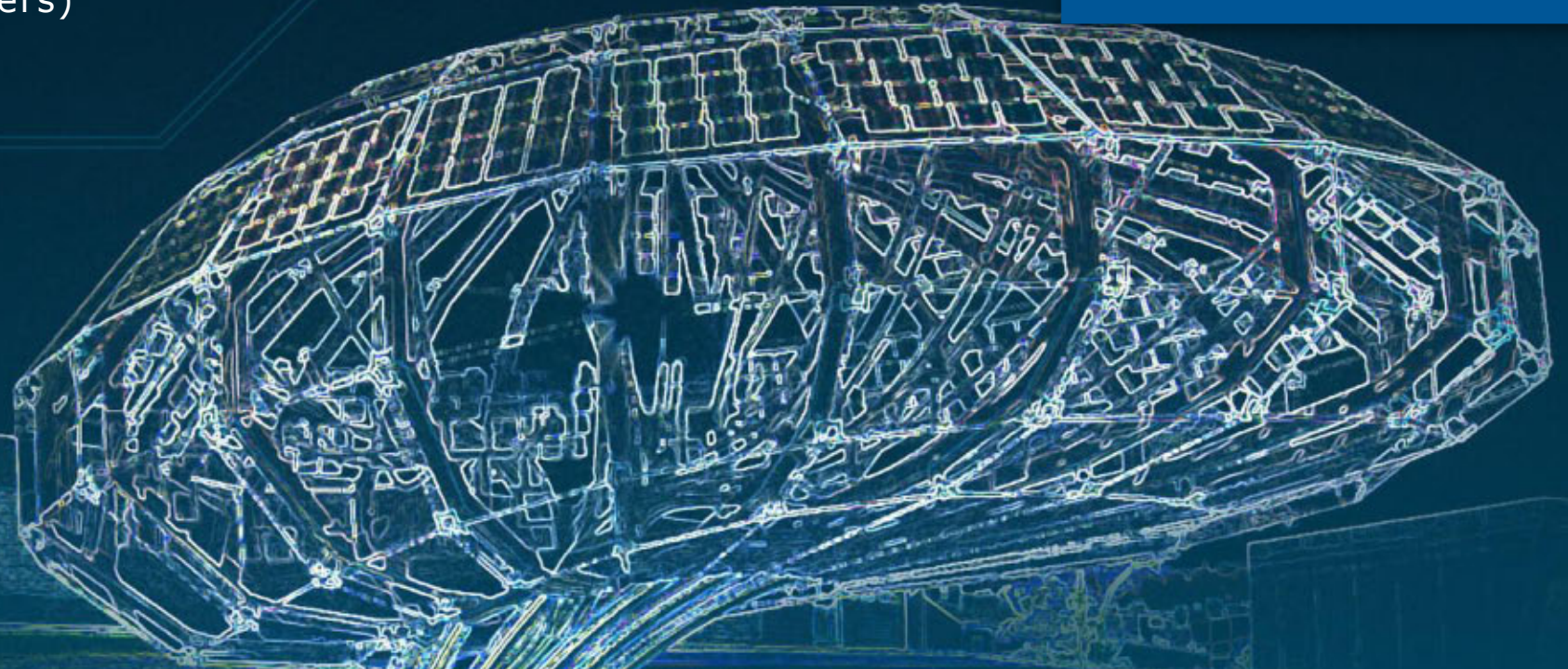


AVL



AVL List GmbH (Headquarters)



Solid Oxide Fuel Cell Combined Cooling, Heating and Power using Renewable Fuels for a Sustainable and Highly Efficient Energy Supply

**Michael Seidl**

# AGENDA



- Introduction
- SOFC CCHP
- Fuel flexibility
- Conclusion
- Outlook

# AVL – WORLD WIDE



**America**  
 Argentina  
 Brasilia  
 Canada  
 Mexico  
 USA

**Europe**  
 Germany  
 France  
 United Kingdom  
 Italy  
 Austria (HQ)  
 Poland  
 Romania  
 Russia  
 Sweden  
 Slovenia  
 Spain  
 Czech Republic  
 Turkey  
 Hungary

**Asia**  
 China  
 India  
 Indonesia  
 Japan  
 Korea  
 Thailand

**Australia**

■ Headquarter – Fuel Cell Development Center  
 ■ Fuel Cell Development & Sales



**9500 employees (3850 in Graz)**  
**45 affiliates**  
**Turnover 2017: > 1550 Mio €**

# AVL COVERS MANY CUSTOMER SEGMENTS

Development of powertrains - combustion engines, hybrid systems, electric drive - simulation and test systems



Passenger Cars



2-Wheelers



Racing



Construction



Agriculture



Commercial Vehicle



Locomotive

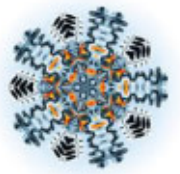


Marine



Power Plants

TRADITIONAL CORE BUSINESS



Powertrain Engineering



Advanced Simulation Technologies



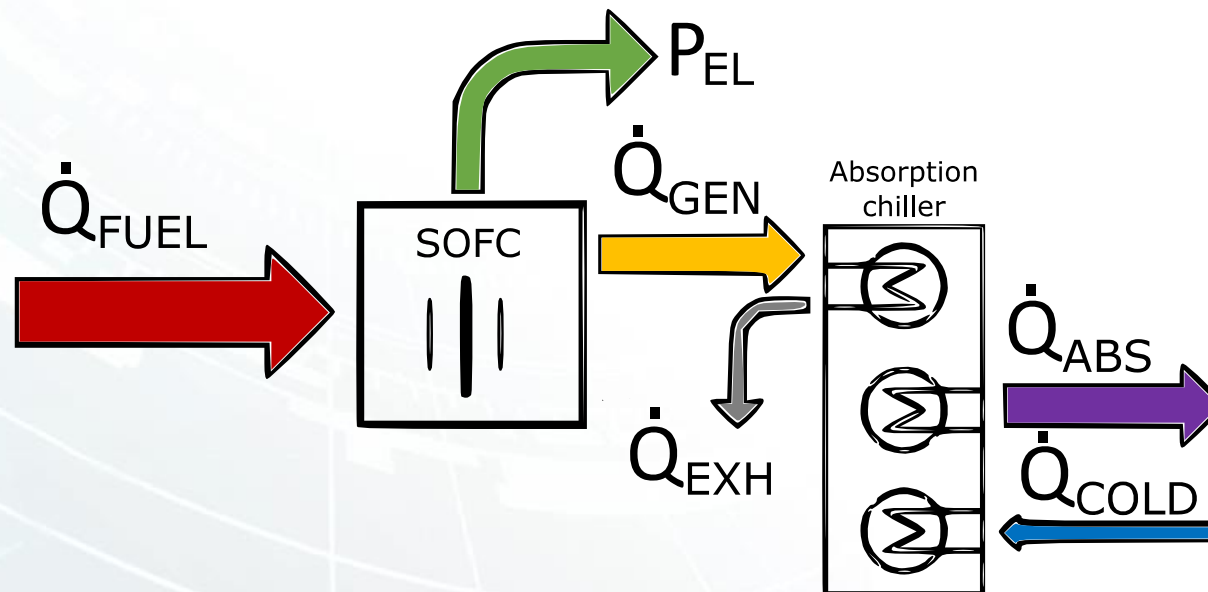
Instrumentation and Test Systems



PEM & SOFC Engineering  
(since 2002)

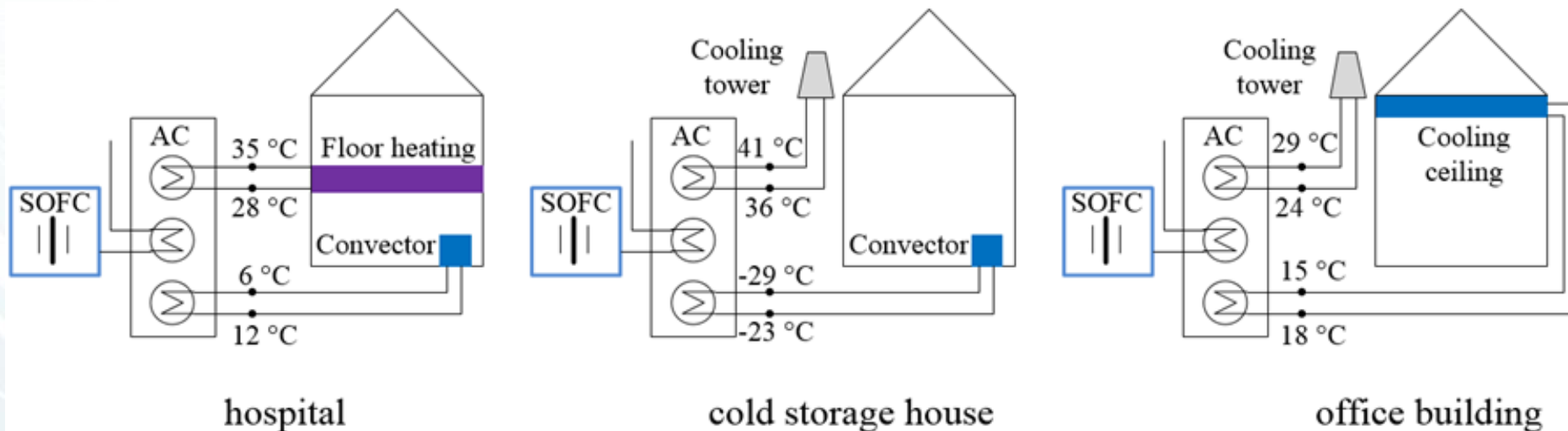
# SOFC CCHP - R&D project „SOFCool“

- **6 kW<sub>el</sub>** SOFC system for biogas and renewable diesel  
Steam reforming and hot anode gas recirculation  
Electrical efficiency >55 %  
Gas cleaning unit (S, Cl and NH<sub>3</sub>)
- **5 kW<sub>cold</sub>** absorption heat pump by TU Graz



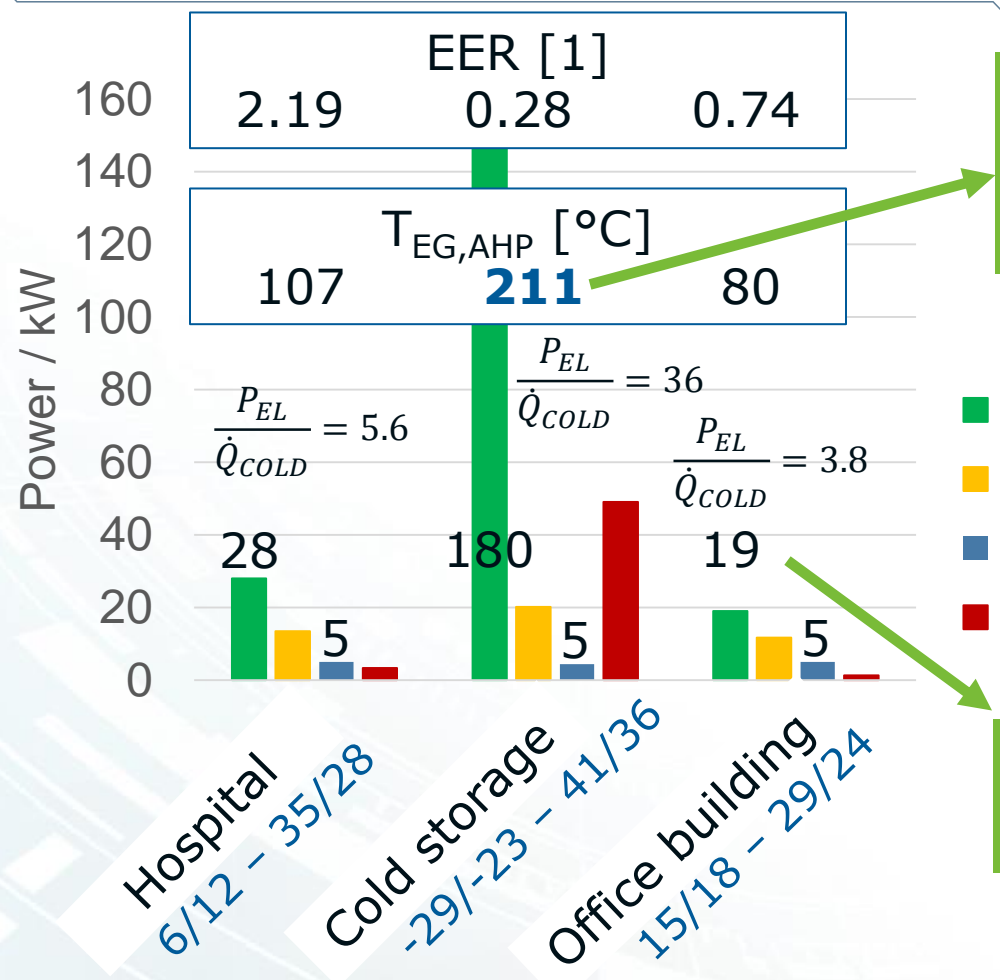
## Why SOFC CCHP?

- Additional opportunities for SOFC technology in cooling applications
- Increase of annual operating hours of SOFC systems for heat and/or cooling driven applications



→ SOFC CCHP technology enables continuous generation of electricity, heat and cooling power

# SIMULATION OF RATIO $P_{EL} / P_{COLD}$



Cooling house  $\rightarrow t_{Generator,out}$  large  
Only little SOFC heat can be used in absorption heat pump

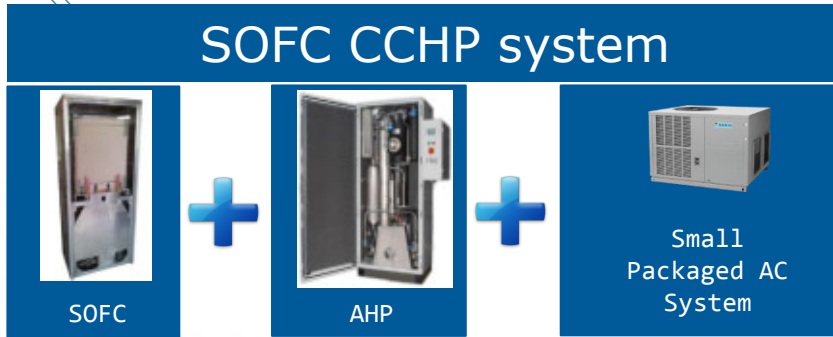
Office building  $\rightarrow t_{Generator,out}$  small  
Smallest ratio between  $P_{el}$  to  $Q_{Cold}$

$$EER = \frac{\dot{Q}_{COLD} + (\dot{Q}_{COND+ABS})}{\dot{Q}_{GENERATOR}}$$

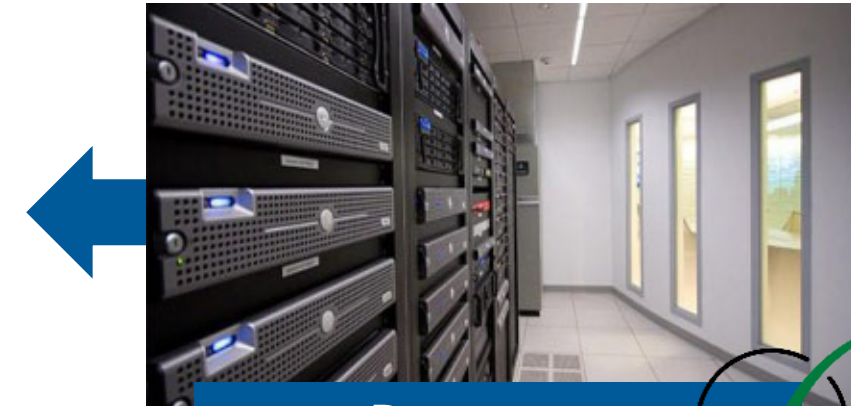
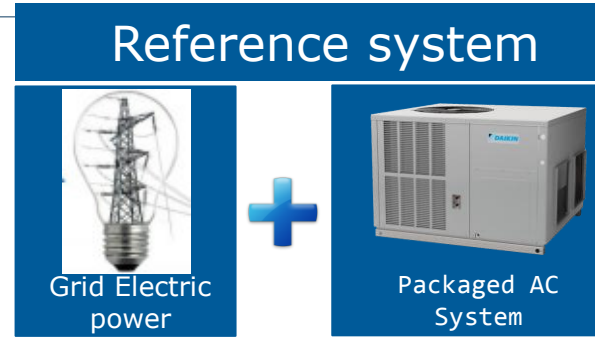
$$\dot{Q}_{GENERATOR} = \dot{Q}_{EG,SOFC} - \dot{Q}_{EG,AHP}$$

$\rightarrow$  Cold and cooling water T determines the ratio between the system sizes of SOFC and AHP

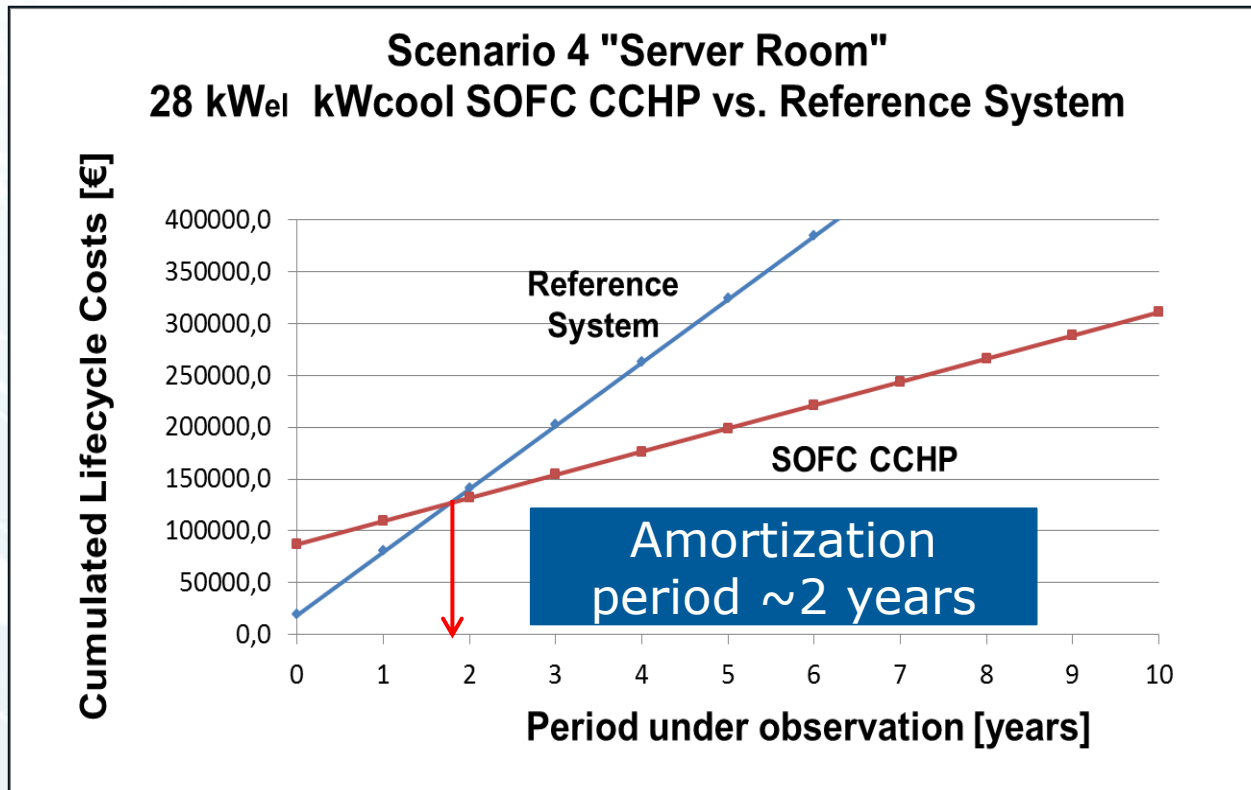
# TOTAL COST OF OWNERSHIP



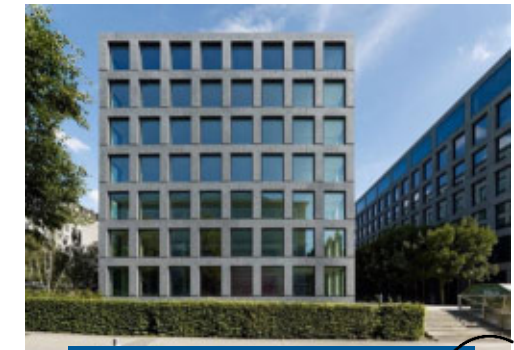
VS.




Data center 




## Further investigated applications



Office building <6 years 



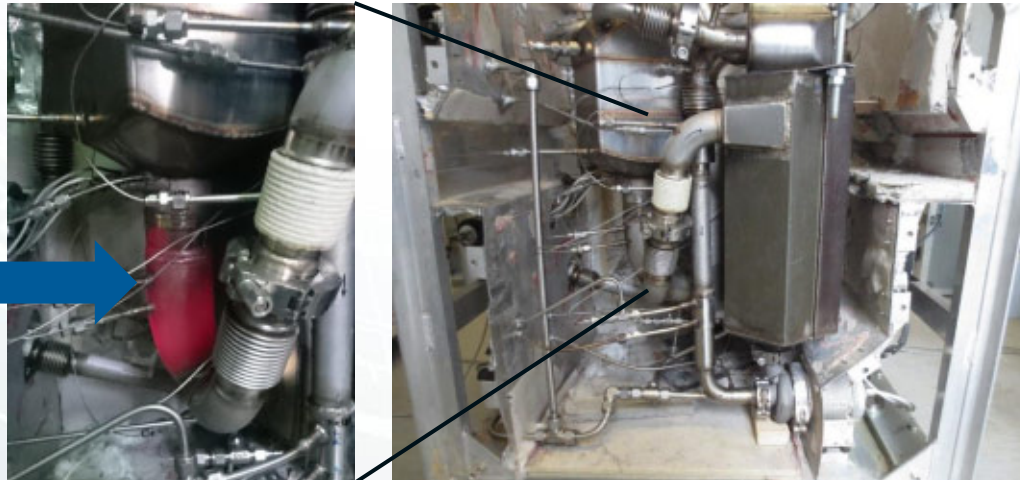
Apartment building <6 years 

# SOFC SYSTEM

## Multi-fuel SOFC system development

- Hot anode recirculation cycle
- Steam reforming
- Diesel start-up burner and diesel evaporator
- Biogas start-up burner

Diesel burner



## AVL SOFC CHP



## Boundary condition

- $P_{el} = 6 \text{ kW}$

Additional heat for AHP will be simulated by electric heating

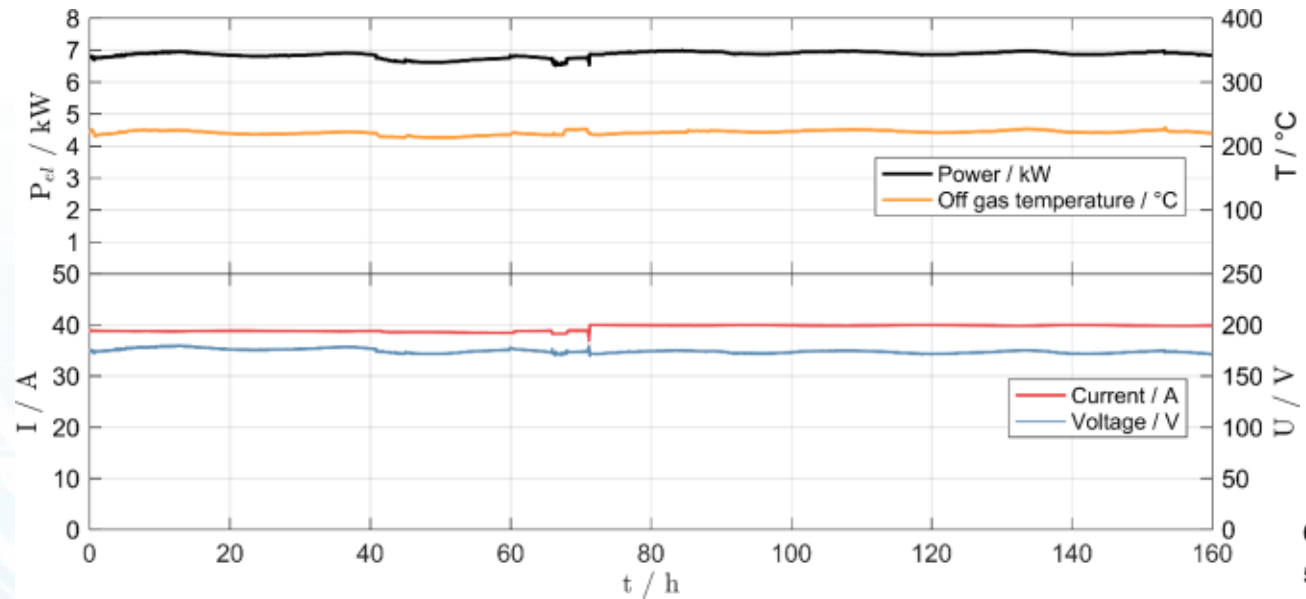
## SOFC stack module

- IKTS stack module
- 8 x 30 cell stacks

## Gas processing

- Heat exchanger
- Start-up burner
- Afterburner
- Steam reformer
- Air blower
- Hot anode gas recirculation blower

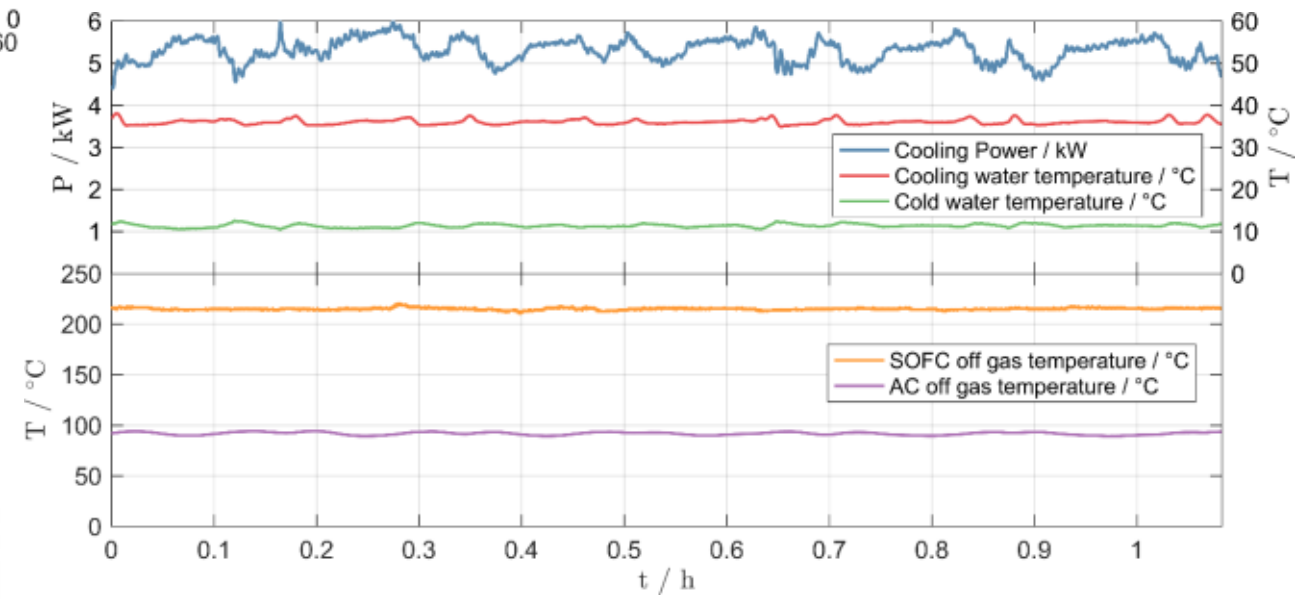
# CCHP OPERATION



Absorption Chiller  
(Powered by 13 kW heating)



SOFC system  
7 kW<sub>el</sub> at  
59.7 % η<sub>DC</sub>



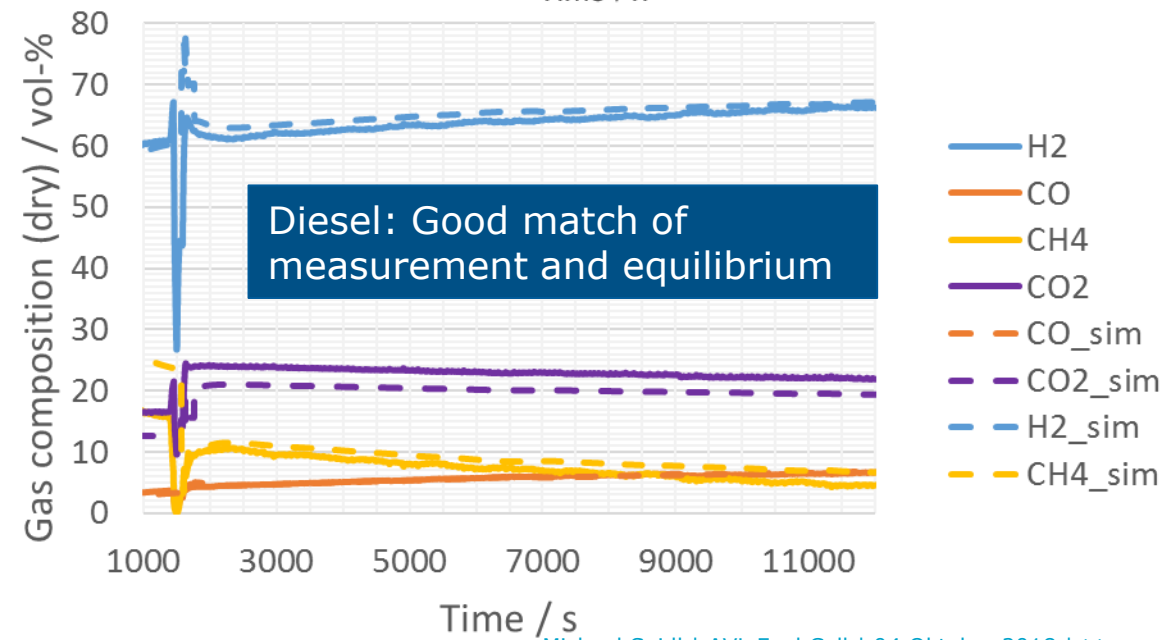
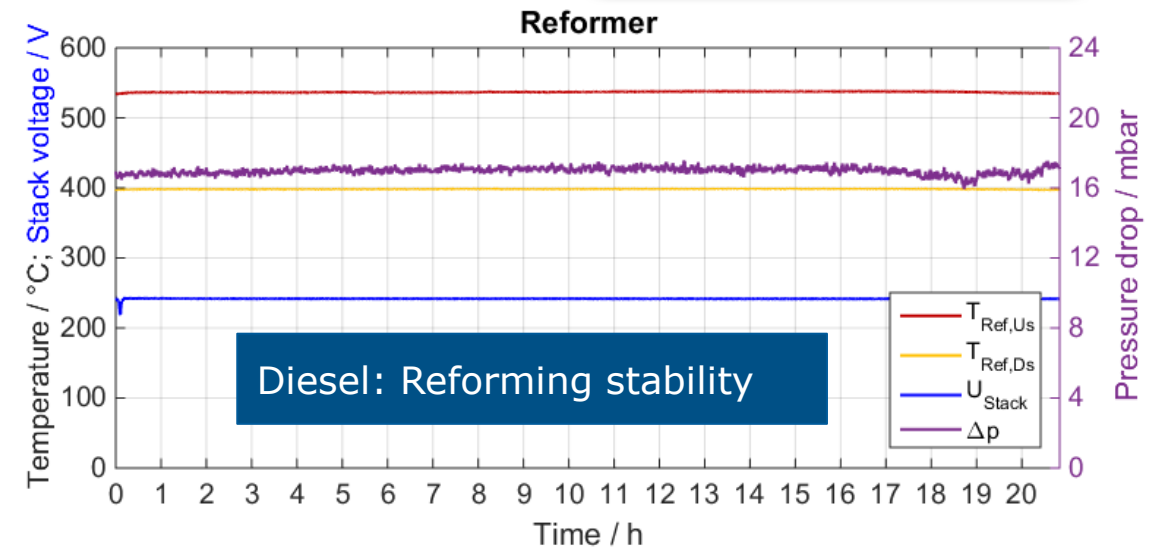
# DIESEL AND BIOGAS OPERATION

- System **operation** with simulated **biogas** (NG with 40% CO<sub>2</sub>) was performed successfully.
- Start-up burner was operated with simulated biogas.

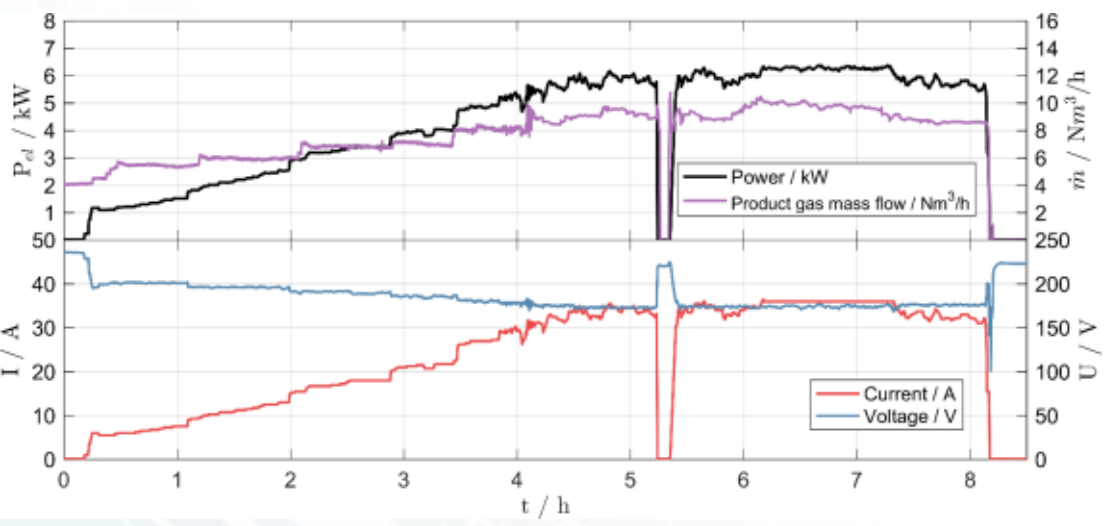
## Diesel steam reforming results in system

- "Old" stack module in OCV @ ~550 °C
- Diesel reforming performance in hot anode gas recirculation cycle successfully tested

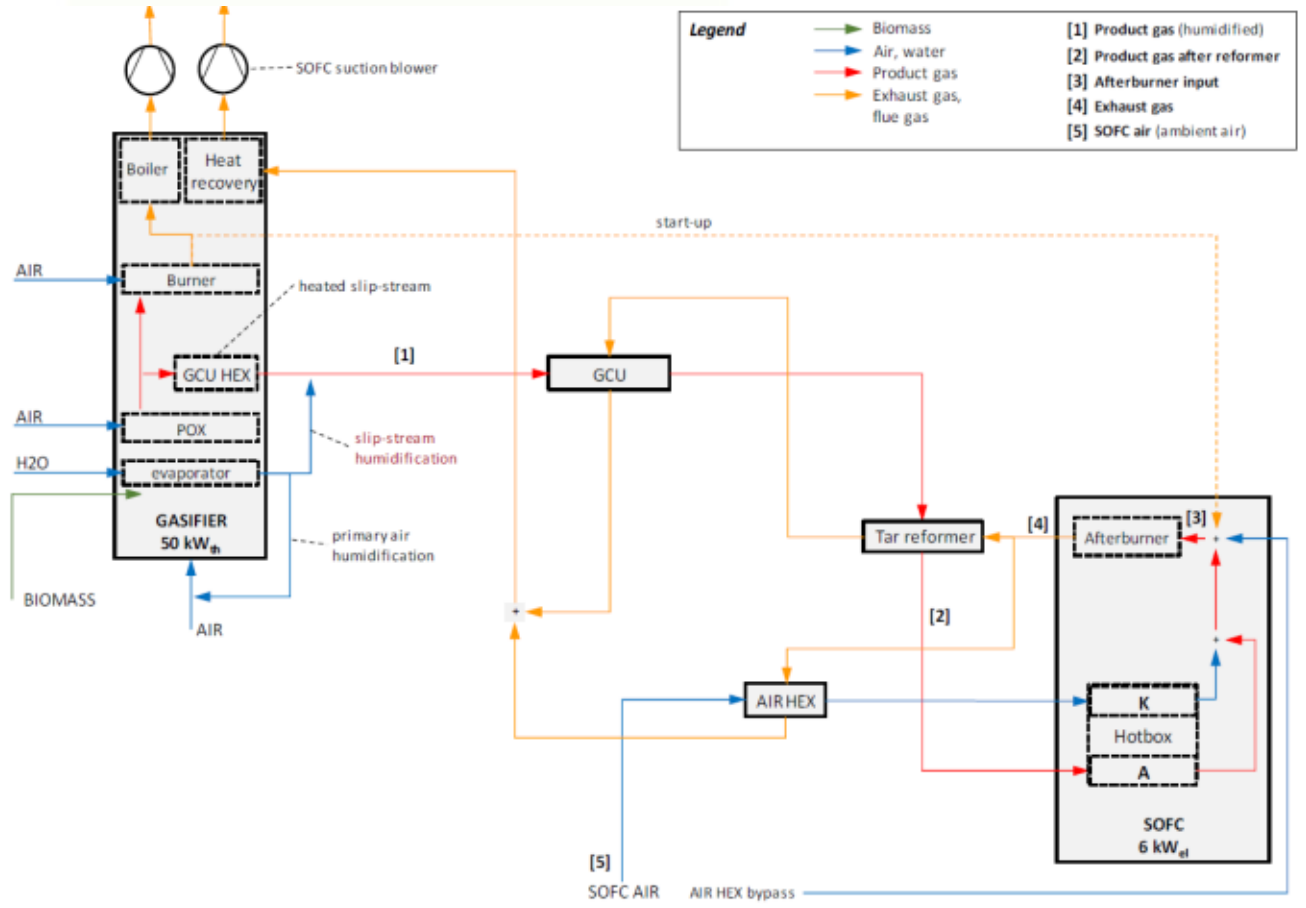
- Stable reformer temperatures
- Stable gas composition at reformer outlet
- Stable pressure drop over reformer
- Stable OCV



# FlexiFuel-SOFC (EU: Horizon2020)



- 6.3 kW<sub>el</sub> from gasified wood chips
- Automated heat-up, thermomanagement and operation



## CONCLUSION

- SOFC CCHP very attractive towards demand-oriented generation of electricity, heat and cooling power
- Very attractive business cases for buildings and data centers
- Multi-fuel operation (natural gas, biogas, diesel, gasified biomass)

## OUTLOOK (SOFC5-60)

- Next generation AVL SOFC CHP design. 5 kW<sub>AC</sub> / 60 % AC
- Design considers certification
- First two prototype systems will be in operation in November 2018



FEEL FREE TO CONTACT



**Michael Seidl**

Development Engineer Fuel Cell

E [michael.seidl@avl.com](mailto:michael.seidl@avl.com)

W [www.avl.com](http://www.avl.com)

AVL List GmbH

Hans-List-Platz 1 / 8020 Graz

Austria

Thank You



[www.avl.com](http://www.avl.com)

