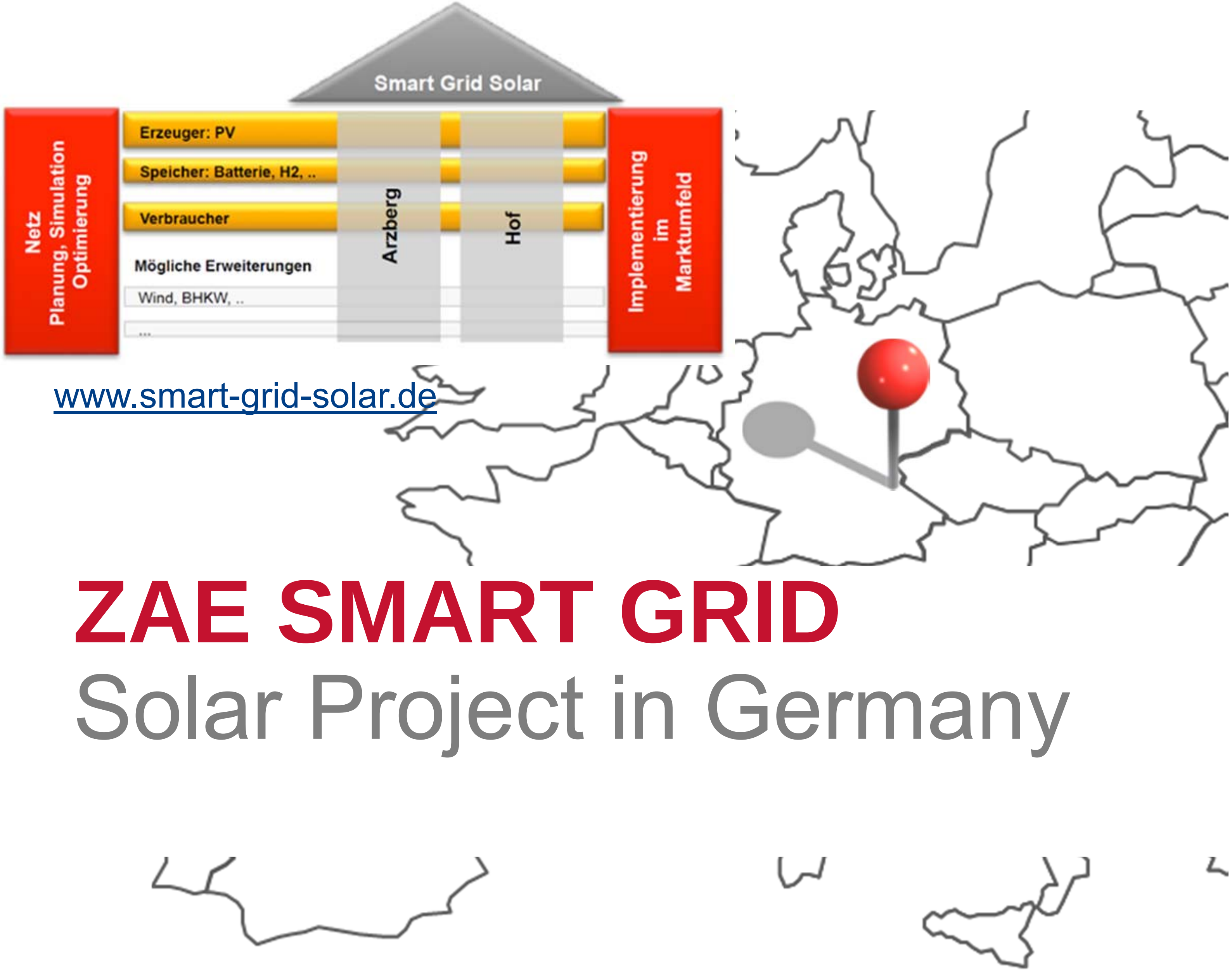


www.smart-grid-solar.de

ZAE SMART GRID

Solar Project in Germany

The hydrogen chain

„Green production“

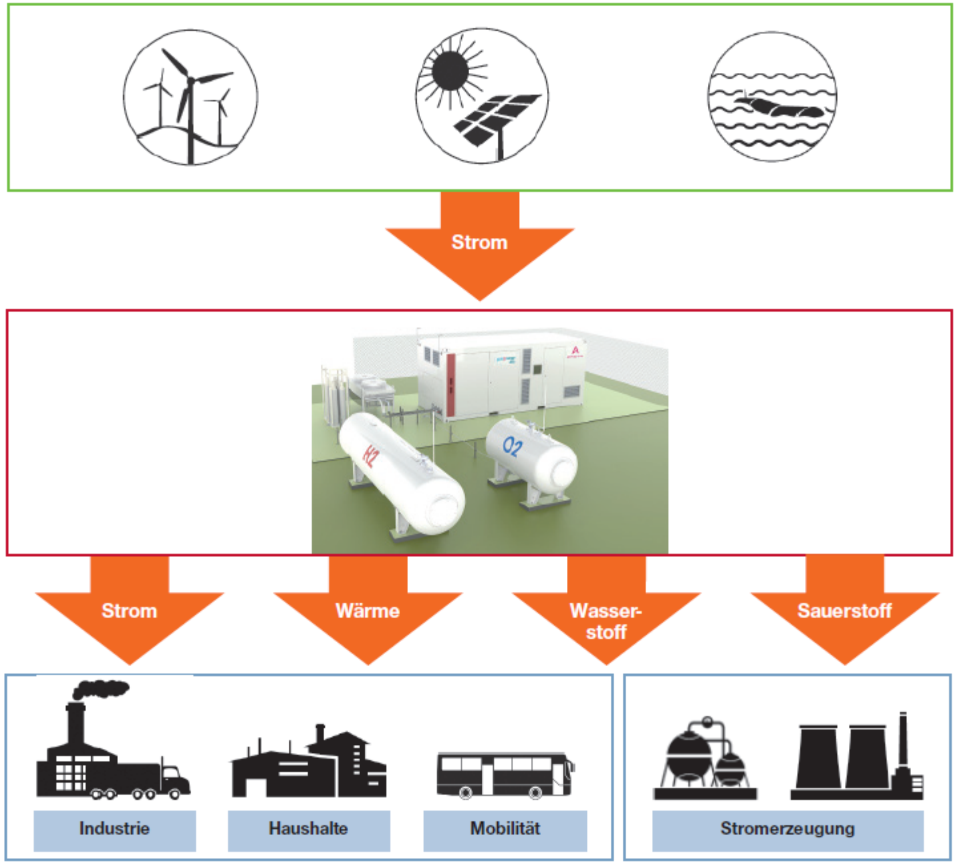
- „green“ production of hydrogen (Solar, wind turbine)

→ H_2/O_2 production via water electrolysis

- Hydrogen as energy storage (electricity storage, thermal use, grid stabilization)

→ Multiple-use applications

- Hydrogen as a substitute of fossil fuels (Cars, Fuel Cell utility vehicles, Electricity-/H_2 – gas station)
- Power to Gas
- Power to Chemicals



- **Wasserstoffmobilität (Lokale Flotten: Autos, Taxis, Busse, Gabelstapler etc.)**
- **Industrieanwendungen (direkte Nutzung von Wasserstoff, Sauerstoff und Wärme)**
- **Kommunale Einrichtungen (Schwimmbäder, Hotels, Nahwärme etc.)**

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The hydrogen chain
at the Smart Grid Solar Project

75 kW PEM Elektrolyzer

Hydrogen production

Topics for the testing:

- Smoothing of fluctuating PV-grid fed in profiles
- Dynamics of a PEM ELY
- Efficiency at partial load
- Combination of short/long-term storage components

300 kWh LOHC* Storage

Long-term storage

*) LOHC = Liquid Organic Hydrogen Carrier

- Performance of LOHC storage
- Steady hydrogen production for seasonal storage
- Cycle stability of LOHC
- Degradation LOHC
- Technology field test(TRL 7)

5 kW Fuel Cell

Reconversion

- Dynamics of PEM fuel cell
- Extension of feed-in times (virtually)
- Combination of short/long-term storage components

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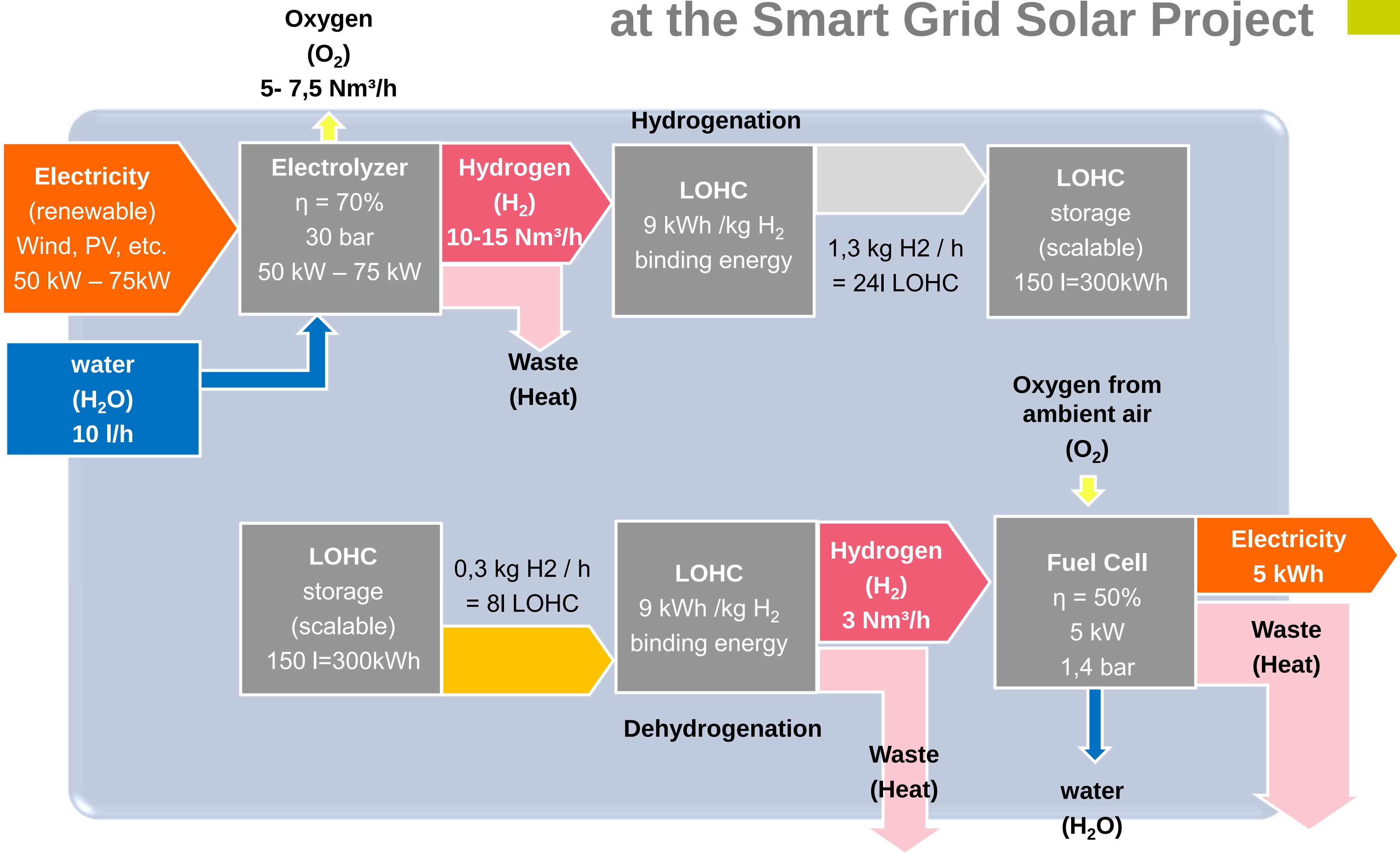
The hydrogen chain
at the Smart Grid Solar Project



The hydrogen chain
at the Smart Grid Solar Project

75 kW
PEM Elektrolyseur

Wasserstofferzeugung

Themen für die Komponententests:

- Glättung von unsteten PV Einspeiseprofilen
- Dynamik eines PEM ELY
- Effizienz unter Teillast
- Kombination Kurzzeit-Langzeit Speicherkomponenten

300 kWh
LOHC* Speicher

Langzeitspeicher

*) LOHC = Liquid Organic Hydrogen Carrier

- Betriebsverhalten LOHC Speicher
- Konstante Wasserstoffproduktion als Saisonalspeicher
- Zyklenstabilität LOHC
- Degradation LOHC
- Technologie Feldtest (TRL 7)

5 kW
Brennstoffzelle

Rückverstromung

- Dynamik der PEM BZ
- Virtuelle „Einspeiseverlängerung“ (in die Nacht)
- Kombination Kurzzeit-Langzeit Speicherkomponenten

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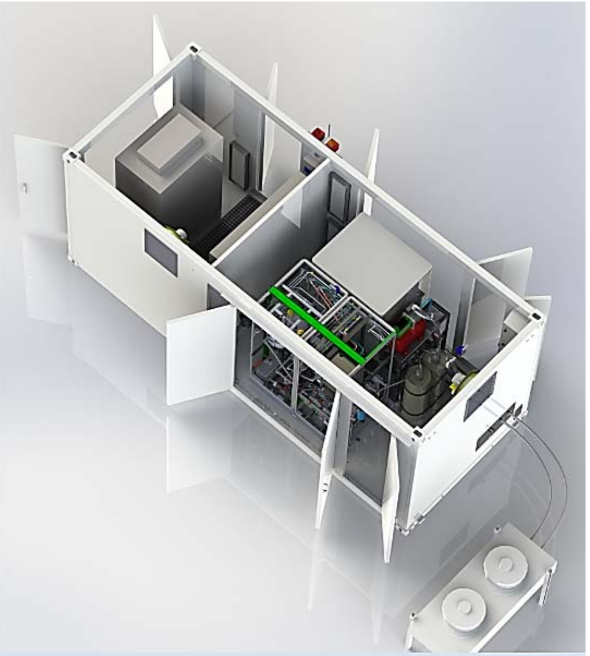
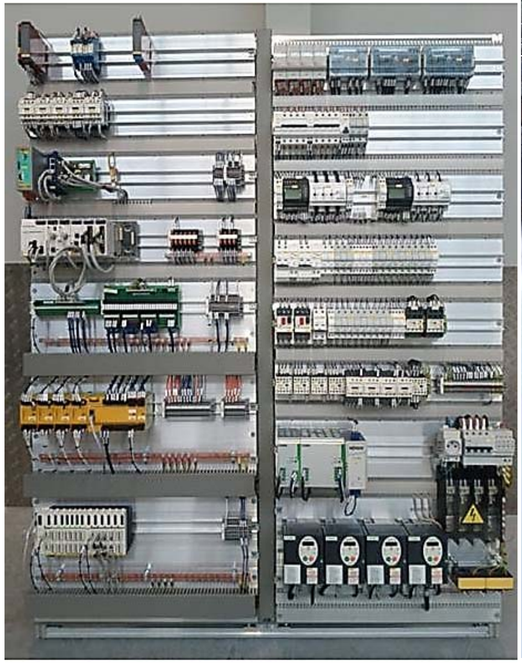
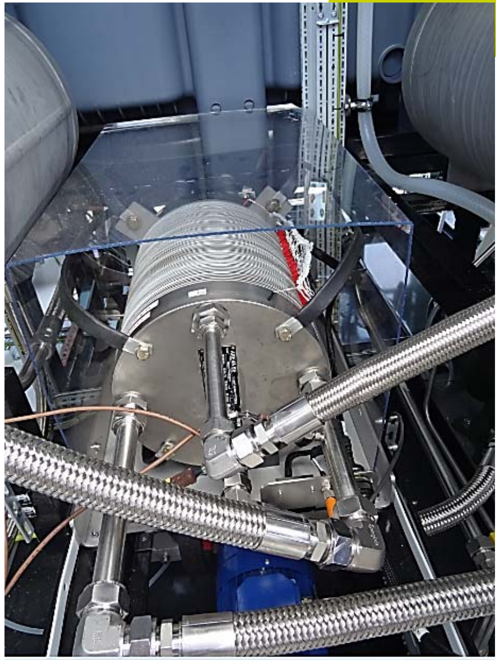
- AREVA in Germany short information
- Smart Grid Solar Project – AREVA Scope - The hydrogen chain
- **Close up: The AREVA PEM electrolyser used in the project**
- The PEM elektrolyseur in the field – measurements from the testfield Arzberg

Details and characteristics of the electrolyser



N°	Characteristics Stack design: 65 cells, active surface 300cm²	Measured values
1	Nominal flowrate: 10Nm³ H_2/h (370 amp in the stack)	370 amp
2	Maximum flowrate: 15Nm³ H_2/h (550 amp in the stack)	520 amp /14.2Nm³ H_2
3	Nominal Pressure: 35barg H_2 for 75kW	80kW 35 barg H_2, 34 barg O_2
4	Overall electrical consumption < 5kWh/Nm³ at nominal flowrate	ok
6	Operating range (in % of nominal flowrate): 10-150%	ok
7	Power from local grid connexion 400V TRI	395V
8	CE certification	ok

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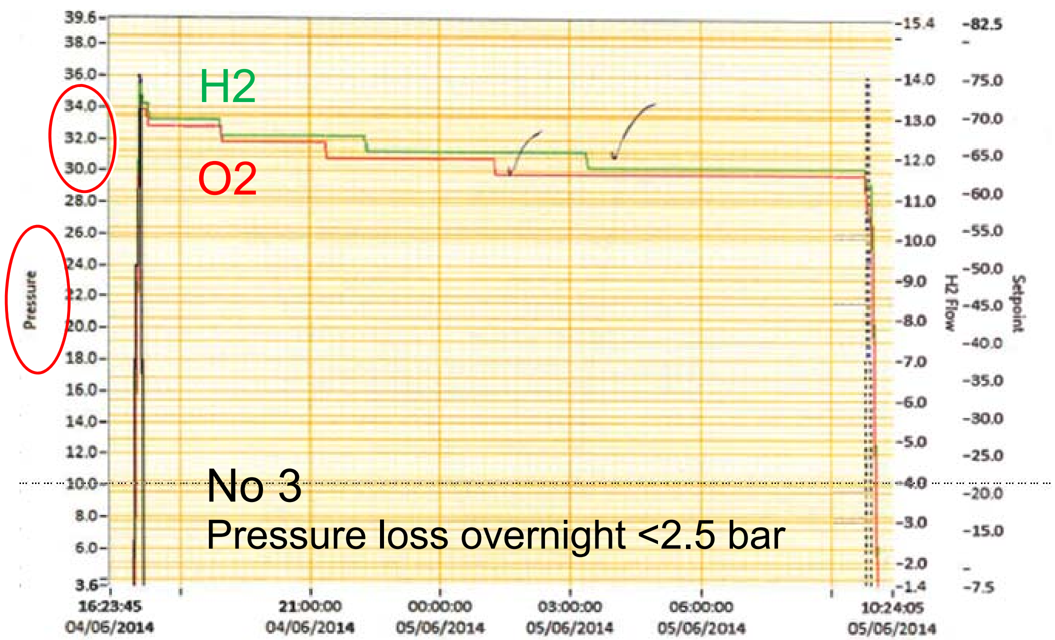
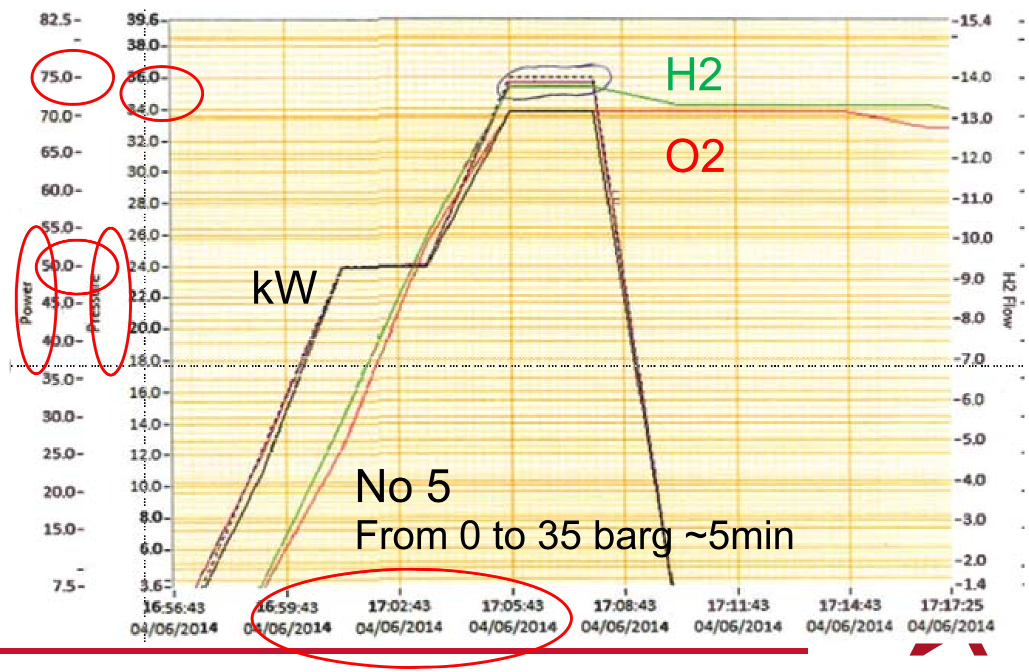
Characteristics measurements from factory acceptance test

N°	Step	Supply	Value obtained
1	Start up set	Time (s) to contactor (first current on the stack) closure to reach set power (50 kW) , starting at 0barg	~ 95sec
2	Power range	Average value of cells voltage at 550 amp (74,7kW, 14,11Nm³/h, 524A)	130V/65 cells
3	Stand by >12h	Pressure loss during longterm hot stand-by H_2 and O_2 pressure curves in function of time	H2 < 2.5 bar
4	Hot stand-by max	Time (s) to contactor (first current on the stack) closure to reach maximum power (75 kW) , starting at 35barg	~14sec
5	Cold stand-by max	Time (s) to reach 35barg at maximum power (75kW)	~ 5min 44sec





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Delivery and installation
of the PEM Electrolyzer, 65 cells, 300cm², 35 bar

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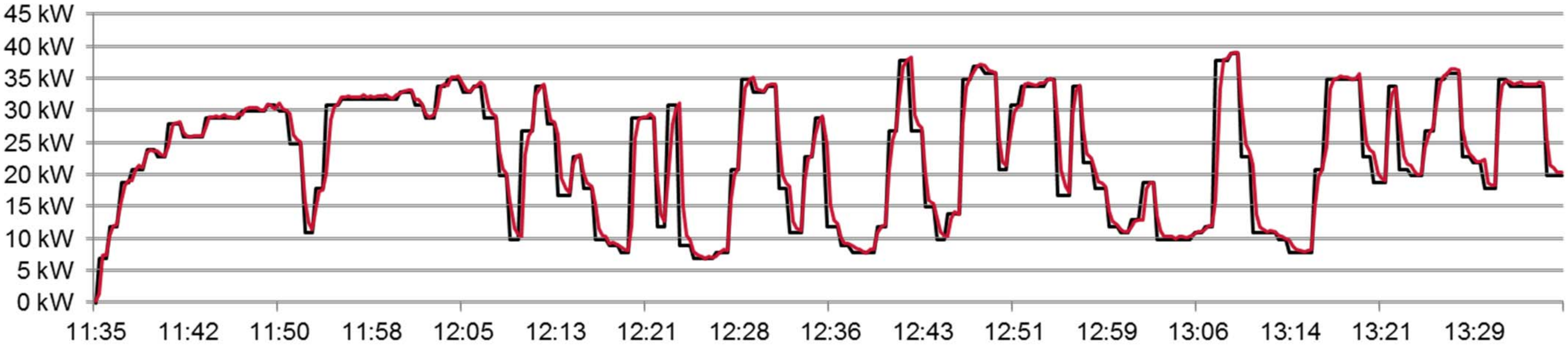
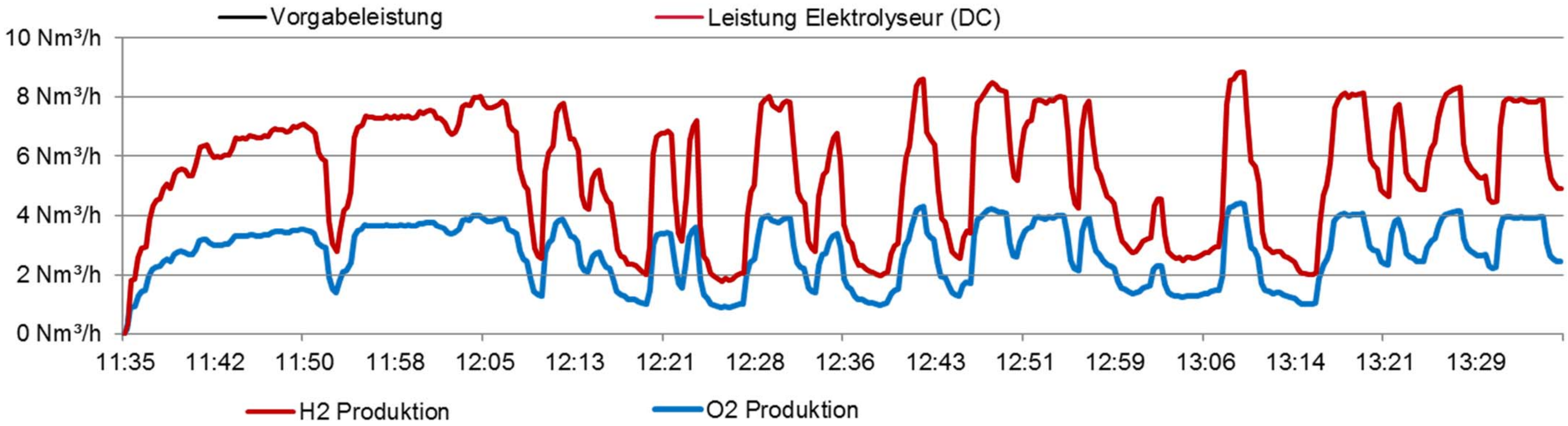
Measurements from the testfield in Arzberg:
Dynamics: Following the PV-Profile

Nachfahren eines PV-Profils vom 13.05.2015





The PEM electrolyzer follows volatility without problems
Dynamic H2 und O2 production from „green electricity“

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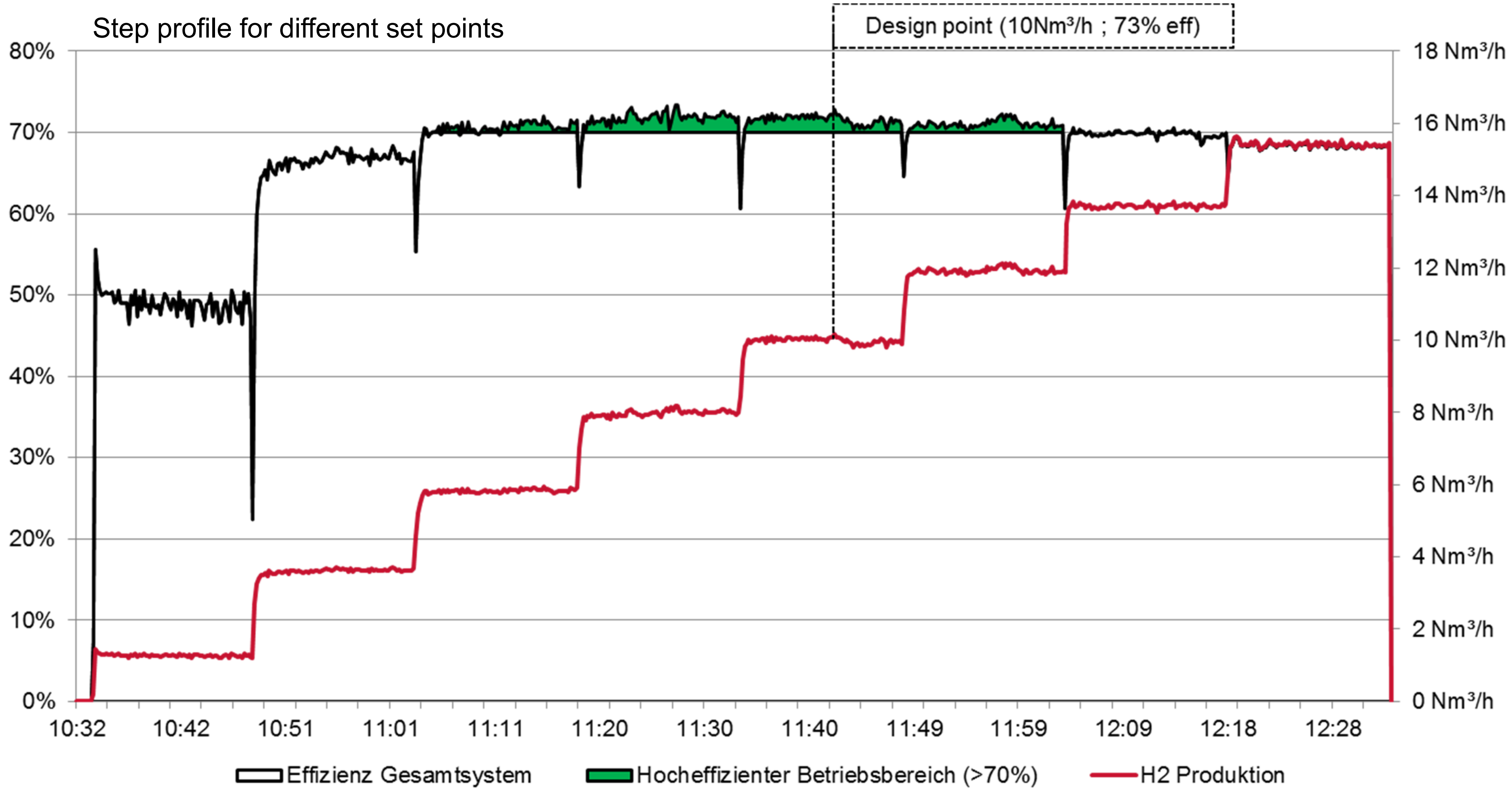
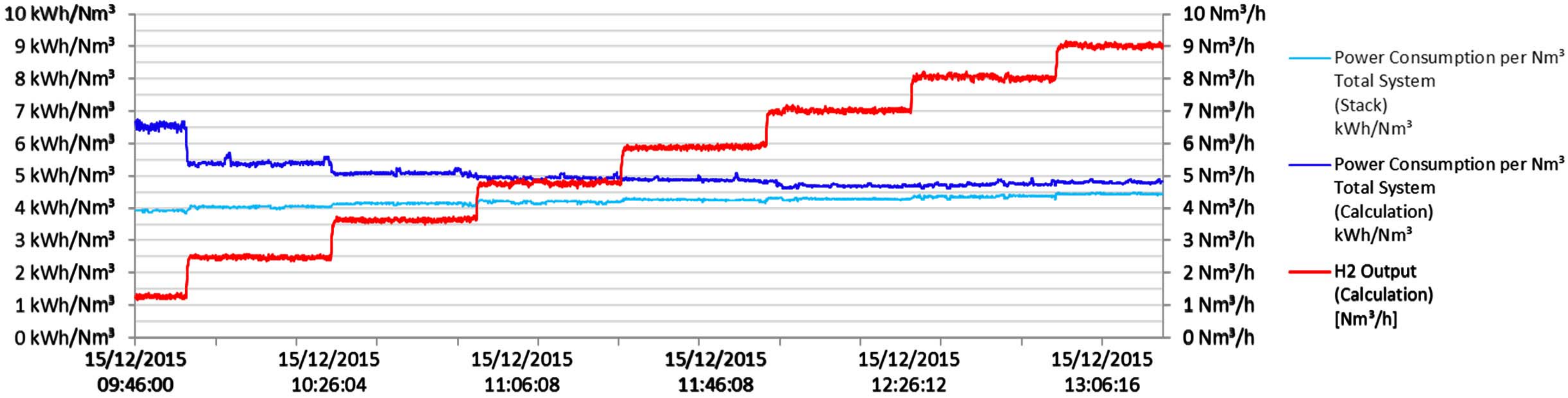
Measurements from the testfield in Arzberg:
Efficiency complete system vs. hydrogen production

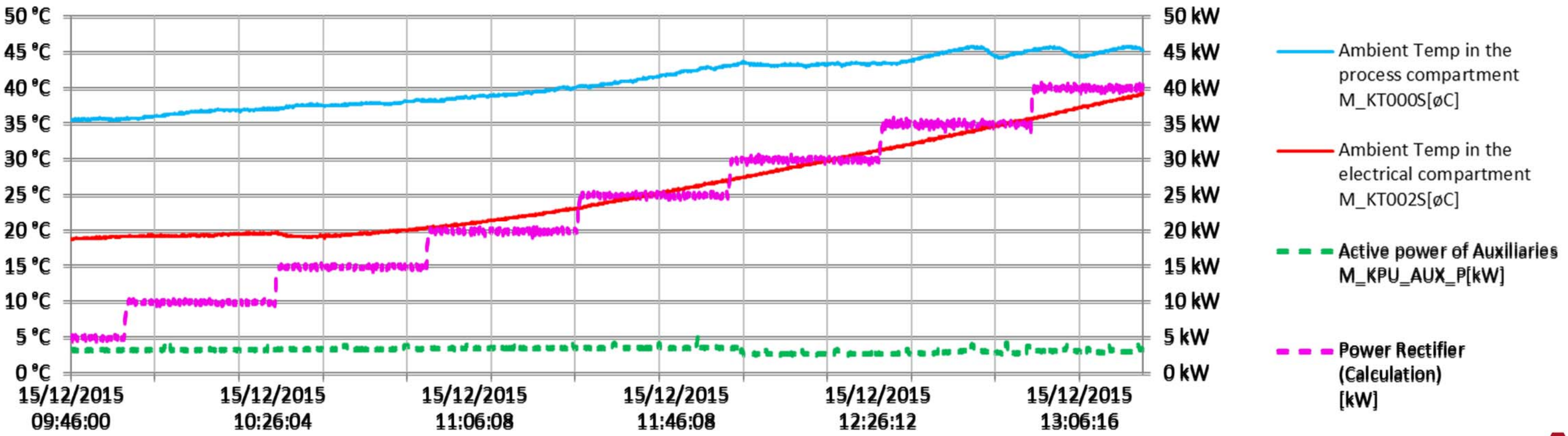


High efficiency over a large operating range, highest efficiency at the design point

Alll values based on heating value (HHV – 3,54 kWh/Nm³)

Measurements from the testfield in Arzberg:
Energy consumption stack vs total system





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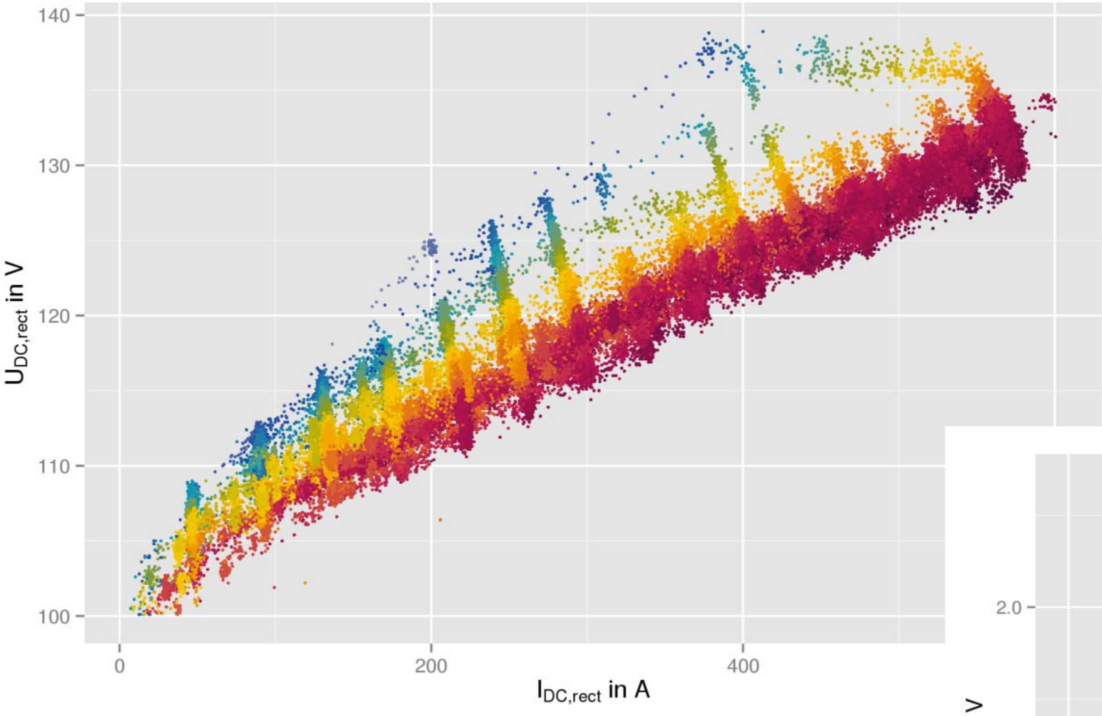
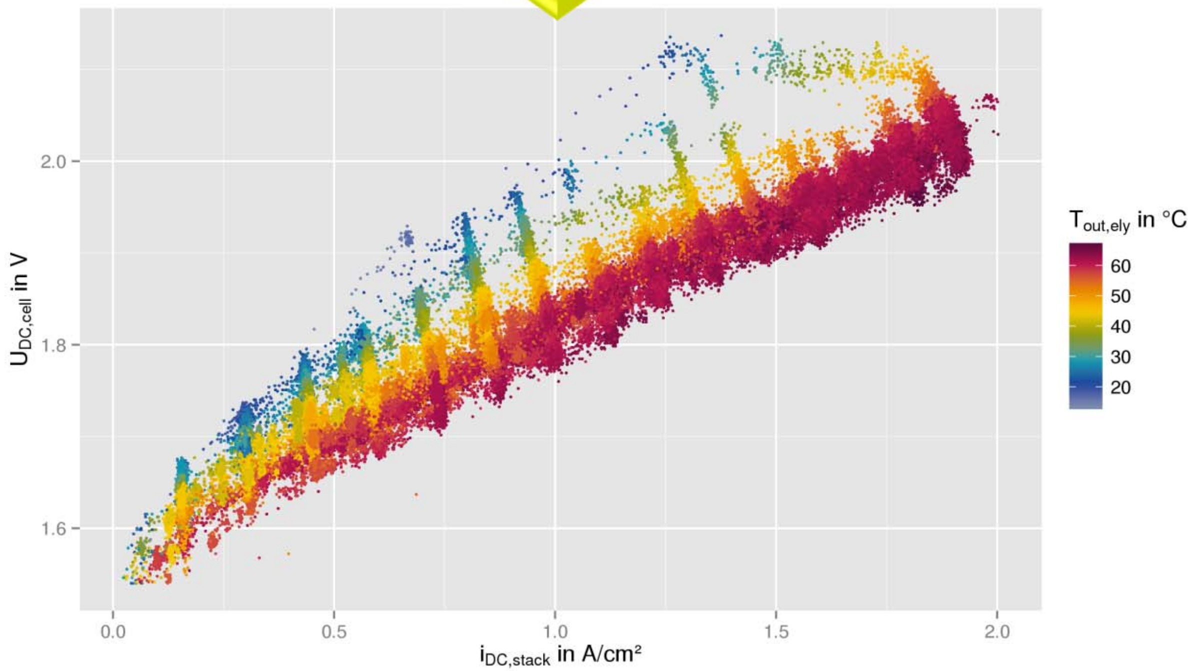
Measurements from the testfield in Arzberg:
U-I curves and temperatures



Per stack

Per cell



- **Each measurement = 1 dot**
- **T values taken every second at the stack outlet**
- **Cold temp = start ups**
- **Isoline stripes = process control keeps the DC power to the set value because (U_{DC} *I_{DC} =const)**

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Energy storage

Thank You for the attention!

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