

Simulation of the indoor climate of livestock buildings to assess of adaptive measures to reduce heat stress due to climate change

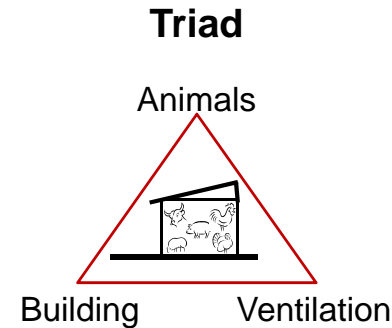
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Model structure



Balance equations

Sensible heat
Latent heat
CO₂
odour
(NH₃)

Temporal resolution

one hour (steady-state)

Air Treatment

heating, cooling pads, fogging,
earth tubs, heat exchange

Limitation

mechanically ventilated building



Objectives

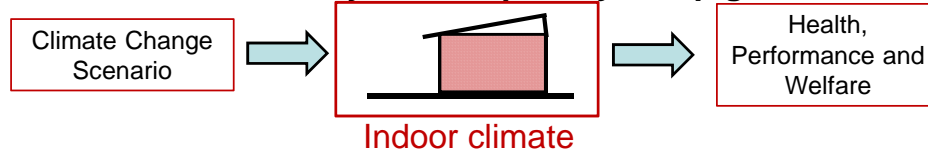
Background

Impact assessment of climate change scenarios on farm animals in confined livestock buildings

Grazing animals ~ cattle



Confined livestock systems ~ poultry and pig

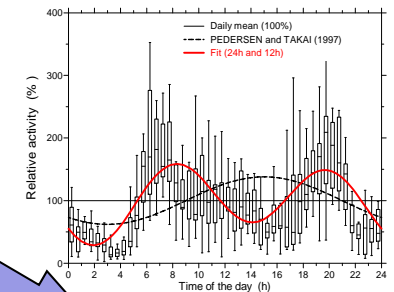


Animals

Total energy release

$$Q_A = c M^{0.75}$$

Diurnal variation



$$Q_A = \text{Sensible Heat} + \text{Latent Heat}$$

increase of temperature + increase of humidity

$$\text{CO}_2 \text{ release} \propto \text{Total energy release } Q_A$$



Building

Construction elements (setup and area)

Wall, ceiling, windows and doors

Sensible heat S_B loss due to thermal transmittance

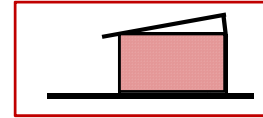
Heat transfer coefficient (U value)

Sum of the two convective heat transfer coefficients (air-wall) and the thermal conductivity (wall)

$$S_B = U A (T_o - T_i)$$

Application of the model

Meteorological data



Indoor climate



Impact on the animals

Reference data (1981-2010)

Climate change scenario RCP 4.5 (2036-2065)

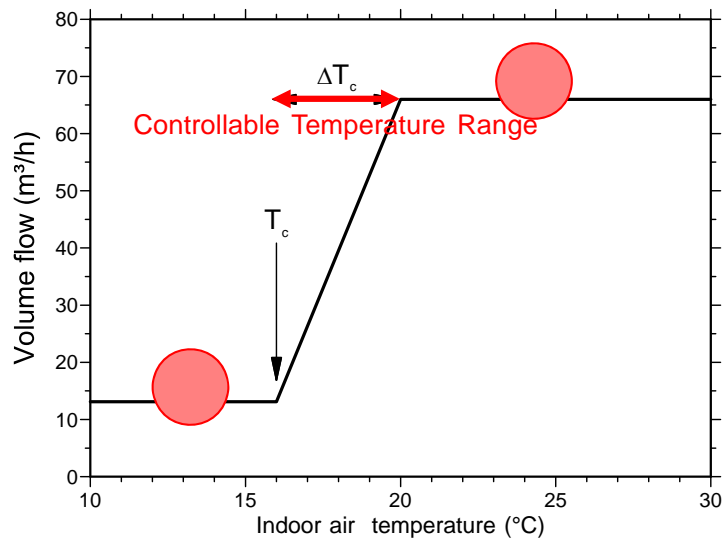
Core Module: Mechanical ventilation

Air treatment: cooling pads, fogging, earth-air Heat exchanger, heat exchanger

Management: inverted feeding regime, animal density

Ventilation system

Design parameters (V_{max} and V_{min}) and control unit



Air treatment

Heating

Earth - air heat exchanger

Heat exchanger regenerative recuperative

Cooling pads

Water fogging systems

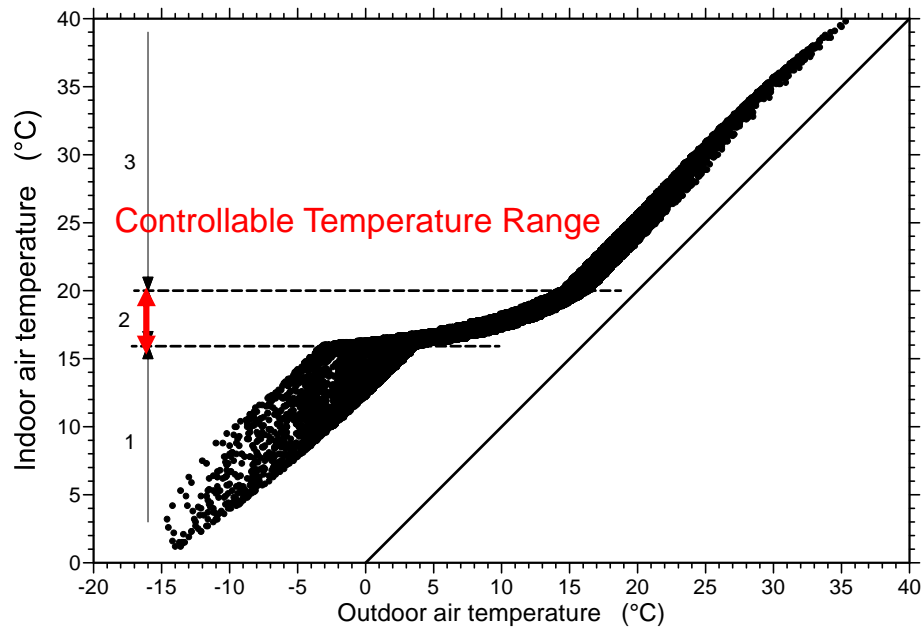
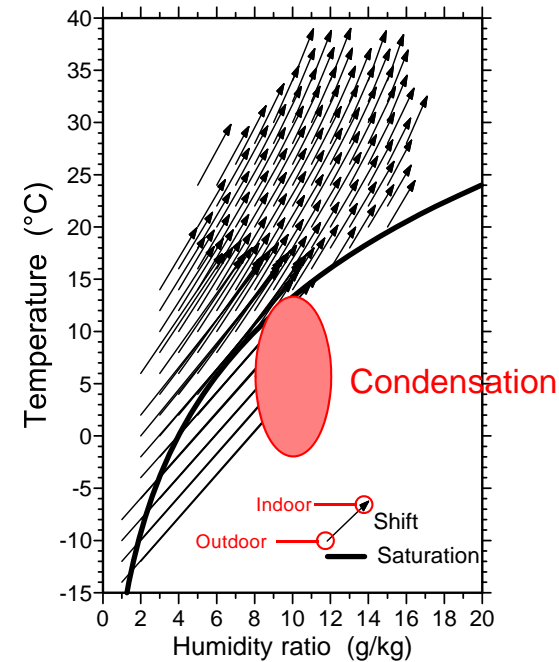
Output of the simulation

Thermal environment

indoor temperature and humidity
condensation
heat stress indices ~ THI

Indoor air quality = emission concentration

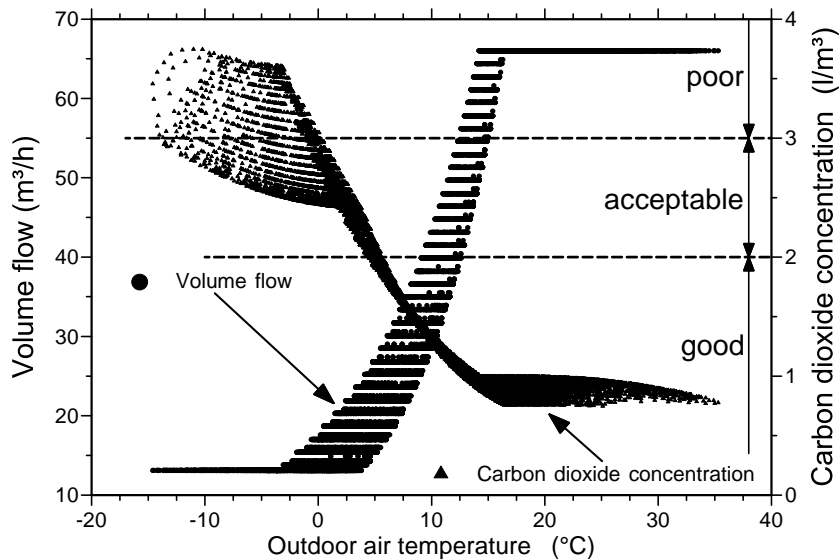
CO₂ ~ GHG
NH₃ ~ precursor for PM
odour ~ annoyance



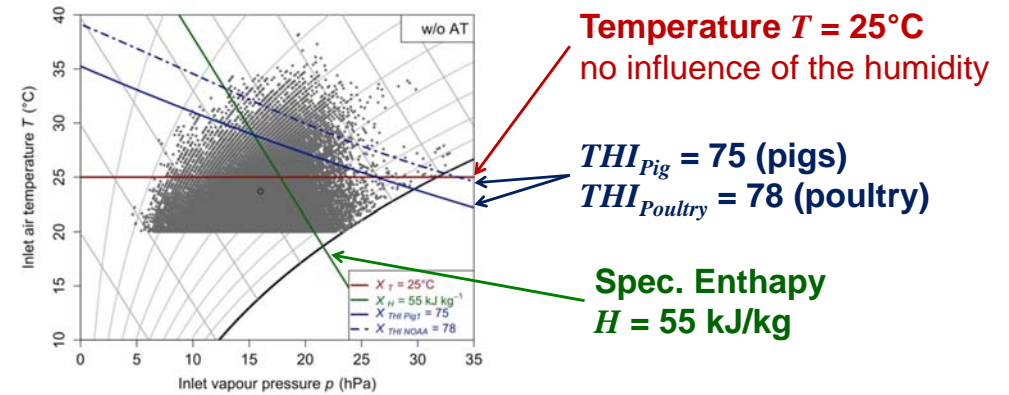
Thermal indoor climate

Indoor temperature	Relative humidity F (%)			Sum
	< 50	50 - 70	> 70	
T _i > 20°C	12.6	10.5	3.9	27.0
16°C ≤ T _i ≤ 20°C	1.4	39.0	0	57.4
T _i < 16°C	0	0	16.6	16.6
Sum	14.0	26.5	59.5	100

Optimum



Heat stress measures



Temperature $T = 25^{\circ}\text{C}$
no influence of the humidity

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

Spec. Enthapy
 $H = 55$ kJ/kg

Assessment of heat stress

Heat stress metrics

Single values: Temperature

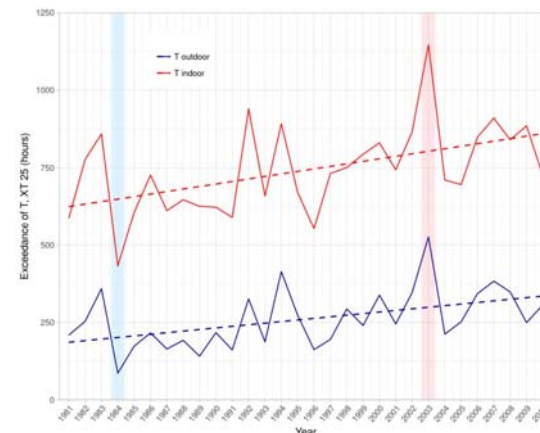
Combined values: THI ~ combination of temperature and Humidity (and air velocity) exceedance of a certain threshold

Performance / welfare / health measures

Impact related measures

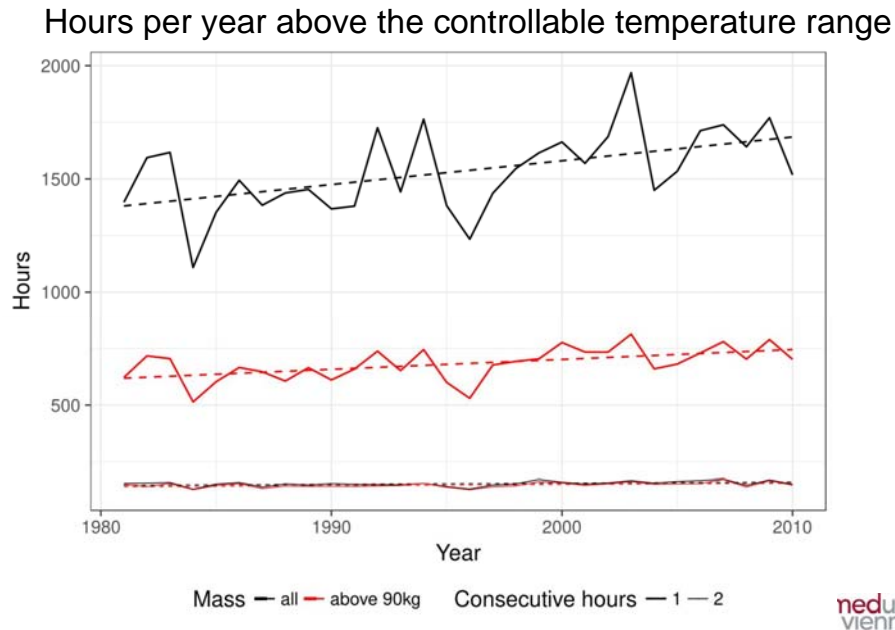
- Daily weight gain
- Feed conversion ratio
- Laying performance / milk production
- ? Welfare measures
- ? Health measures (~ need of medication)

Heatstress 1981 to 2010



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

Hours above the controllable range



Acknowledgements

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PiPoCooL Climate change and future pig and poultry production: implications for animal health, welfare, performance, environment and economic consequences is

(ACRP8 – PiPoCooL – KR15AC8K12646)

www.vetmeduni.ac.at/pipocool/

Model application

Impact on livestock

- Business as usual: assessment of the resilience
- Adaptation measures: costs and benefits
- Vulnerability and adaptive capacity

Impact on the environment

- CH₄ ~ not relevant for pig and poultry
- CO₂ ~ GHG
- NH₃ ~ precursor for PM, eutrophication
- odour ~ separation distance to avoid annoyance