Performance Investigation of a Desiccant Assisted Air Conditioning System During Winter and Summer

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TUHH

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Introduction

Air Conditioning – Challenges

theguardian

World set to use more energy for cooling than heating

Rising demand for air conditioning and refrigeration threatens to make planet hotter and undermine pledges to rein in emissions

Jon Henley

Monday 26 October 2015 09.04 GMT

The world faces a looming and potentially calamitous "cold crunch", with demand for air conditioning and refrigeration growing so fast that it threatens to smash pledges and targets for global warming.

Worldwide power consumption for air conditioning alone is forecast to surge 33-fold by 2100 as developing world incomes rise and urbanisation advances. Already, the US uses as much electricity to keep buildings cool as the whole of Africa uses on everything; China and India are fast catching up. By mid-century people will use more energy for cooling than heating.

And since cold is still overwhelmingly produced by burning fossil fuels, emission targets agreed at next month's international climate summit in Paris risk being blown away as governments and scientists struggle with a cruel climate-change irony: cooling makes the planet hotter.

"Most people tend to think of energy in terms of heat and light and transport," said Toby Peters, visiting professor of power and the cold economy at the University of Birmingham. "But more and more, it's going to be about cold. Demand for cold is already huge, it's growing fast, and we're meeting it in basically the same way we've been doing for a century. Cold is the Cinderella of the energy debate. If we don't change the way we do it, the consequences are going to be dramatic."

Artificial cold is a recent phenomenon: the first domestic air-conditioning unit appeared in 1914, the first home fridges in 1930. As late as 1965, only a third of UK homes had one.

But cold has quietly become a part of 21st-century life, certainly in advanced economies: people expect air conditioning to make homes, offices and cars comfortable (and many cities habitable); most food in the developed world is chilled or frozen; medicines, including vaccines, need refrigeration; industries such as steel, chemicals and plastics depend on cooling; deprived of cold, data centres – and the internet – would collapse in minutes.

Source: www.theguardian.com/environment/2015/oct/26/cold-economy-cop21-global-warming-carbon-emissions

Introduction

Thermal Comfort – Demands

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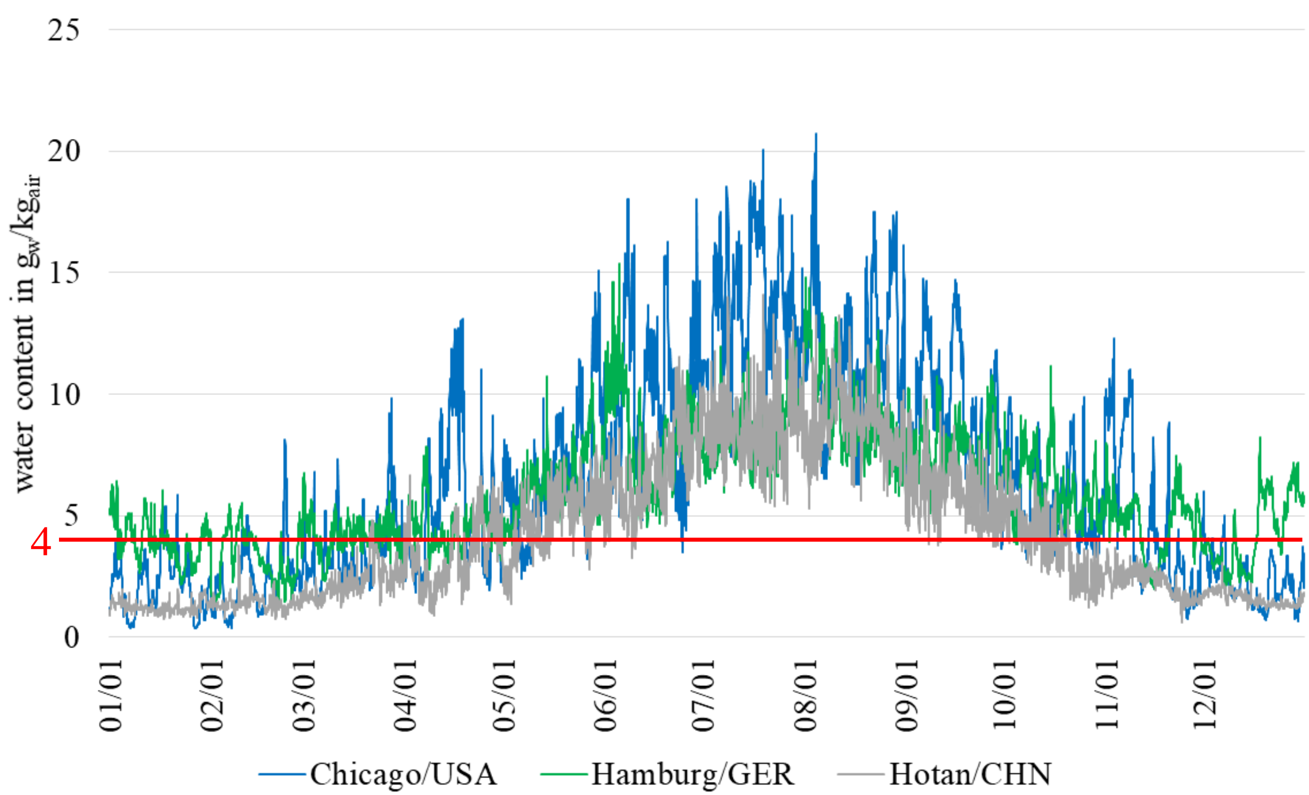

Demand for air humidification during winter

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Outline

- Test facility and system layout
- Experimental investigations and system evaluation
  - » Thermal comfort
  - » Overall system performance
- Summary and outlook

Test Facility

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Test facility

Solarthermal system

Technical installations

Peripheral equipment of the geothermal system

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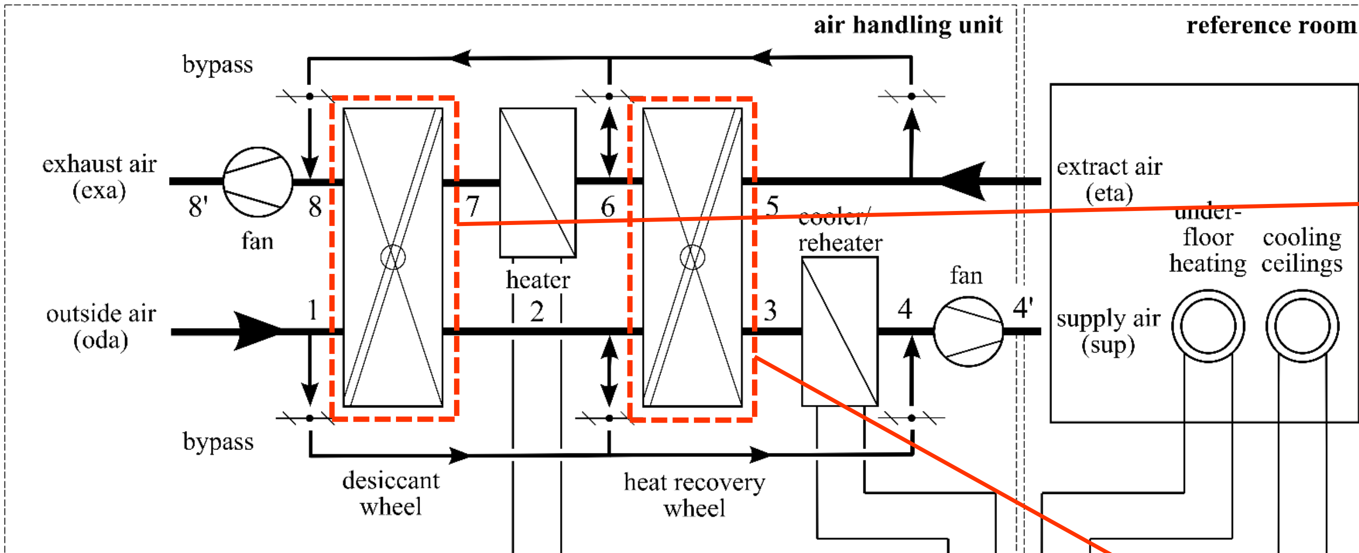
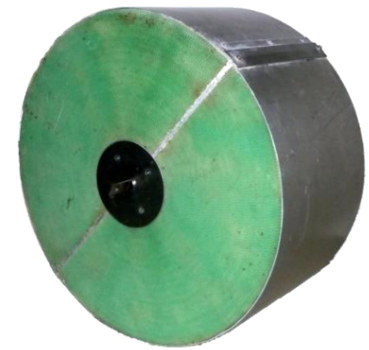
System Layout of the Test Facility





Desiccant wheel (LiCl)

Heat recovery wheel (Al)

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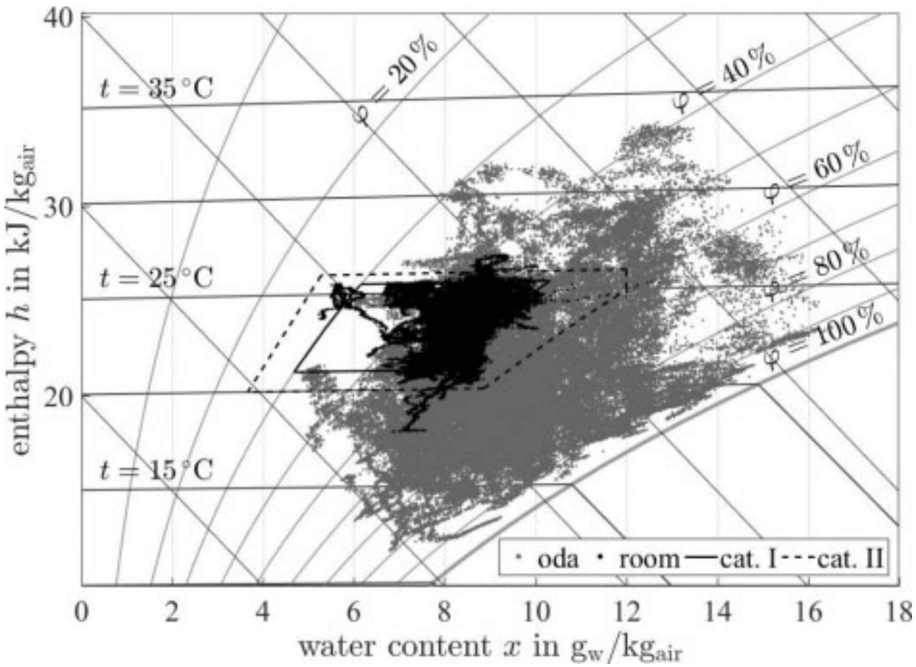
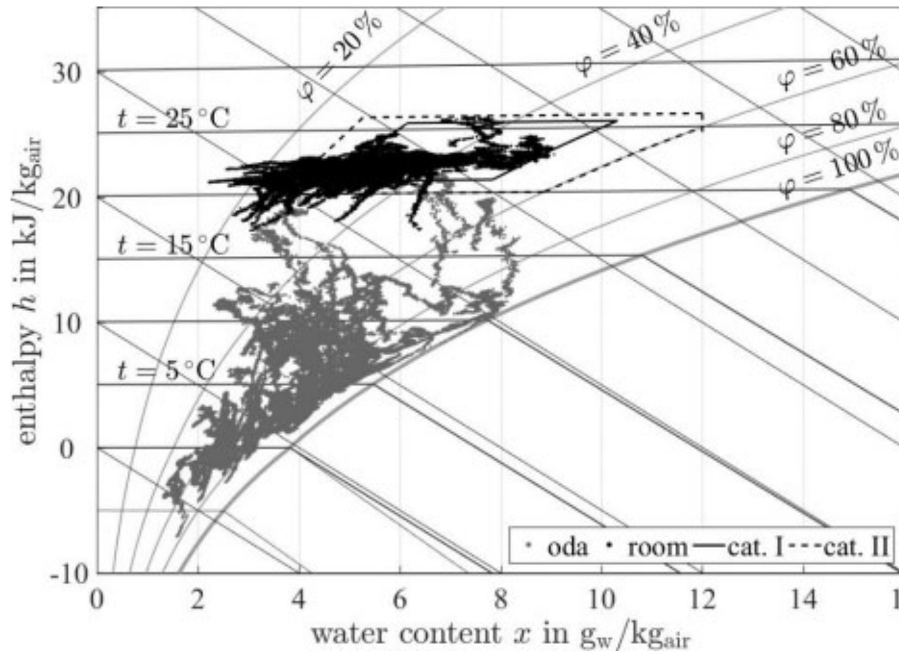
Outside and Room Air Conditions

Cooling period



- Moderate summer period
- 66 % of oda conditions outside comfort area according to cat. I, 49 % according to cat. II
- Room air conditions satisfy cat. I for 77 % (cat. II: 99 %) of operation time

Heating period



- Moderate winter period
- 99.5 % of oda conditions outside comfort areas according to cat. I/II
- Room air conditions satisfy cat. I for 67 % (cat. II: 75 %) of operation time
- Deviations primarily caused by low room temperatures in the morning

Period Evaluation – Reference Systems

Summer Mode

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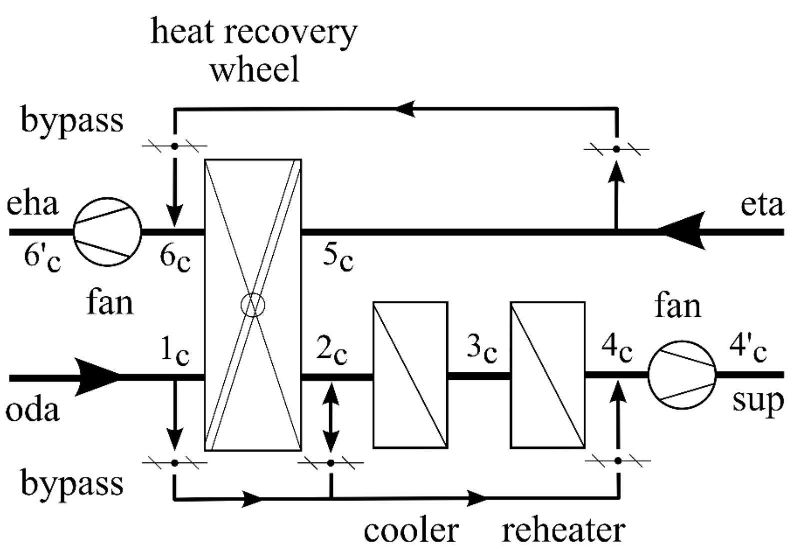
Reference system DP-VC

- Dehumidification relying on dew point condensation
- Compression chiller: $\mathrm{EER_{el}} = 3.0$
- Supply air temperature: $\vartheta_{\mathrm{sup}} = 16\,°\mathrm{C}$



Reference system DW-VC

- Desiccant assisted dehumidification similar to the test facility
- Replacing BHE by compression chiller
- Compression chiller: $\mathrm{EER_{el}} = 3.2$
- Supply air temperature: $\vartheta_{\mathrm{sup}} = 22\,°\mathrm{C}$

Similar air conditions

- oda conditions
- sup water content
- mass flow rate

} Measured data test facility (S-GEO)

Period Evaluation – System Comparison

Summer Mode

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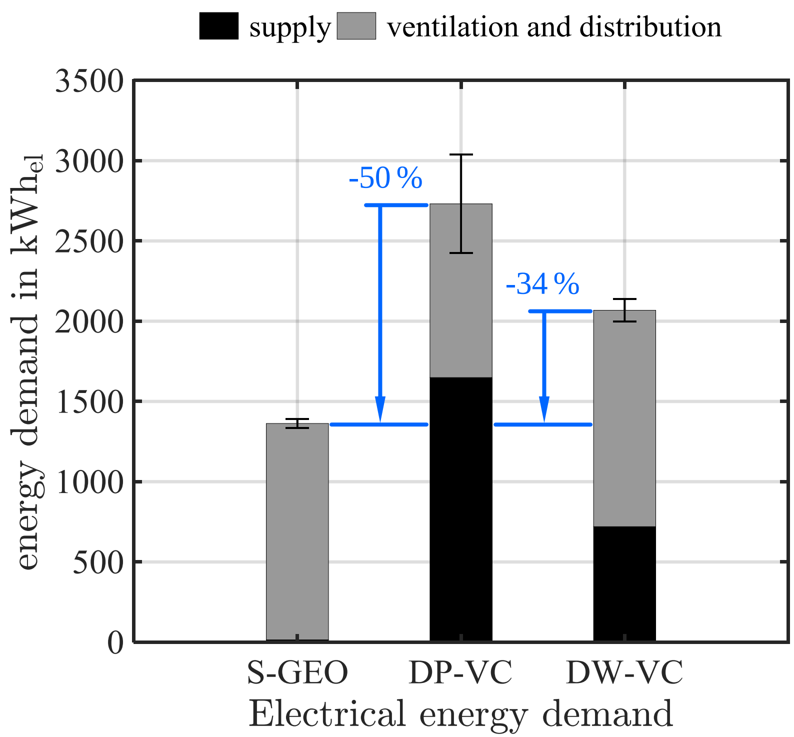

- Electrical energy demand for air conditioning can be reduced significantly
- Additional demand of thermal energy has to be taken into account

Period Evaluation – Reference Systems

Winter Mode

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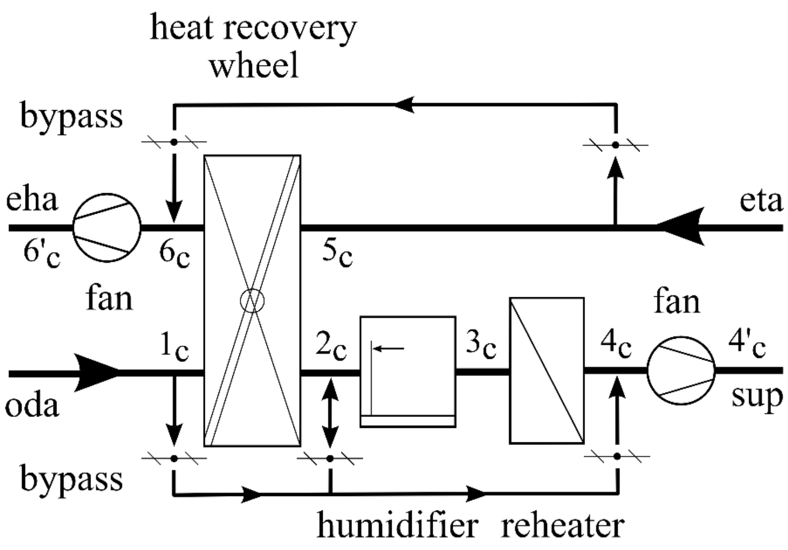
Reference system HP-AH

- Adiabatic humidification
- Electrical powered impeller humidifier
- Heat recovery efficiency: $\Psi = 0.75$

Reference system HP-IH

- Isothermal humidification
- Electrical powered steam humidifier
- Heat recovery efficiency: $\Psi = 0.75$



Similar air conditions

- oda conditions
- sup conditions
- mass flow rate

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Period Evaluation – System Comparison

Winter Mode

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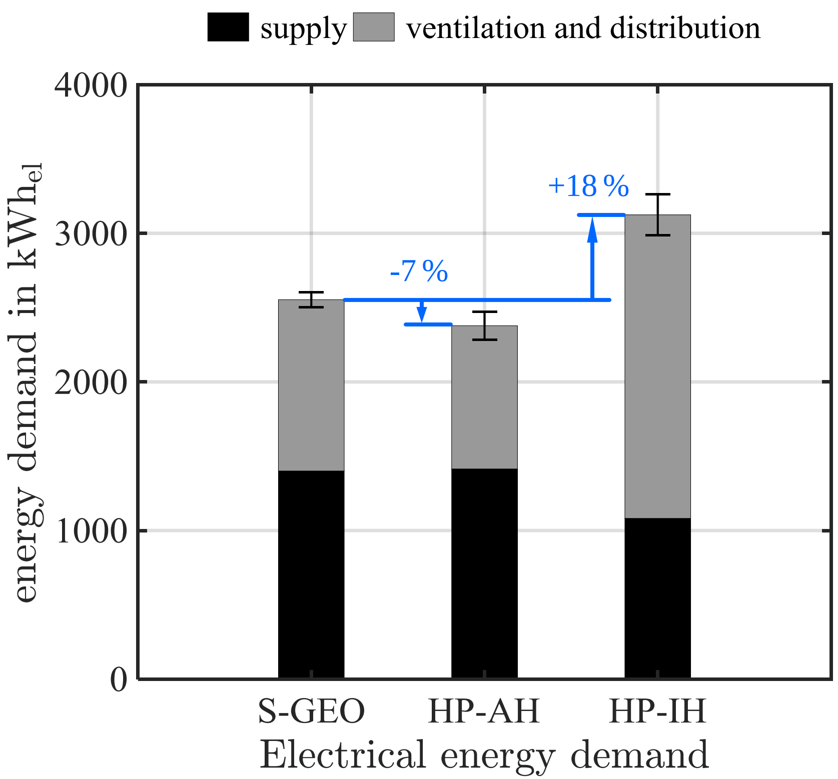

- Demand-oriented air humidification can be provided
- Additional technical equipment is not required

Summary and Outlook

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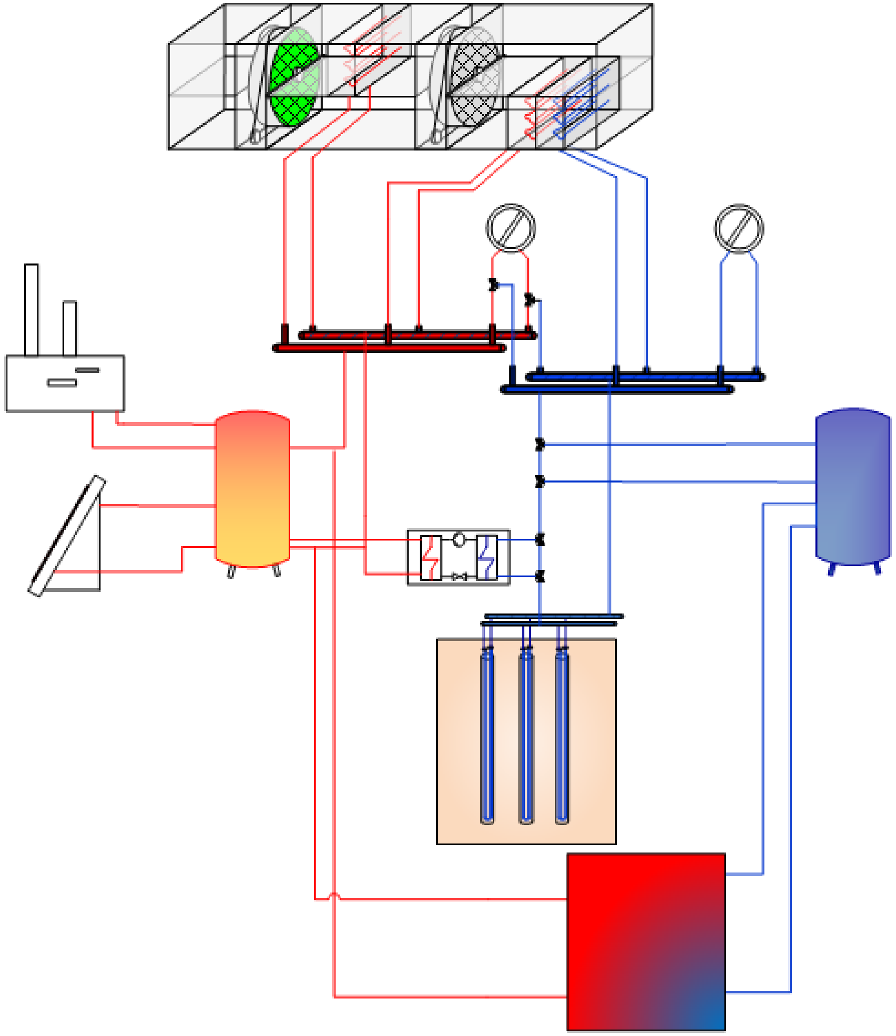
Summary

- Desiccant and geothermal assisted air conditioning system is investigated experimentally during summer and winter mode
- Investigated system can ensure highly comfortable indoor air conditions
- Geothermal system can be operated efficiently throughout the year
- Investigated system is beneficial against conventional air conditioning systems

Outlook

- Alternative desiccant materials are taken into account experimentally/ numerically
- Numerical system model is built for full-year system operation modelling
- Covering peak loads is investigated, e.g. dynamic responding BHE, PCM
- Applicability of the system to large units is investigated considering space requirements of renewable heat sources and heat sinks

Summary and Outlook



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Appendix: Measurement Uncertainties

Measured value		Sensor type / measuring principle	Measurement uncertainty
Air and water temperature	t	Pt100 (accuracy class W 0.1)	$\pm 1/3 \cdot (0.3 + 0.005 \cdot t)$
Soil temperature	t	Thermistor string	$\pm 0.5\,\mathrm{K}$
Relative humidity	φ	Capacitive humidity sensor	$\pm 2\,\%\mathrm{r.h.}$ for $10 \ldots 90\,\%\,\mathrm{r.h.}$
Volume flow (air)	$\dot{V}$	Differential pressure	$\pm 10\,\%$
Volume flow (water)	$\dot{V}$	Electromagnetic flow meter	$\pm 0.5\,\%$ of reading $\pm 1\,\mathrm{mm/s}$
Pressure difference	Δp	Ceramic fulcrum lever technology	$\pm 2\,\%$ of full scale (range: $0 \ldots 300\,\mathrm{Pa}$ and $0 \ldots 1000\,\mathrm{Pa}$)
Electric power	P	AC energy meter	$\pm 2\,\%$ of reading

Appendix: Different Operation Modes (1)

Winter Mode

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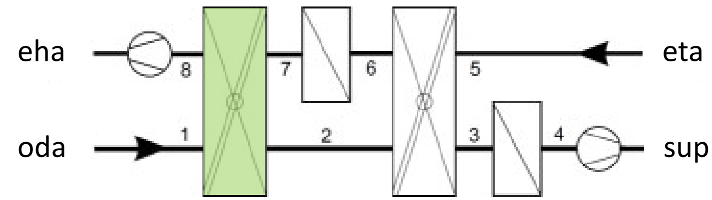
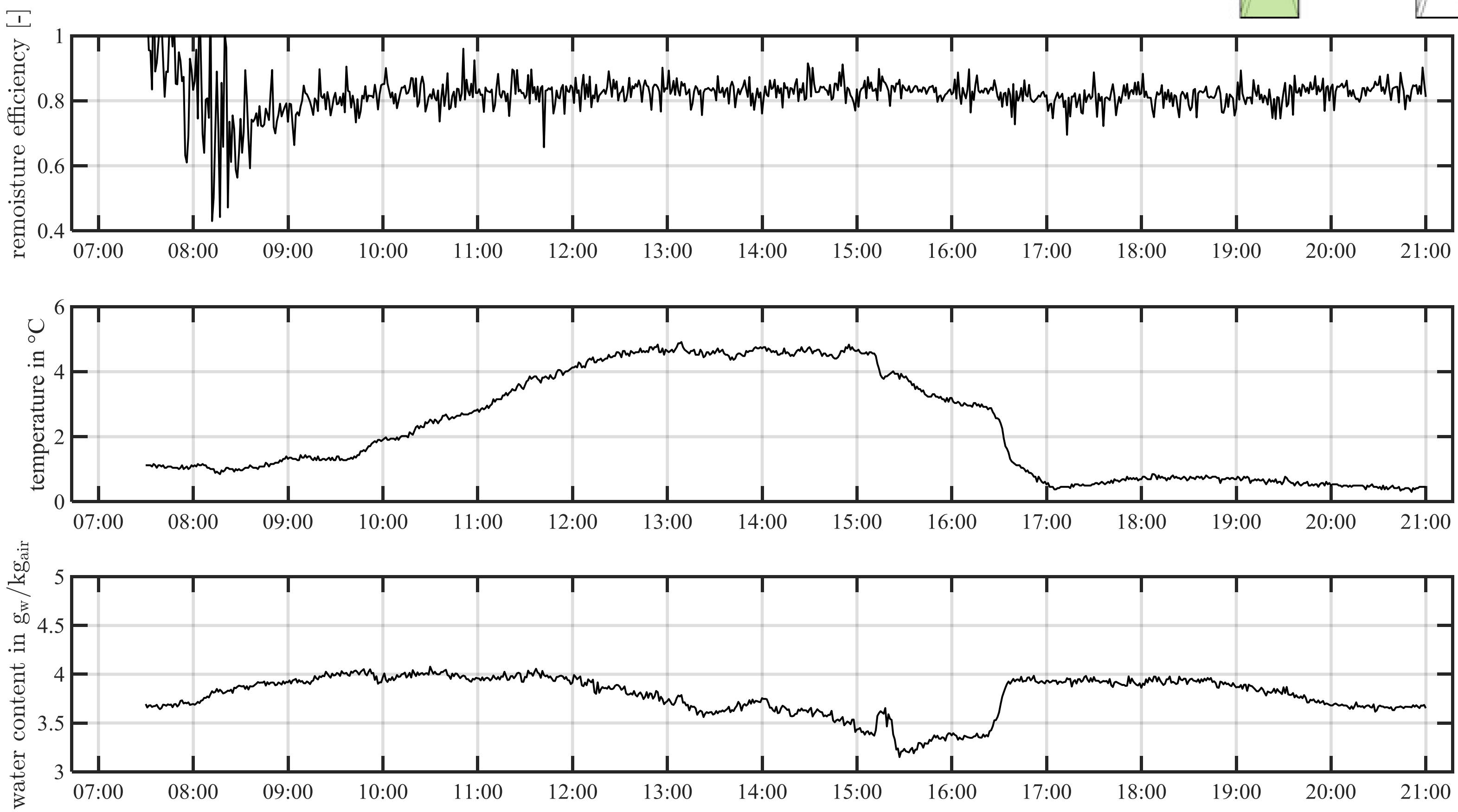
System operation with desiccant wheel based on **silica gel**

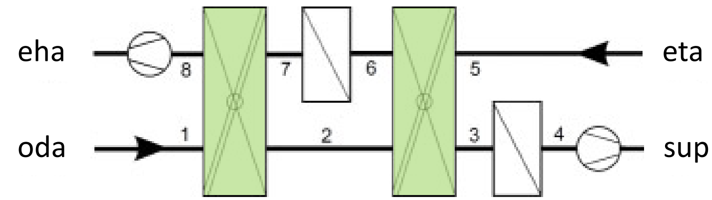


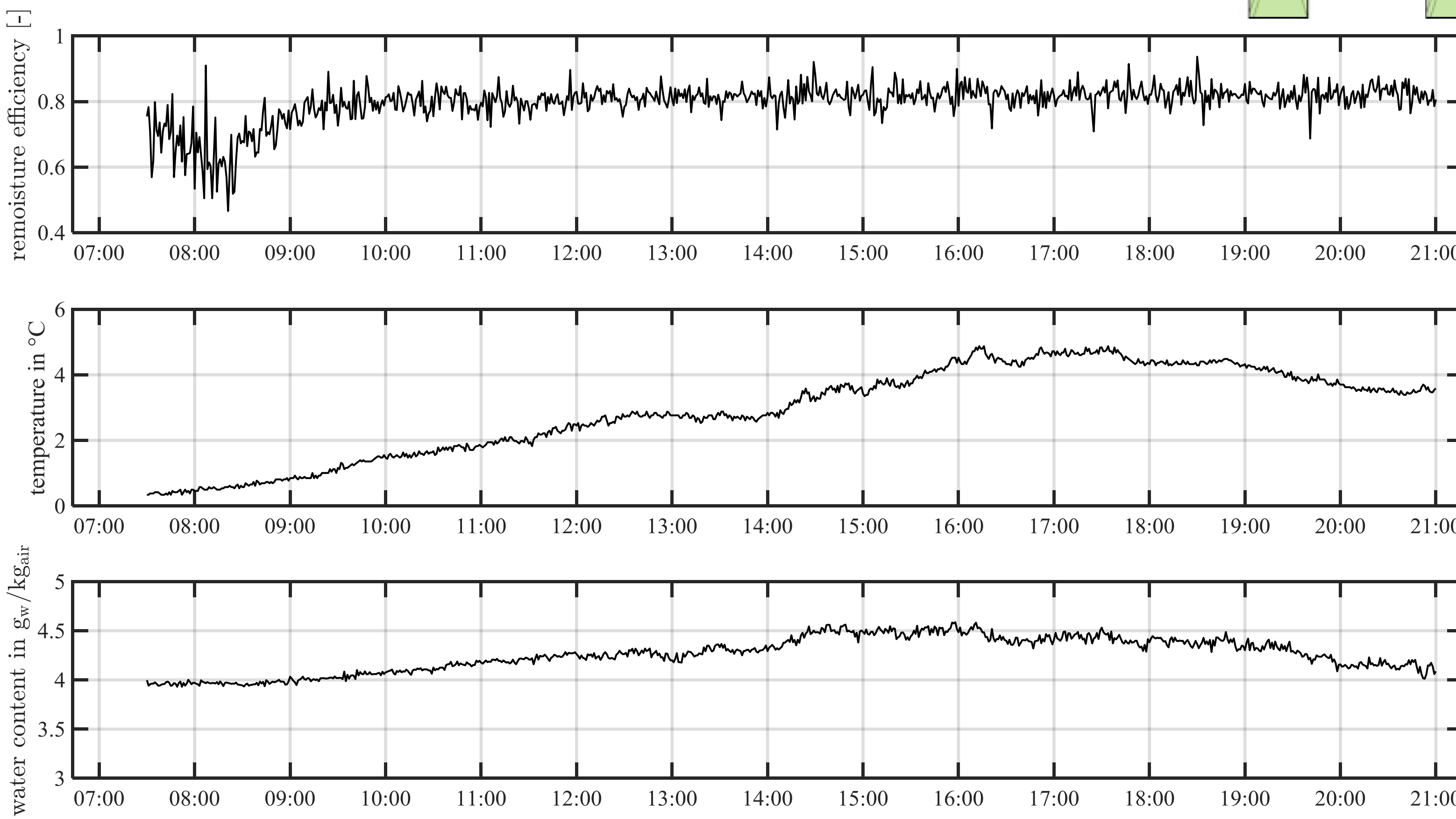


Appendix: Different Operation Modes (2)

Winter Mode

System operation with desiccant wheel based on **silica gel**





Geothermal System – Soil Temperature Profile

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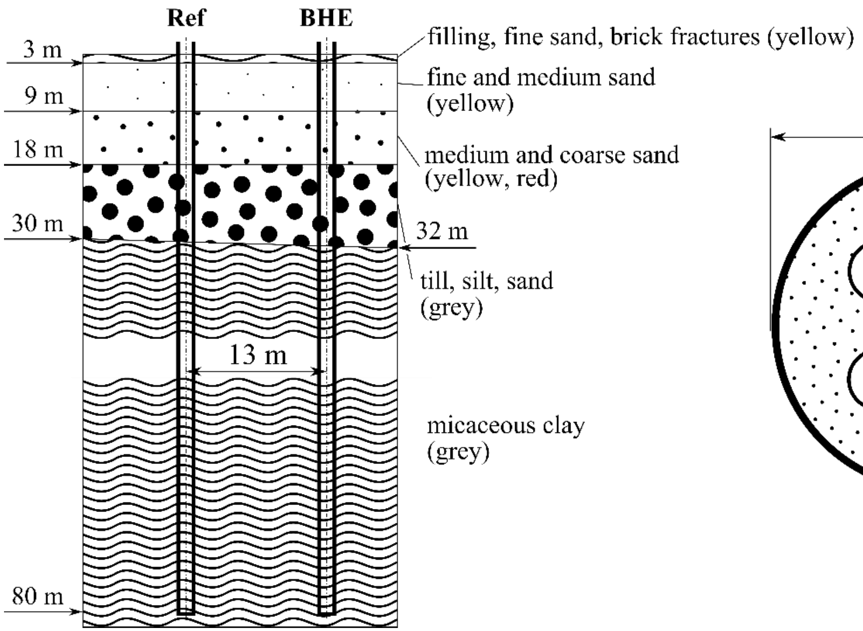
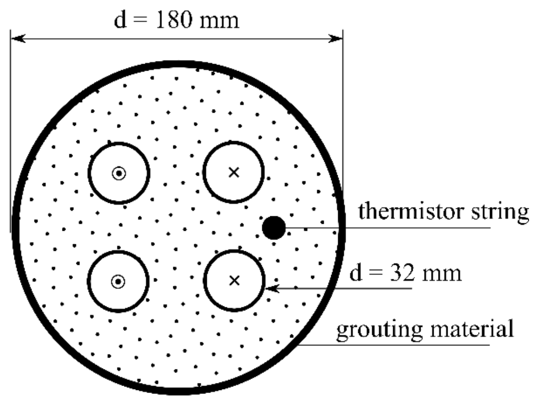
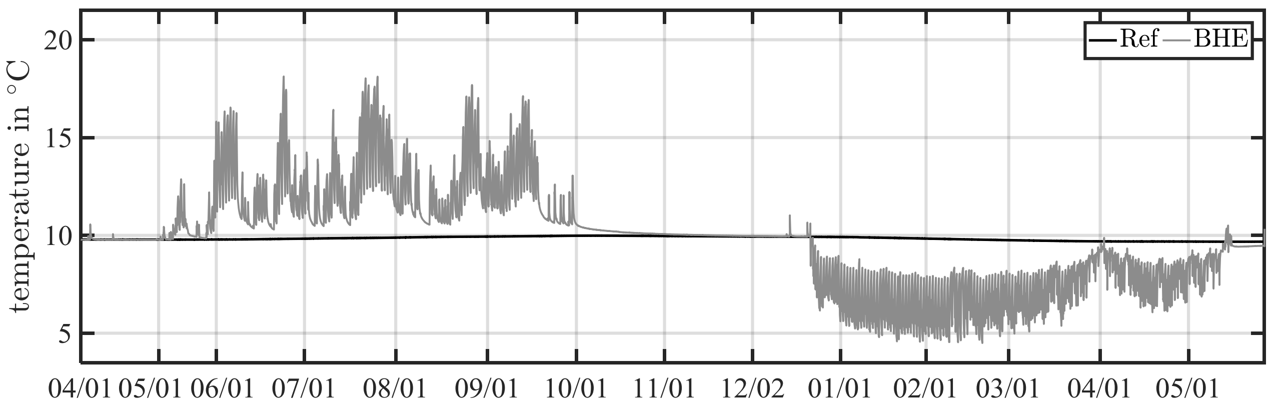




Characteristics

- Double U-tube BHE
- Final drilling depth: 80 m
- No significant ground-water flows



- Equalized energy balance of the soil
- No influence on the surrounding soil

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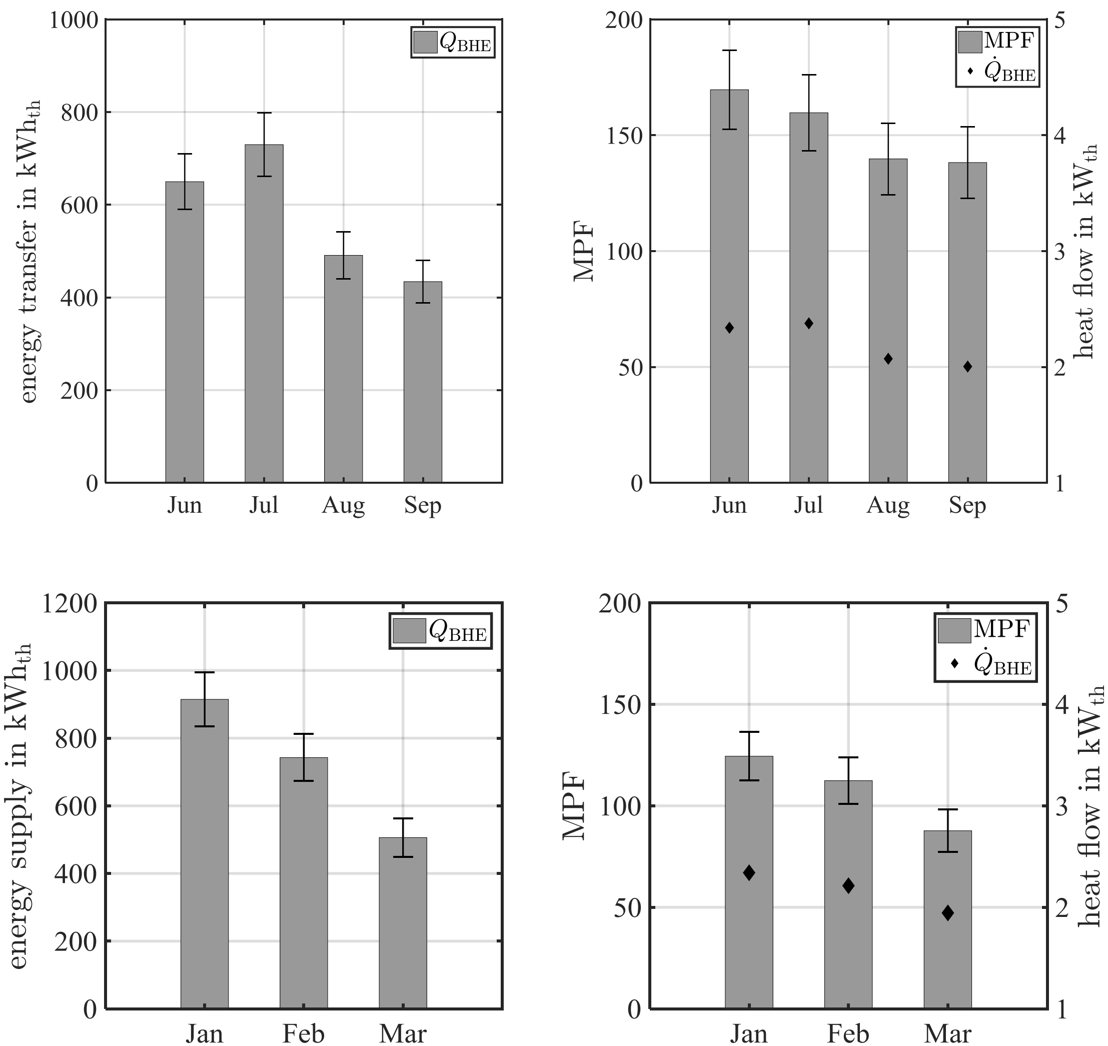
Geothermal System – System Performance



$$\mathrm{MPF} = \frac{\int_{\mathrm{m}} \dot{Q}_{\mathrm{BHE}}\, \mathrm{d}\tau}{\int_{\mathrm{m}} P_{\mathrm{PU}}\, \mathrm{d}\tau}$$

$$\mathrm{SPF} = \frac{\int_{\mathrm{p}} \dot{Q}_{\mathrm{BHE}}\, \mathrm{d}\tau}{\int_{\mathrm{p}} P_{\mathrm{PU}}\, \mathrm{d}\tau}$$

$$\mathrm{SPF}_{\mathrm{su}} = 153 \pm 15$$

$$\mathrm{SPF}_{\mathrm{wi}} = 110 \pm 11$$

$$\mathrm{SPF}_{\mathrm{GHP}} = 3$$