Mitigation of Heat Stress by Energy Saving Air Treatment Devices for Confined Livestock Buildings

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Consortium of PiPoCool

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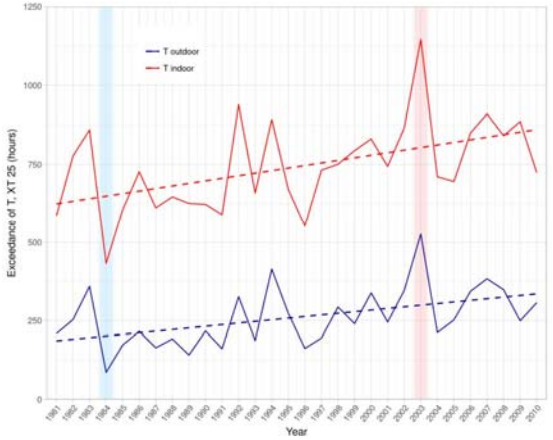
Objectives

Background

Growing concern due to the increase of heat stress inside confined livestock buildings caused by climate change



Increase of heat stress indicators about **1% / a**

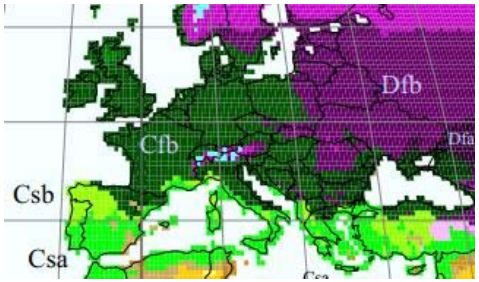
Geographical distribution

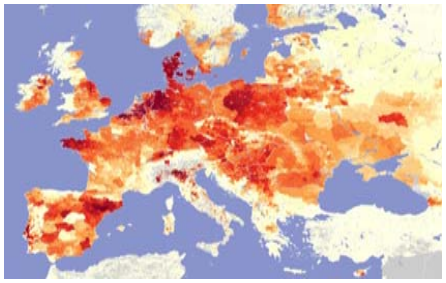
Pig density

Annual Mean Temperature

~5°C

~15°C

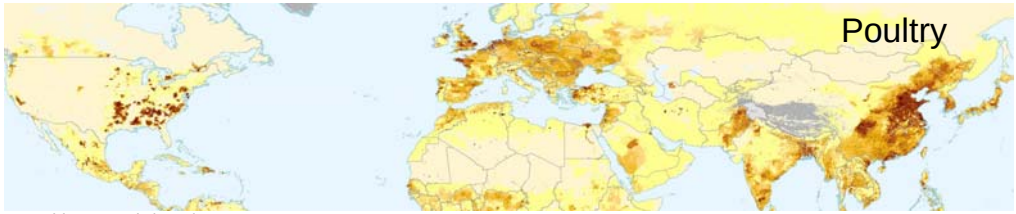




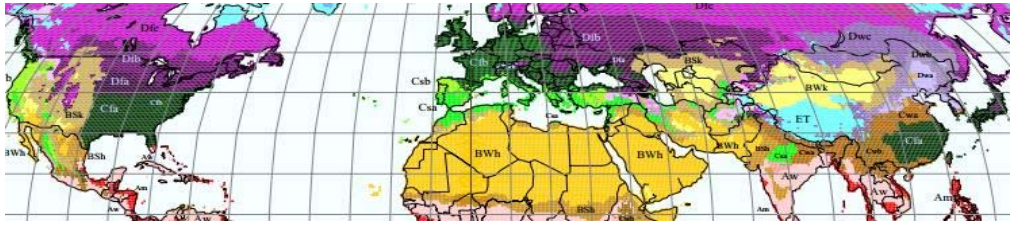
Robinson et al. (2014)

Köppen and Geiger climate classification
Cfb: warm, fully humid, warm summers)

Kottek et al. (2006)



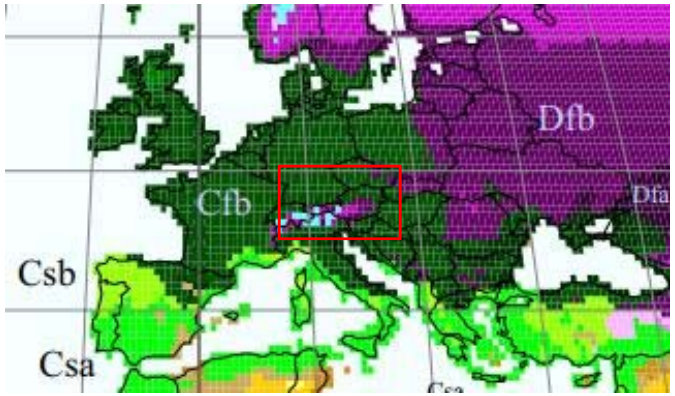
Robinson et al. (2014)



Kottek et al. (2006)

Geographical distribution

Austria
~9°C annual mean temperature



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Assessment of heat stress

Heat stress metrics

Single values: Temperature

Combined values: THI ~ combination of temperature and Humidity (and air velocity THVI) exceedance of a certain threshold

Performance / welfare / health measures

Impact related measures

Daily weight gain
Feed conversion ratio
Laying performance / milk production
? Welfare measures
? Health measures (~ need of medication)

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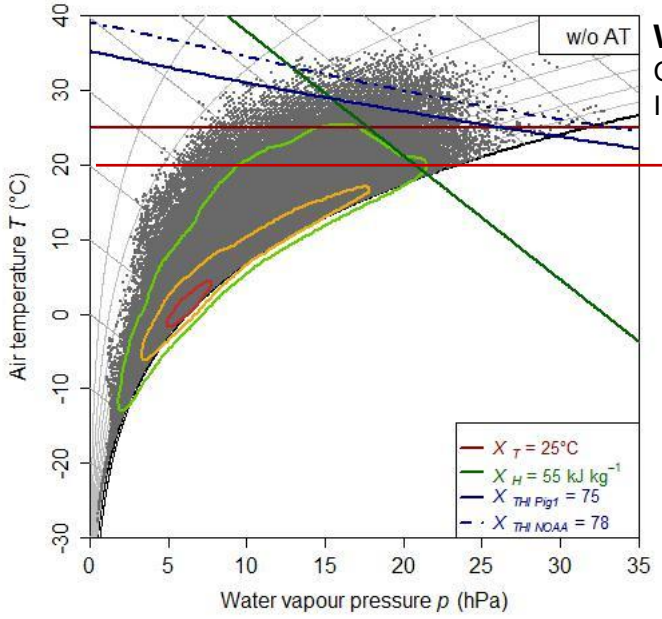
Meteorology of the site



Without Air treatment
Outdoor air temperature = Inlet air temperature

Cut-off > 20°C
= **summer dataset**

11% of entire year

Vitt et al. (2017)

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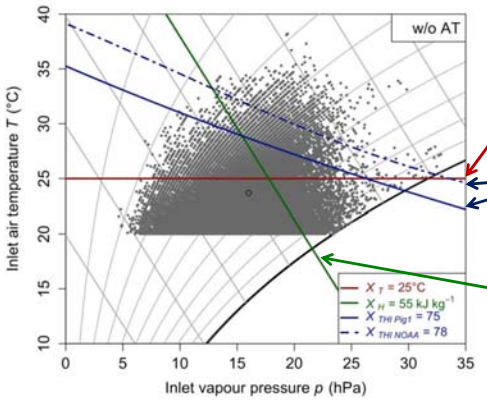
Heat stress measures



Temperature T = 25°C
no influence of the humidity

THI_{Pig} = 75 (pigs)
$THI_{Poultry}$ = 78 (poultry)

Spec. Enthapy
H = 55 kJ/kg

Vitt et al. (2017)

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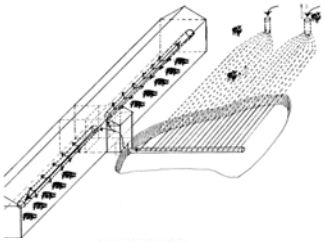
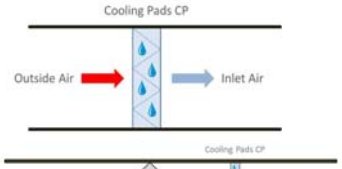
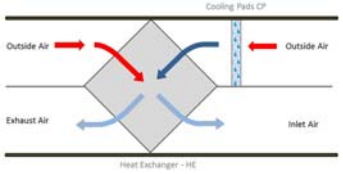
Energy saving air treatment devices



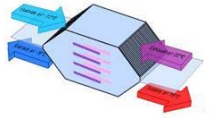
Earth-Air Heat Exchanger EAHE



Direct cooling: Cooling Pads CP



Indirect Cooling:
Cooling Pads + Heat Exchanger CPHE



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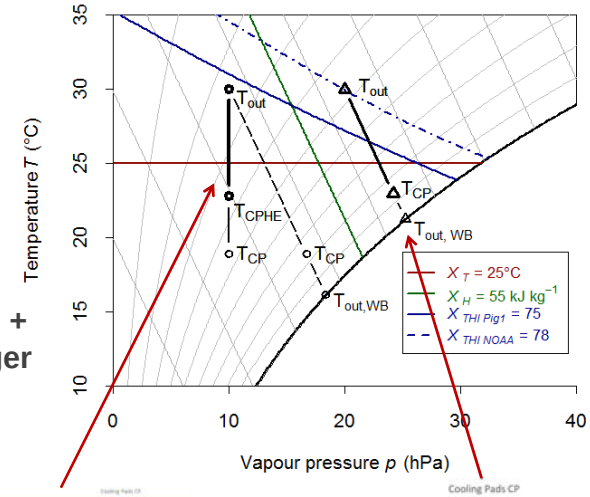
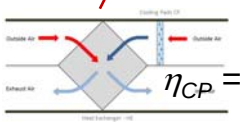
Air treatment process

Cooling Pads + Heat Exchanger CPHE



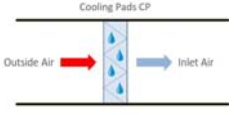
Cooling pads CP



η_{HE} = 65%

η_{CP} = 80%

Vitt et al. (2017)



η_{CP} = 80%

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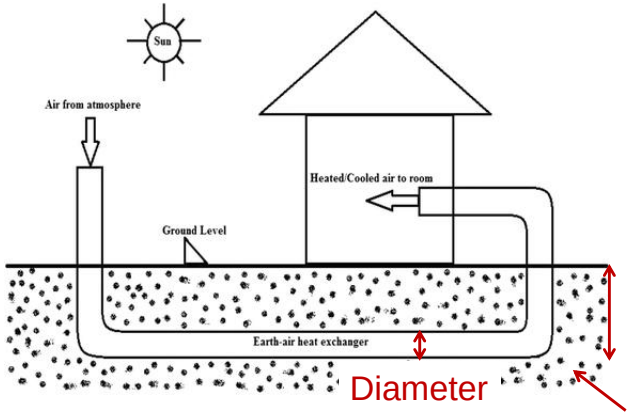
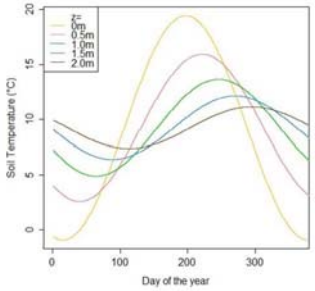
Earth-Air heat exchanger EAHE





Depth of the tubes

Diameter

Thermal properties of the soil

Length of the tubes

Bisoniya (2015)

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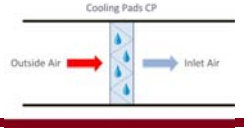
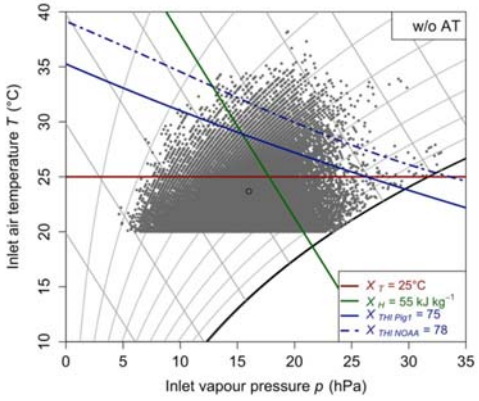
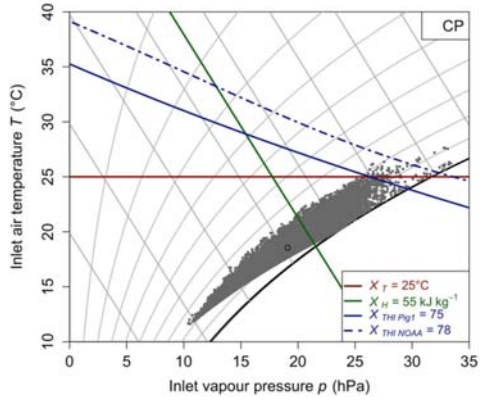
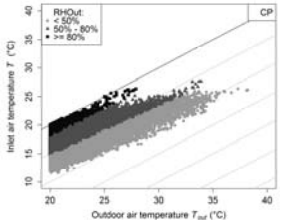
Cooling pads CP









Vitt et al. (2017)

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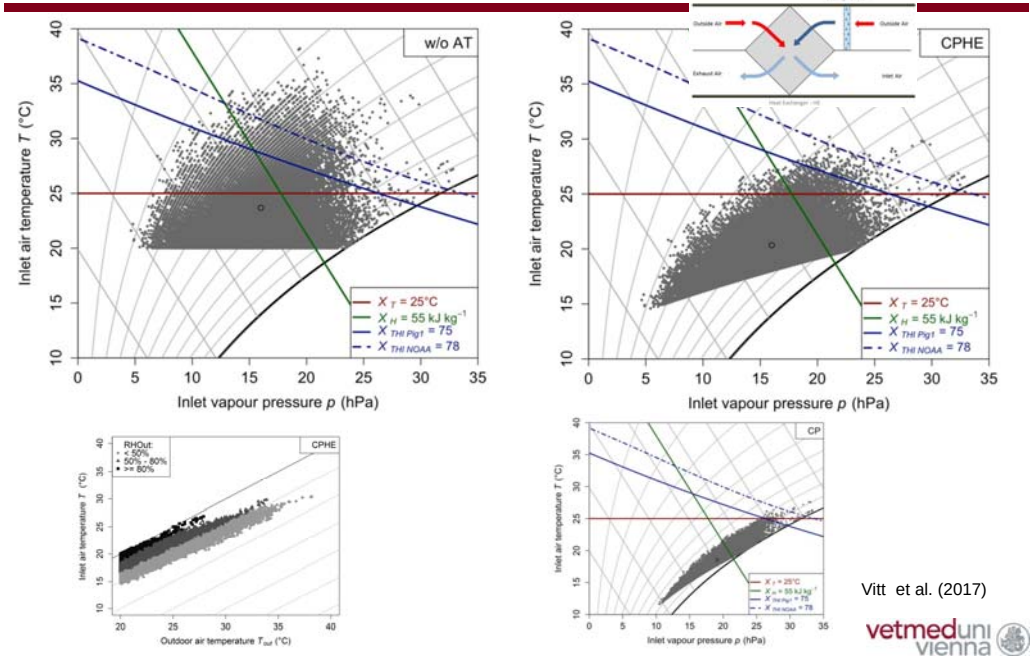
Cooling pads + heat exchanger CPHE



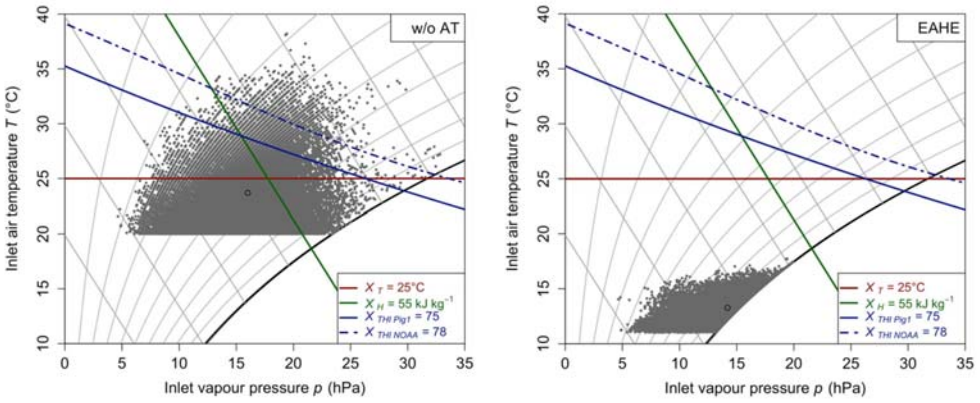
Vitt et al. (2017)

Heat Stress Reduction

Air treatment devices	Heat Stress Metrics			
	Temperature T	Enthalpy H	THI_{Pig1}	THI_{NOAA}
Threshold X	**25°C**	**55 kJ kg^{-1}**	**75**	**78**
Without Air treatment w/o AT				
Frequency P_X (h a^{-1})	275	293	89	29
Area A_X	710	1313	179	39
Duration N_X t = 6/12/18h	26/2/0	20/8/1	7/0/0	2/0/0
Earth-air heat exchanger EAHE				
Frequency P_X (h a^{-1})	0	0	0	0
Area A_X	0	0	0	0
Duration N_X t = 6/12/18h	0/0/0	0/0/0	0/0/0	0/0/0
Cooling pads CP				
Frequency P_X (h a^{-1})	3	293	4	1
Area A_X	7	1313	4	1
Duration N_X t = 6/12/18h	0/0/0	20/8/1	0/0/0	0/0/0
Cooling pads and heat exchanger CPHE				
Frequency P_X (h a^{-1})	40	178	7	1
Area A_X	44	645	8	1
Duration N_X t = 6/12/18h	3/0/0	10/4/1	1/0/0	0/0/0

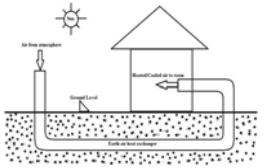
Vitt et al. (2017)

Earth-Air Heat Exchanger EAHE



Vitt et al. (2017)

Air treatment features of EAHE

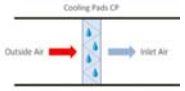


Features of the EAHE

Application:	All the year round ✓
Energy demand:	Pressure drop ×
Summer effect:	Cooling, no heat stress ✓
Winter effect:	Heating, no cold stress ✓
	Increased air quality ✓
Costs:	High ×
Extras:	Damping short-term fluctuations ✓

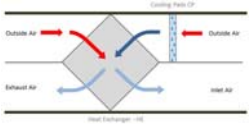
Air treatment features for CP and CPHE

Cooling Pads CP



Application:	Only summertime ×
Energy demand:	Moderate pressure drop ×
Summer effect:	Cooling ✓ Increased humidity ×
Winter effect:	---
Costs:	Low ✓
Extras:	Removal of dust and bio-aerosols ✓

Cooling Pads + Heat Exchanger CPHE



Application:	All the year round ✓
Energy demand:	Pressure drop ×
Summer effect:	Cooling like CP, no humidification ✓
Winter effect:	Heating by the HE, no cold stress ✓ Increased air quality ✓
Costs:	Medium ×
Extras:	Removal of dust and bio-aerosols ✓

Outlook

- **Suitability** of EAHE, CP, and CPHE to reduced heat stress in confined livestock buildings in Central Europe
- **Economic evaluation of air treatment devices** livestock production losses due to heat stress vs investment and maintenance costs
- **Linking various models**
  - Indoor climate of livestock buildings
  - Climate change scenarios
  - Economic farm models

Acknowledgements

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