# Influences of different heating concepts for the energy demand of an airfield luggage tug

*4. VDI-Fachkonferenz*

*Thermomanagment für elektromotorisch angetriebene PKW*

*24. November 2015*

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# Agenda

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2 Design and validation of thermal cabin model

4 Driving cycle

5 Power and energy demand

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# Motivation

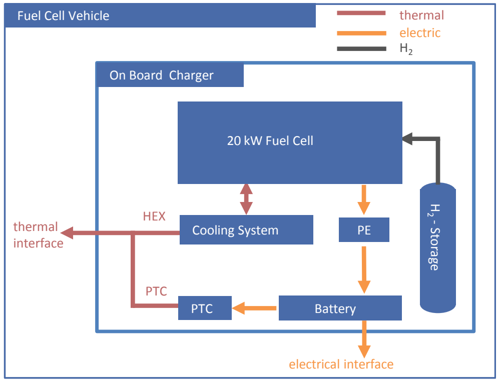
The aim in this project is to design a FC luggage tug based on a powertrain of the BEV
DLR: Develop and analyzes of different heating concepts for the cabin

## Status quo: Battery Electric Vehicle (BEV)

- Dead weigh: 4 t
- 50 kWh lead-acid battery
- $P_{EM,peak}$ = 30 kW
- $v_{max}$ = 30 km/h
- $P_{PTC,peak}$ = 1.5 kW

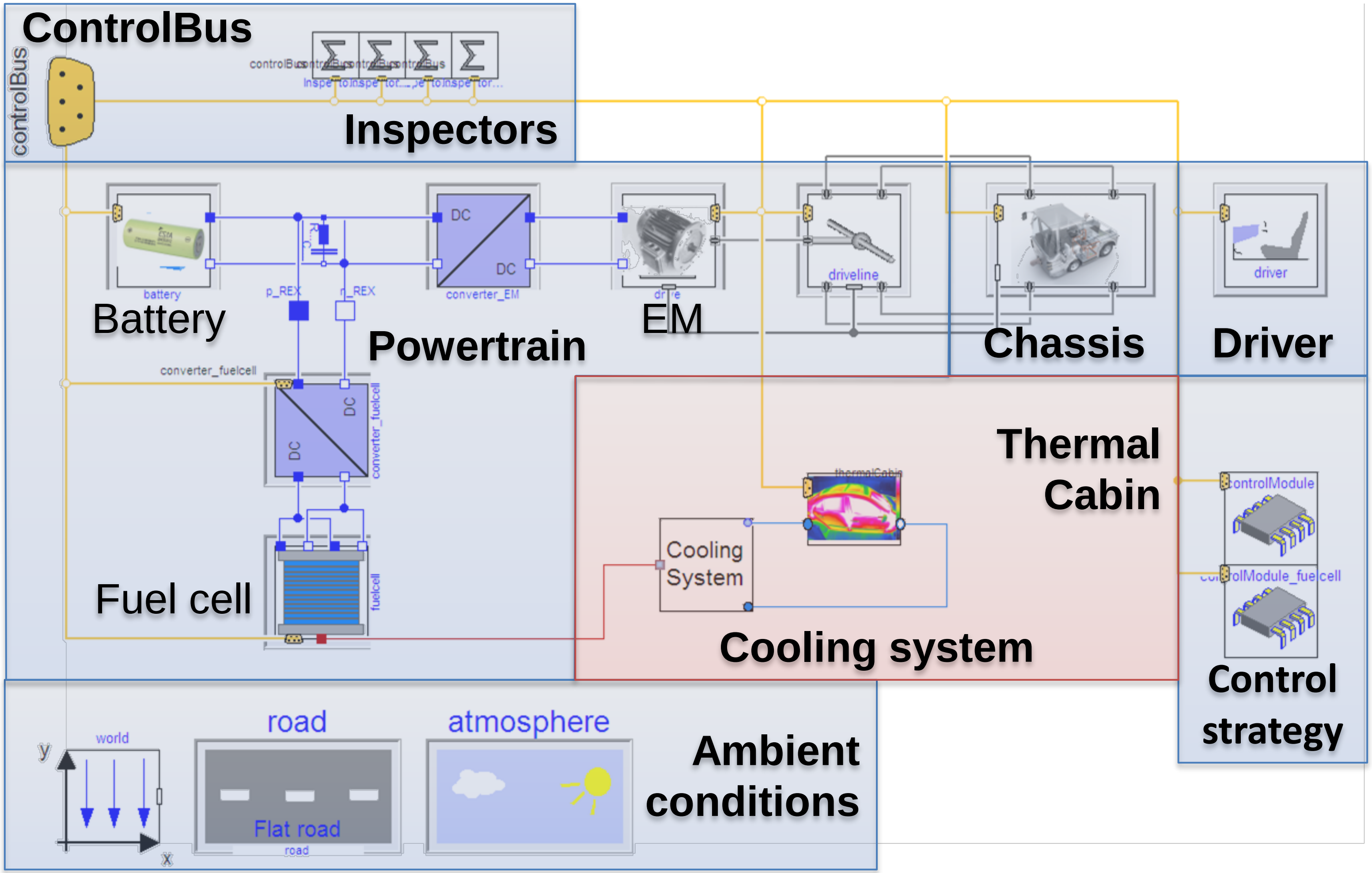
## Aim: Fuel Cell powered luggage tug (FCV)

- 8 kWh li-ion battery
- 20 kW fuel cell
- 3 kg hydrogen
- Same power train as BEV
- ***Usage of the waste heat from the FC***



# Approach: Total vehicle simulation model

Simulations models of the DLR-AlternativeVehicles (blue) and the thermal cabin model (red)

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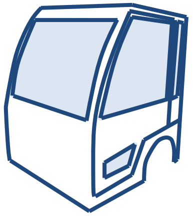
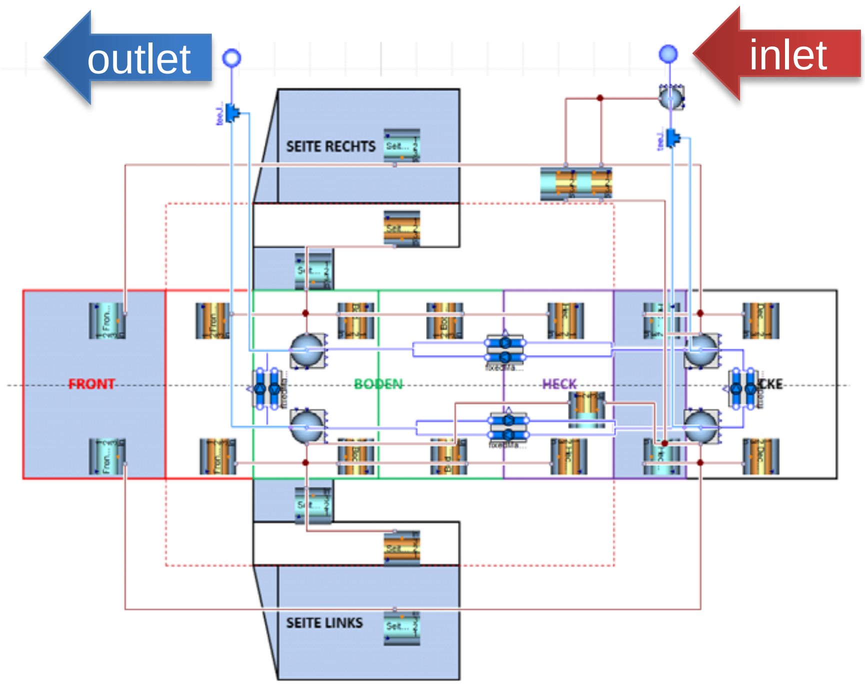
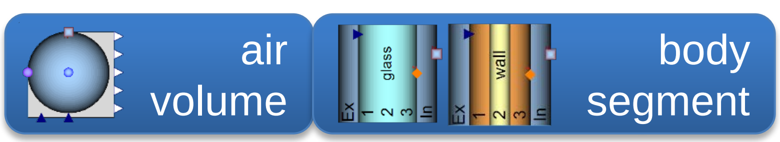
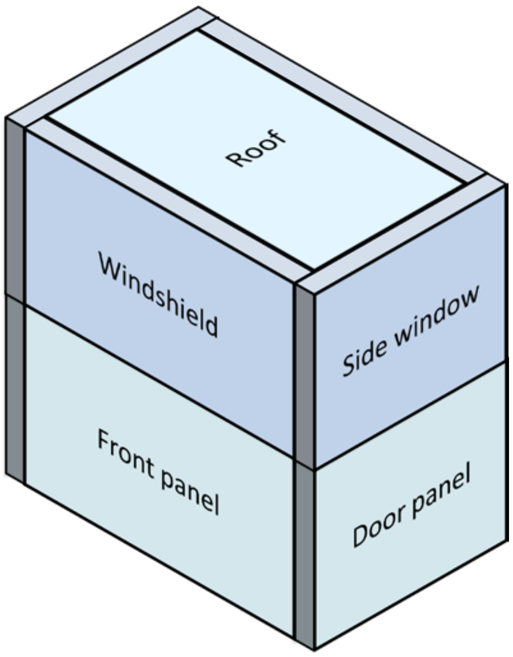
# Approach: Design and validation of thermal cabin model

Thermal cabin as used in simulation (flatplan) and for imagine in 3D-design






# Approach: Design and validation of thermal cabin model

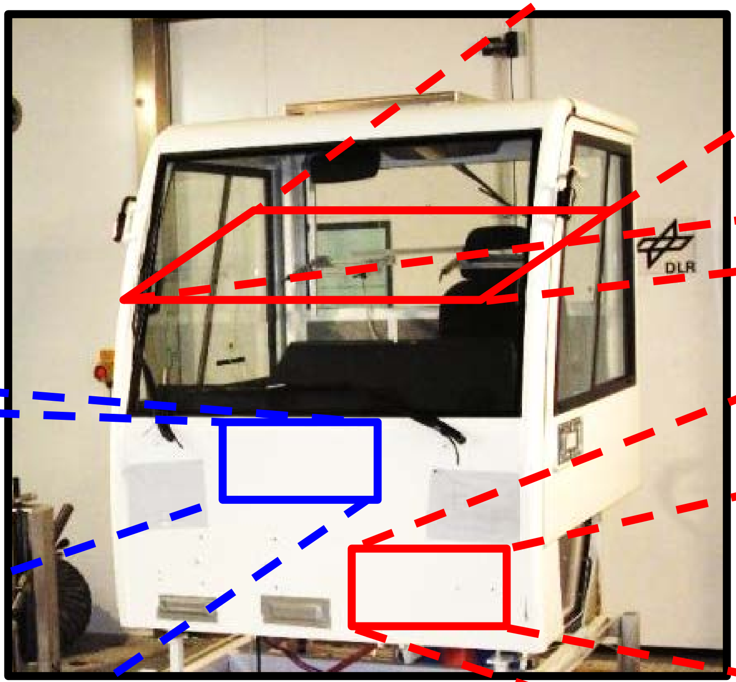
## Measuring of heating-up power, air temperature and air mass flow with the cabin mockup

**Measurement concept:**

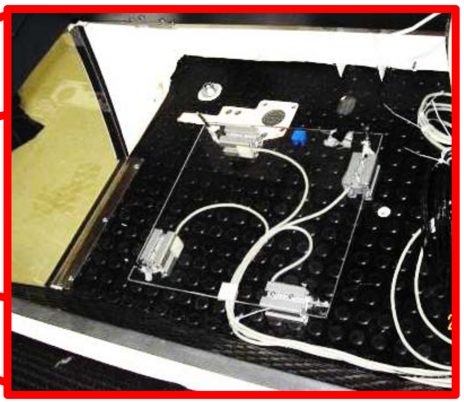
- According to DIN 1946
- Additional requirements

**Sensor integration:**

- Air temperature
- Air mass flow rate
- Power PTC heater



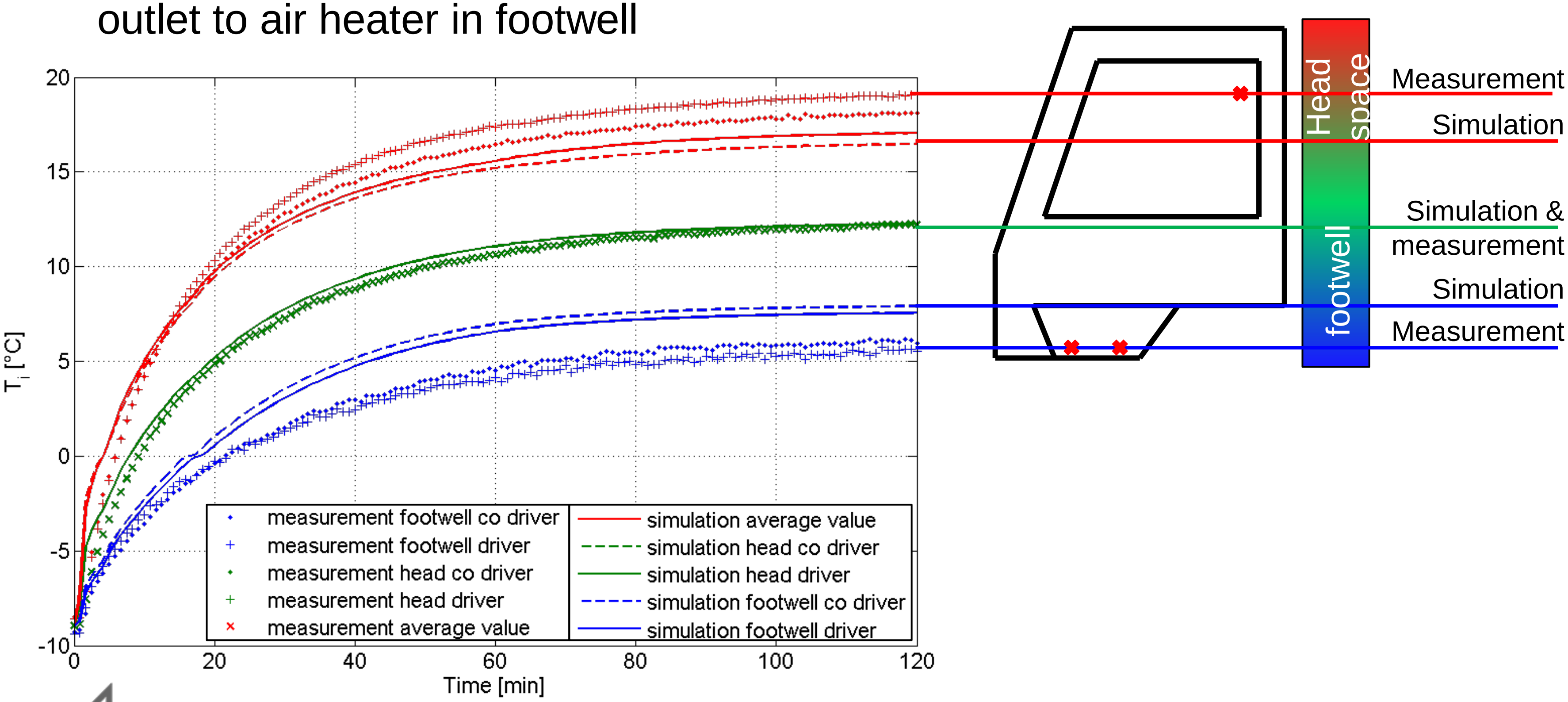




# Approach: Design and validation of thermal cabin model

## Comparison of the simulation results and the measured temperatures in the cabin

- 2 K Variation of real and simulated temperatures cause of the temperature stratification
- Inlet of heated air in head space outlet to air heater in footwell

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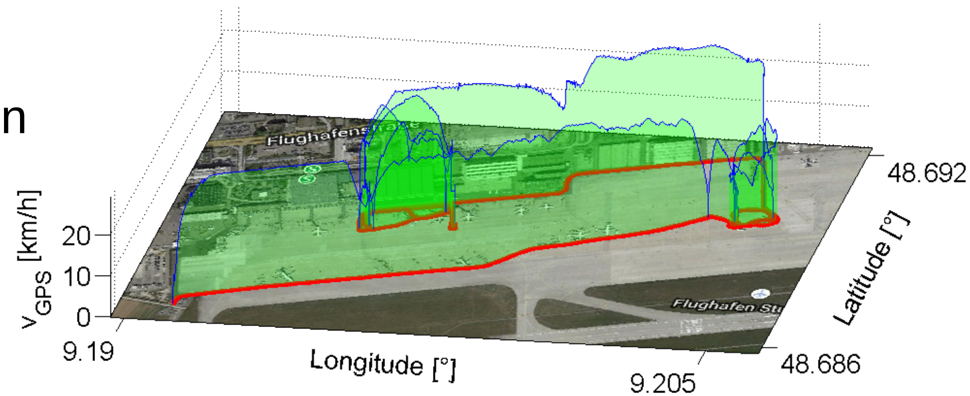
# Approach: Driving cycle

Define of a real life driving cycle for a luggage tug of measured speed profiles

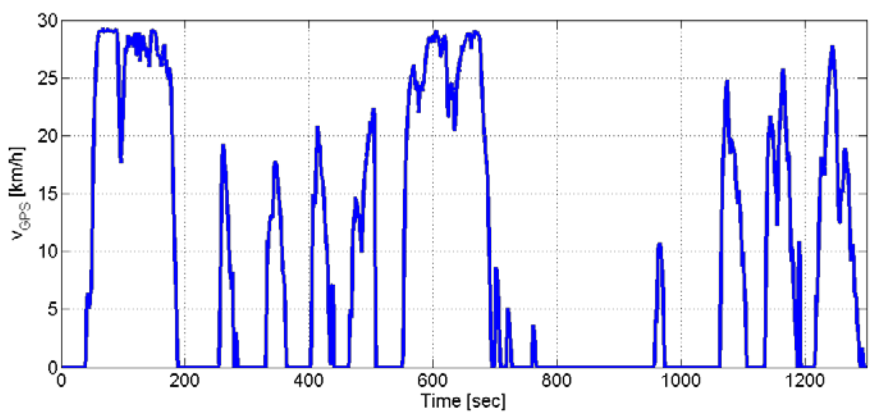
## Raw data:

- Project ***eFleet***, electric apron vehicles at the airport Stuttgart
- Measuring of energy consumption of different apron vehicles



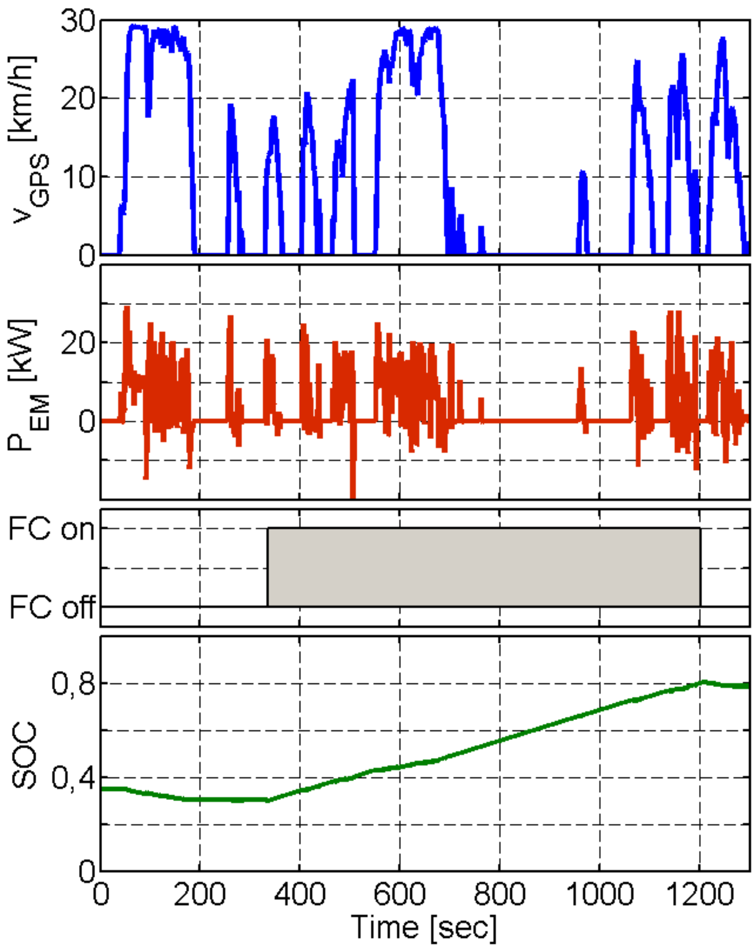

## Define speed cycle for luggage tug:

- Distance: 3.2 km
- Duration: 1300 sec
- $v_{mean}$ = 18 km/h
- $v_{max}$ = 29.5 km/h



# Approach: Power and energy demand

Energy demand for one driving cycle and for the 8h shift operation




**Simulation results for one cycle:**

- $E_{tract}$ ~ 1.1 kWh
- $E_{spec.,tract}$ ~ 34.4 kWh/100km
- $P_{mean,tract}$ ~ 3 kW
- Max Charge: ~ 5.5 C

**Calculated energy for 8h shift operation:**

- $E_{tract}$ ~ 23.3 kWh
- $E_{waste\ heat}$ ~ 25 kWh

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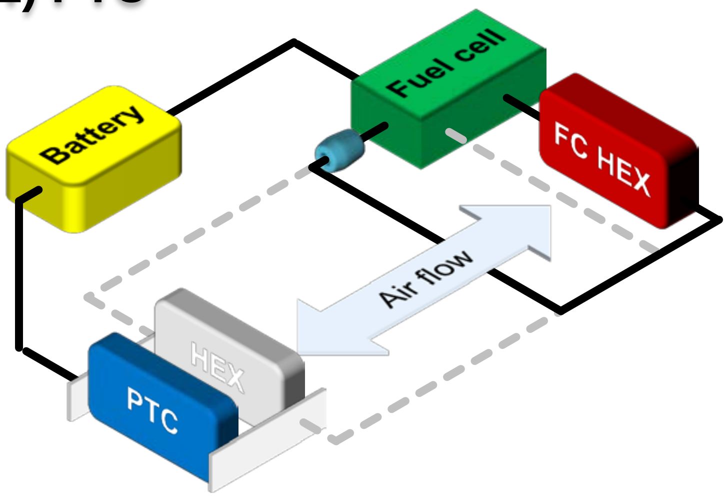
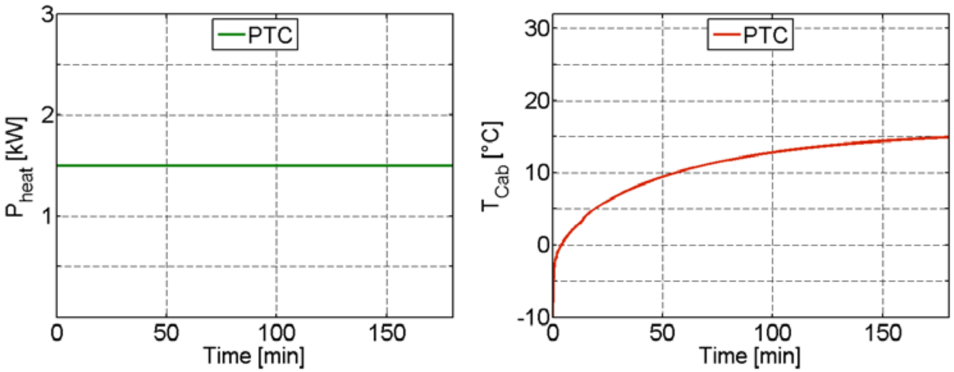
# Approach: Simulation results of different heating concepts

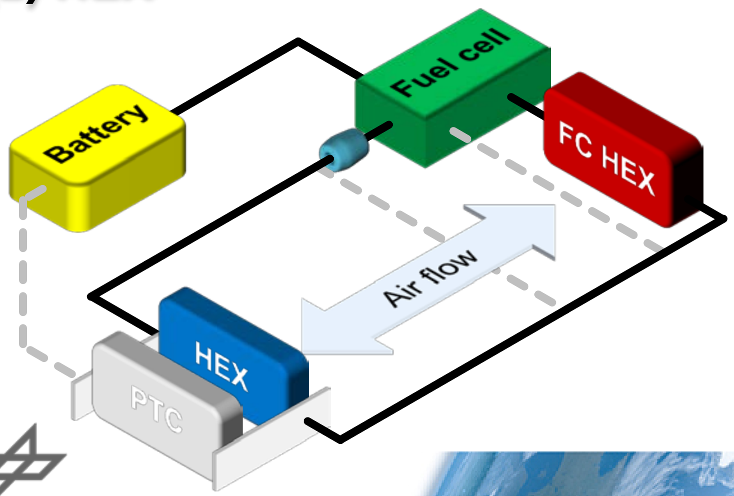
Functional design and the simulated results for the heating power and cabin temperature

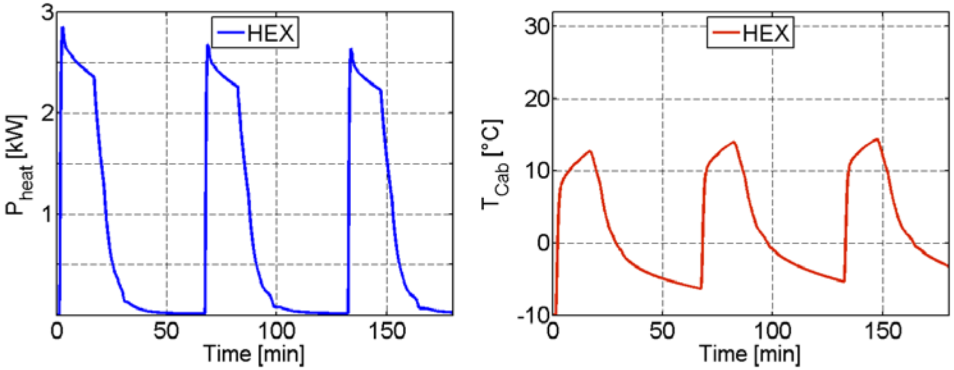
## (1) PTC




## (2) HEX

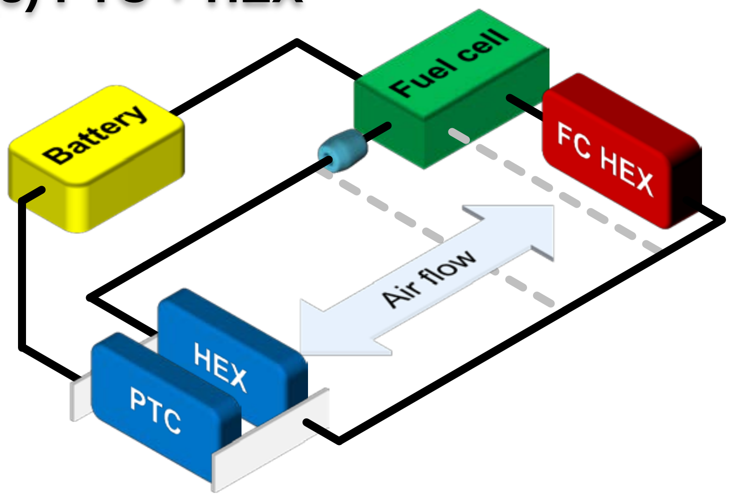


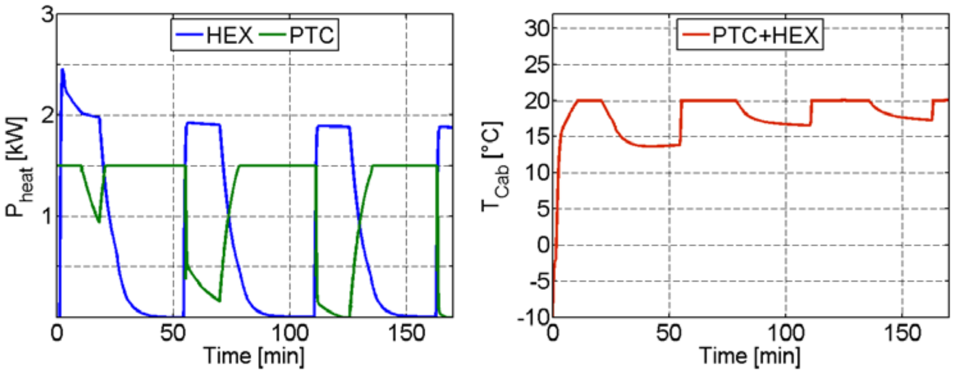



# Approach: Simulation results of different heating concepts

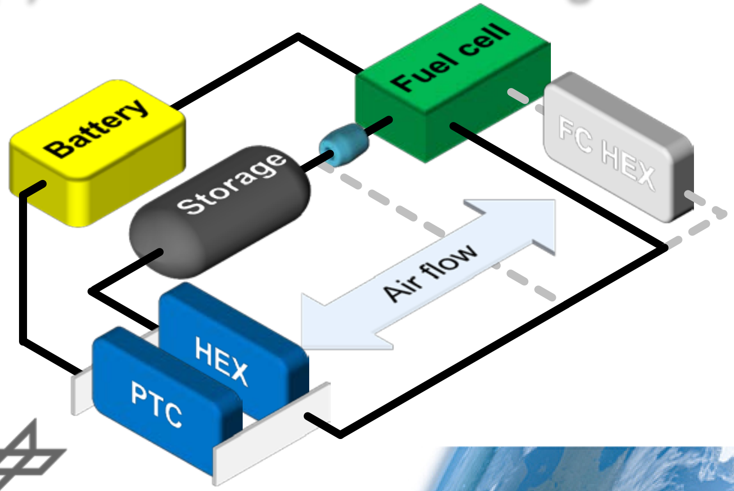
Functional design and the simulated results for the heating power and cabin temperature

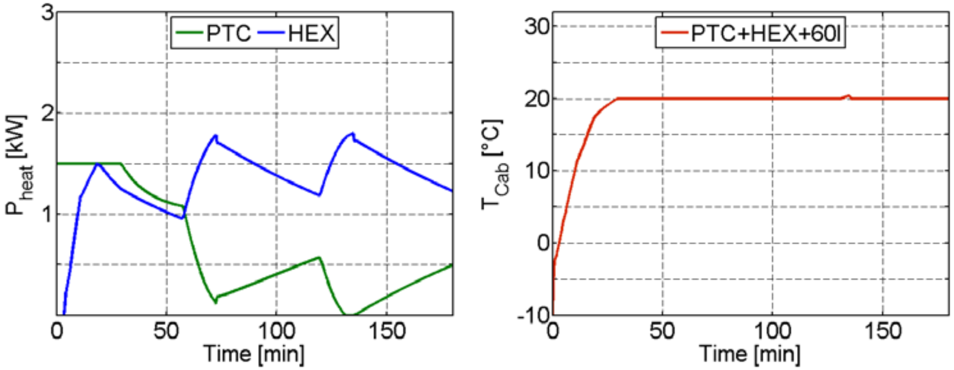
## (3) PTC + HEX




## (4) PTC + HEX + 60l-Storage



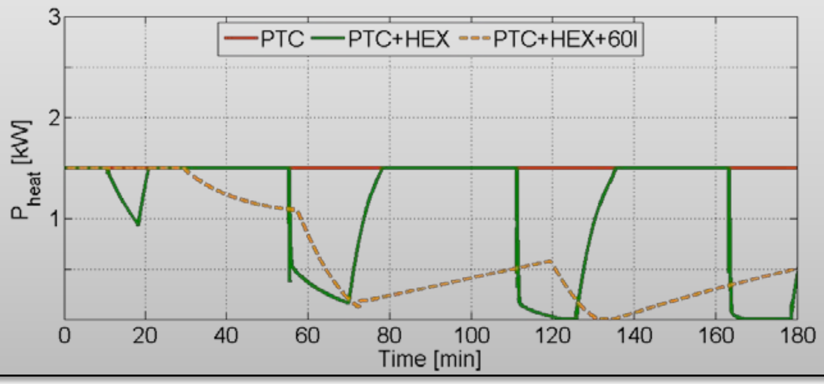



# Approach: Simulation results of different heating concepts

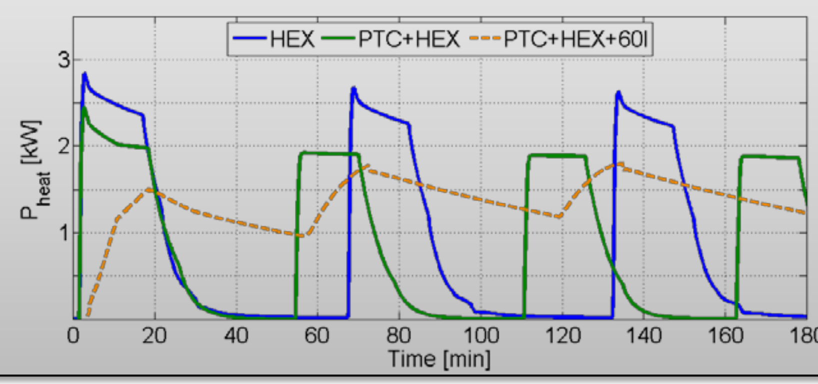
## Power of PTC, of HEX and the cabin temperature for all different heating strategies

### Power source for the cabin heating

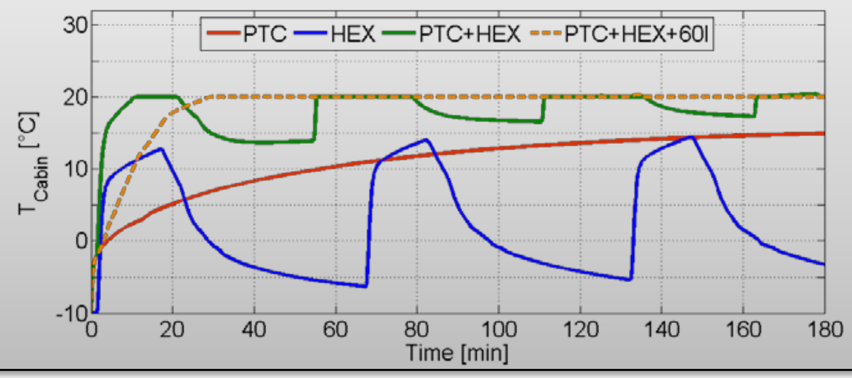
PTC




HEX




### Regulated/adjusting temperature in cabin

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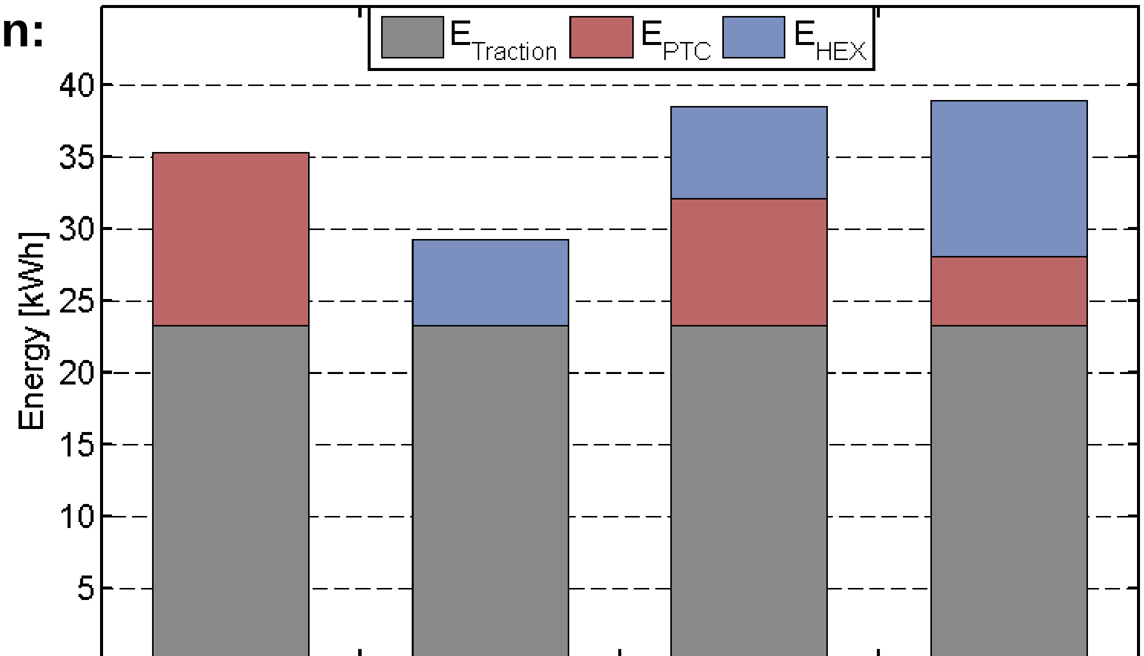
# Approach: Simulation results of different heating concepts

## Resulting energy demand of all four heating concepts for one shift operation (8h)

**Lowest energy consumption:**
- HEX

**Controllability:**
- PTC

**Cabin temperature:**
- PTC+HEX+60l




| | PTC | HEX | PTC+HEX | PTC+HEX+60l |
|---|---|---|---|---|
| $P_{PTC,mean}$ | 1.5 kW | -- | 1.1 kW | 0.6 kW |
| $P_{HEX,mean}$ | -- | 0.75 kW | 0.8 kW | 1.35 kW |
| $E_{PTC}$ | 12 kWh | -- | 8.8 kWh | 4.8 kW |
| $E_{HWT}$ | -- | 6 kWh | 6.4 kWh | 10.8 kWh |
| $T_{cab,mean}$ | 11 °C | 1 °C | 18 °C | 19 °C |

# Summary and Conclusion

**Summary:**

- Virtual luggage tug created using „Alternative Vehicles“ library in Modelica
- Cabin model validated
- Thermal management system designed and calculated in 4 cases
- Energy demand for shift working derived

**Conclusion:**

- Usage of fuel cell waste heat lead to:
  - lower energy demand for electric heating
    → less hydrogen consumption
  - higher average cabin temperature using a 60 liter enthalpy storage system

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