Temperaturas elevadas – Instalaciones eficientes para hacer frente al calor

Stefano Benni

Profesor asociado del Departamento de Ciencias Agrarias y Alimentarias de la Universidad de Bolonia

Introduction

- Optimal environmental conditions in pig barns are essential for the well-being and productivity of the animals.
- High temperatures and humidity can have detrimental effects on pig health, growth, and reproduction, leading to economic losses for farmers.
- The intensive and closed breeding model makes the indoor air environment in the pig house one of the main external drivers directly related to the growth and development of pigs.

Thermo-Neutral Zone

A widely accepted concept to define the optimal thermal conditions:

- Thermo-Neutral Zone, an effective temperature range in which animals have to use a minimal amount of energy to keep their core body temperature constant.
- lower boundary: **lower critical temperature (LCT)**,
- upper boundary: **upper critical temperature (UCT)**.
- Outside of this zone, the animal suffers from cold stress or heat stress:
  - *Discomfort,*
  - *Loss of productivity.*
  - *…Death.*

Limits of thermal neutral zone and comfort zone in pig farm.

LCT = Lower Critical Temperature, TNZ = Thermo-Neutral Zone,
TCZ = Thermal Comfort Zone, UCT = Upper Critical Temperature

Animal category	Weight (kg) or age	LCT TNZ (°C)	Upper limit TCZ (°C)	UCT TNZ (°C)	Source
Newborn piglets		34	38		Loncke et al., 2009
Piglets in farrowing compartment		32	35		Loncke et al., 2009
	< 5.4	29			Baker, 2004
	5.4 - 6.35	24			Baker, 2004
Nursery	age 21d - 65d	25	29		Amaral et al., 2020
	18	17			Baker, 2004
	just weaned	26 - 28			Faure et al., 2013
Fattening pigs	27	13			Baker, 2004
	45	12			Baker, 2004
	60	18 -20			Faure et al., 2013
			19.8	22.3	Brown-Brandl et al., 2001
Breeding - gestation sows		12			Baker, 2004
		15		22	Lucy and Safranski, 2017
Lactating sows		16		25	Machado et al., 2016

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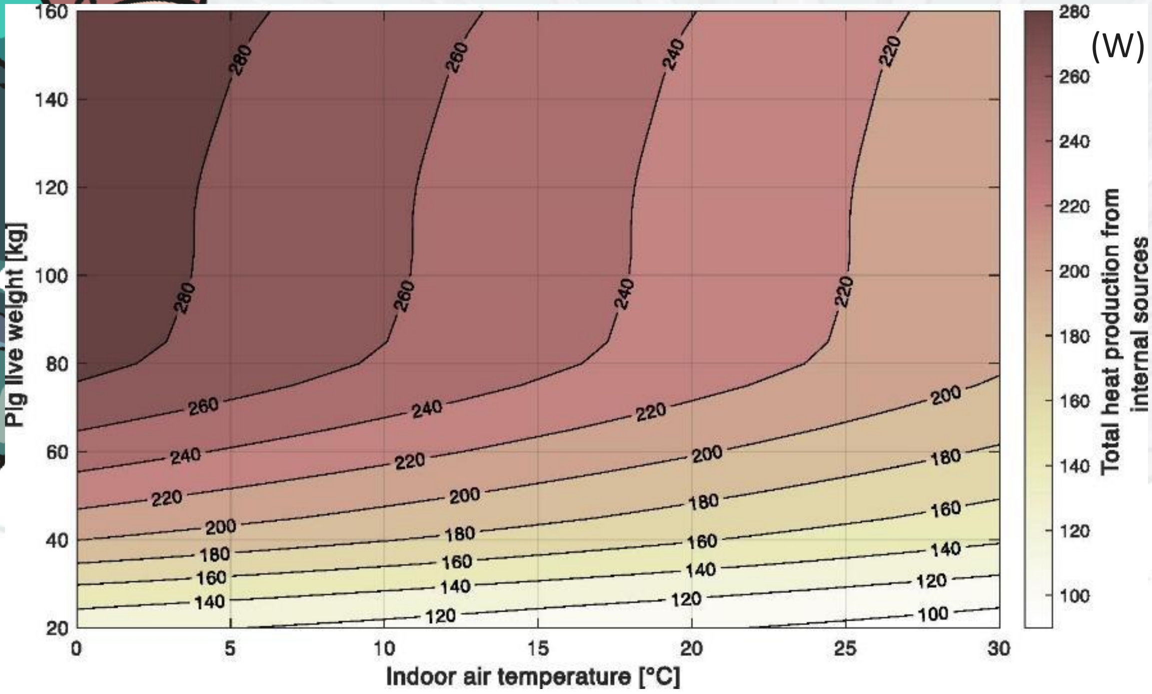
Influence of heat stress on productivity in pig farms

Animal category	Performance parameter influenced by heat stress
Sows in farrowing compartment	• Increase in body weight loss during lactation with consequences on reproductive performance • Lower milk yield which results in lower body weights of piglets at weaning
Early pregnant sows	• Increased risk of early abortion -> decreased number of farrowings per sow or litter size
Sows at the end of gestation	• Decrease of gestation period • Reduced litter birth weight • Negative effects on reproduction performance of the offspring
Piglets at the end of the nursery period	• Lower body weights • Lower daily growth rate
Heavy fattening pigs	• Lower body weights • Lower daily growth rate • Increased mortality

Considering heat stress, the most important risk groups amongst pigs are **sows in the farrowing** compartment, sows at the **end of gestation** and heavy **fattening** pigs.

Total Heat Production

- THP values of pigs by ASHRAE standards from data collected in either the 1970s (nursery piglets) or the 1950s (growing-finishing pigs).
- Brown-Brandl et al. (2014): increase of THP of 16%
- Physiological signs of heat stress already at lower ambient temperatures.

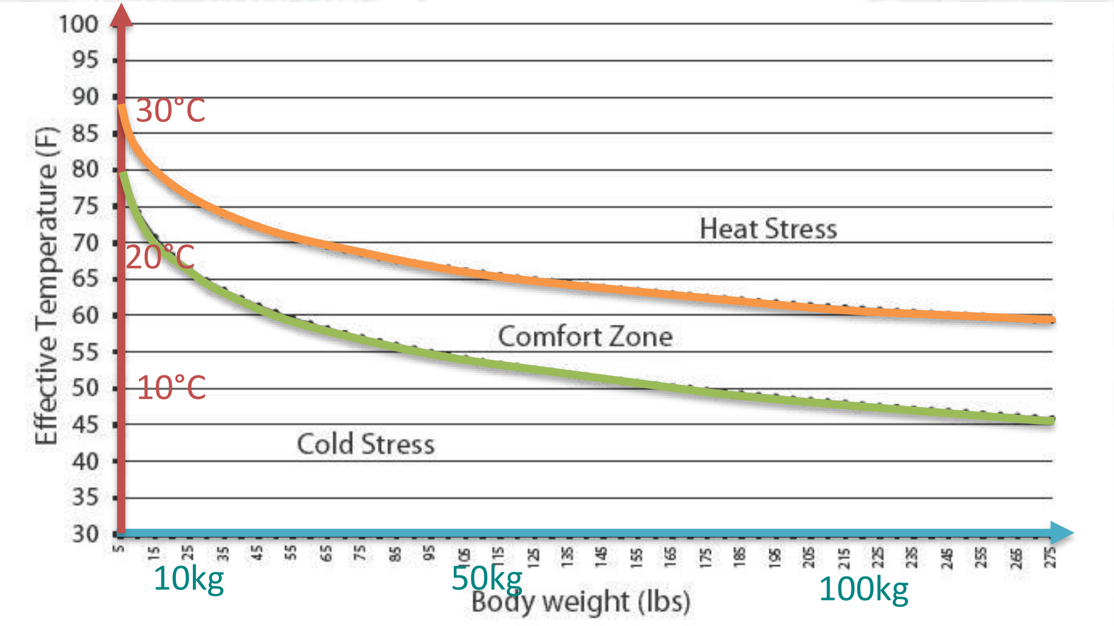


Source: Costantino A., Comba L., Cornale P., Fabrizio E, 2022. Energy impact of climate control in pig farming: Dynamic simulation and experimental validation, Applied Energy, 309, 118457

Based on equation by:

Pedersen S&, Sällvik K. 4th Report of Working Group on Climatization of Animal Houses – Heat and moisture production at animal and house levels. Horsens: 2002.

Effective temperature for pigs



Floor type	Effect (°C)
Lying mat	+1.7
Uncoated wire	-5
Plastic coated wire	-3.9
Extruded plastics	-3.9
Dry concrete	-5
Wet concrete	-10

Air speed (m/s)	Effect (°C)
0.15	-3.9
0.45	-8
1.5	-10

McFarlane, J. M., (2004). How do your pigs really feel? Marysville, Ohio: Animal Environment Specialists.

Temperature-Humidity Index (THI)

$$THI = 0.8 \times T + \left[\left(RH / 100 \right) \times \left(T - 14.4 \right) \right] + 46.4$$

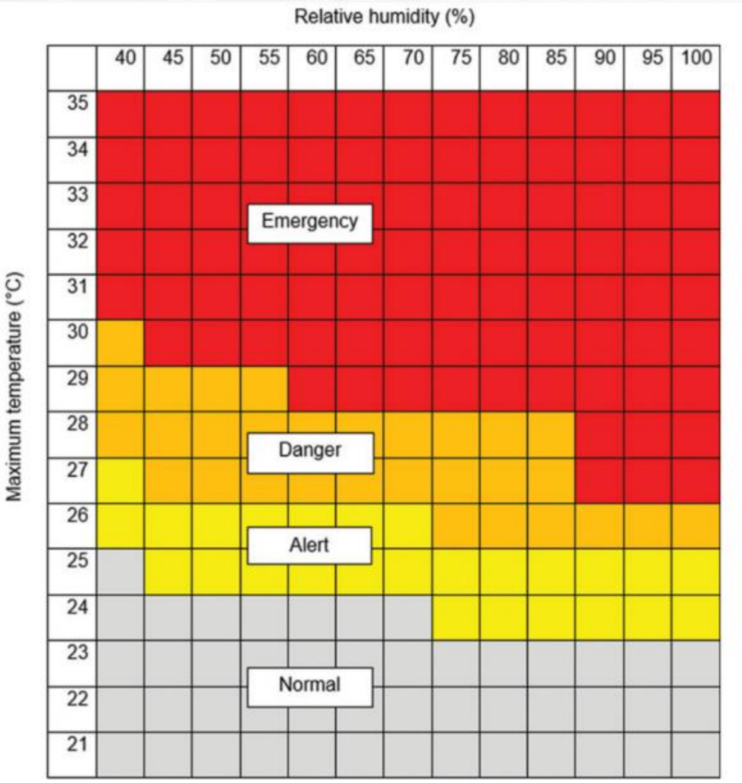
T = dry bulb temperature (°C),

RH = relative humidity (%).

THI: unitless value

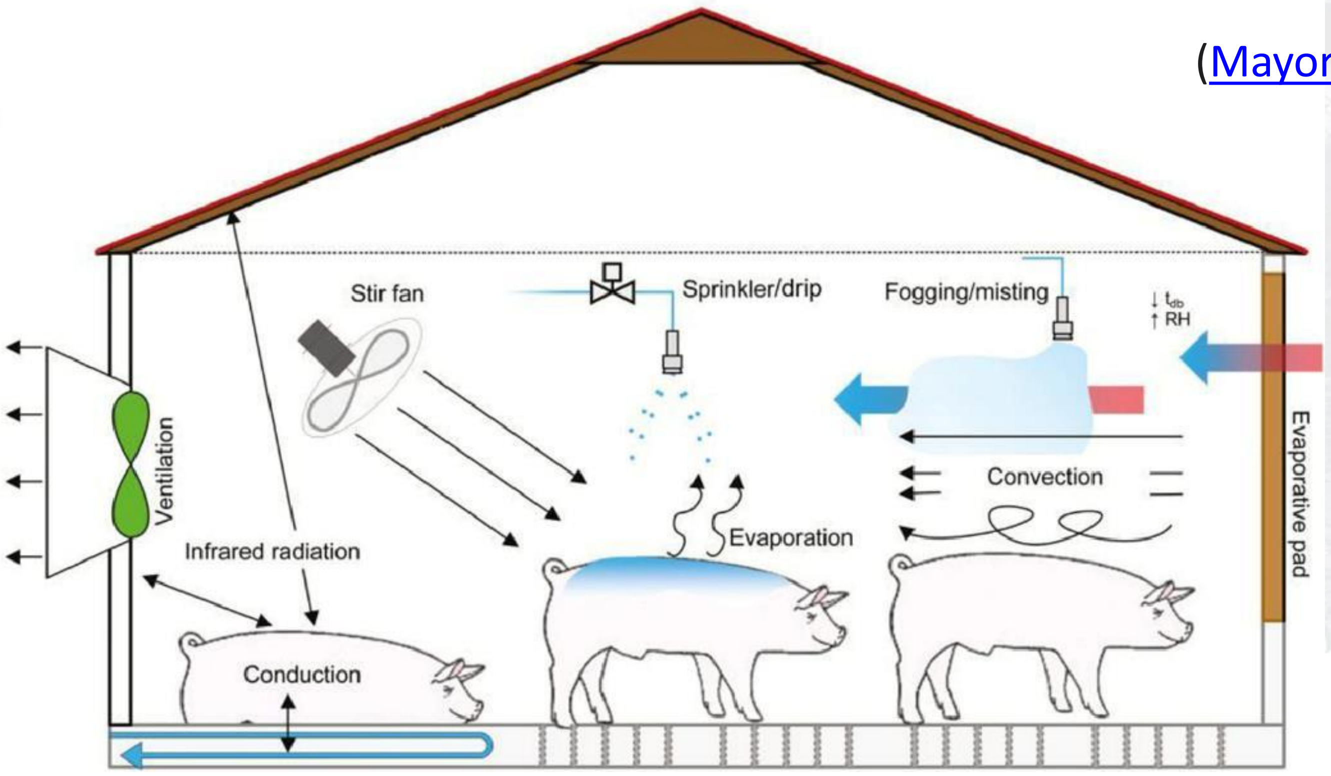
Four categories related to livestock thermal comfort:

- normal (THI≤74),
- alert (75≤THI≤79),
- danger (80≤THI≤83),
- emergency (≥84).



Types of cooling systems

(Mayorga et al., 2019)



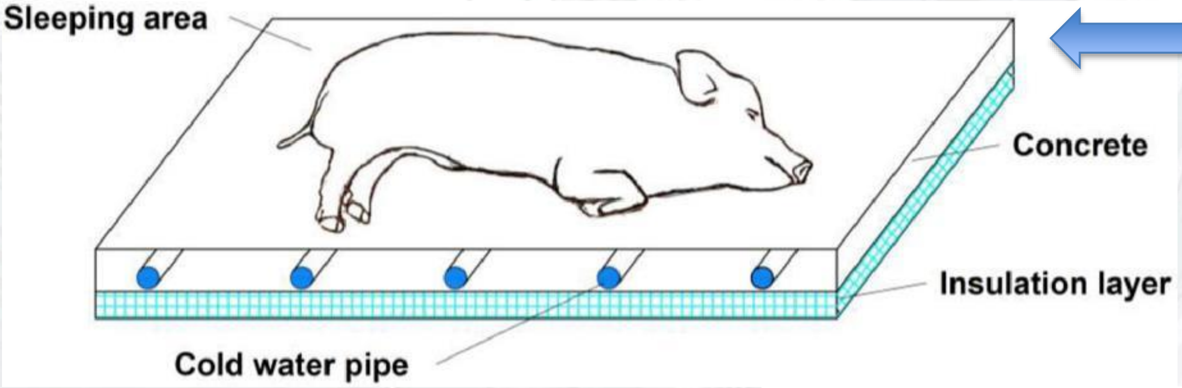
Cooling systems characteristics

Category	Cooling principle	Advantages	Disadvantages
Convection-evaporative cooling terminal	The sensible/latent heat exchange between the indoor air and the pig	•High ventilation rate, good air quality •Using the air-cooling effect to increase the heat dissipation of pigs	•The cooling effect of the evaporative cooling is affected by the outdoor weather •High indoor relative humidity due to water evaporation
Radiation-conduction cooling terminal	Increasing the sensible heat dissipation of the pig by radiation or conduction	Effective in relieving heat stress in pigs even at high room temperatures	•High cost of installation •Solid structure, easily contaminated by excrement, needs to be cleaned regularly

(Munters, 2022)

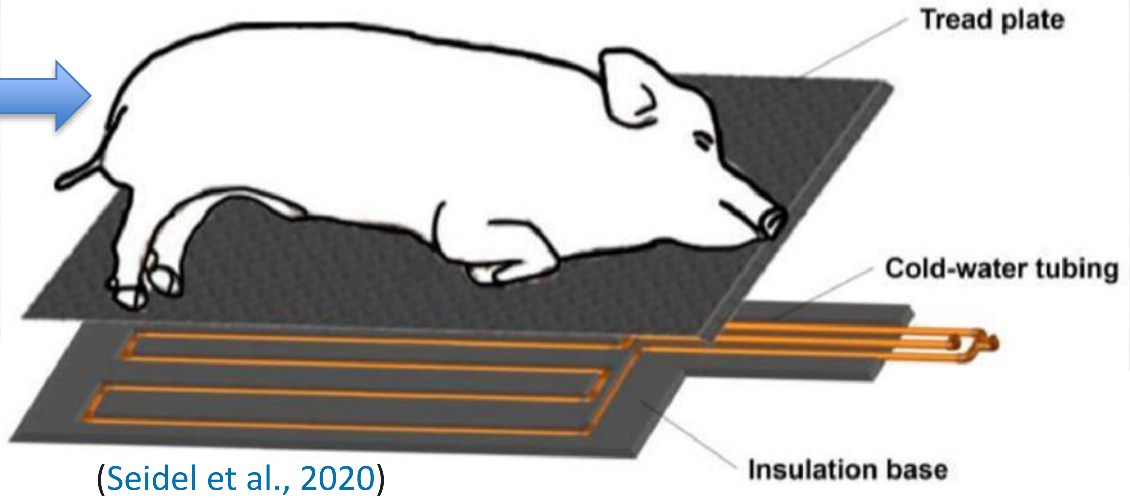
Cooling type	Key factors	Advantages	Disadvantages
Natural ventilation	Vent design, system operation and management, building orientation and location	Fuel conservation and cost saving	•Unstable cooling effect •Not suitable for multi-floor buildings
Pad-fan	Inlet air temperature and humidity, wet curtain geometry, over-curtain air speed	Excellent cooling effect in dry climate areas	•Large non-uniformity of indoor temperature •High indoor humidity •High airtightness requirements for pig houses, otherwise airflow short circuit will seriously affect the cooling effect
Fogging/misting and ventilation	Inlet air temperature and humidity, ventilation rate, the overall coordination of the fogging and ventilation parts	•Fast cooling and low room temperature •Suitable for boar houses	High indoor humidity
Drip/sprinkle and ventilation	Water flow rate, ventilation rate	Local cooling, suitable for lactating houses	Persistent dripping and prolonged hours lying may cause pigs to develop shoulder ulcerations and increase the chances of squeezing the piglets
Fan-coil	Circulating air volume, inlet water temperature, water flow rate	Stable cooling effect and suitable indoor humidity	Lack of fresh air supplementation and recycling of indoor air may lead to the growth of bacteria
EAHE	The geometry of the buried pipe, the thermo-physical properties of the ground and air, and the thermo-hygrometric conditions of the air at the inlet of the buried pipe and the air flow rate	•Cooling and dehumidification of fresh air, good air quality •Low fluctuation of room temperature	A large area of land is required to ensure a stable cooling effect

Water-cooled floor or pad



The water-cooled floor is suitable for the particular thermal comfort demands in the lactating house. Cold water pipes under the sow cage floor only, higher air temperature, and infrared light to meet the thermal demand of piglets.

The W-C pad decreased the gilt's heat production, moisture production, and respiration rate by 10%, 34%, and 22%, respectively.
It reduced the duration of time spent standing and sitting by 53%, increased the lying time of the lactation sows by 11%, especially the lying laterally time by 23% (Parois et al., 2018)

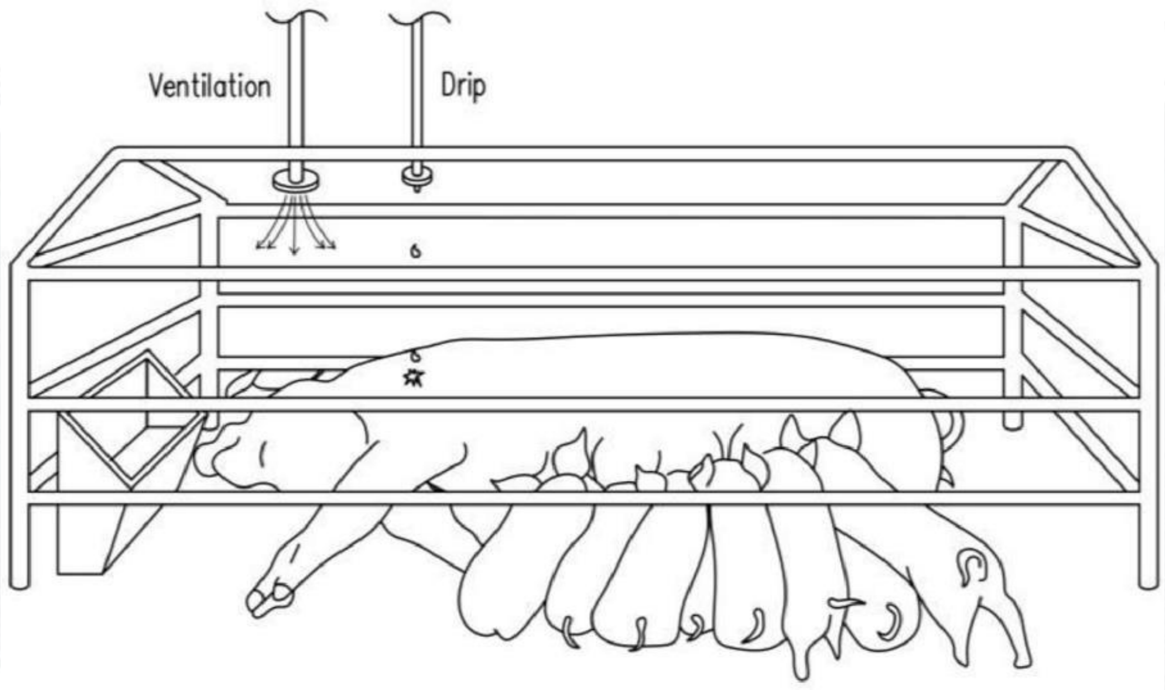


(Seidel et al., 2020)

Radiation-conduction cooling

Cooling terminal type	Key factors	Advantages	Disadvantages
Water-cooled floor	Water temperature, water flow, heat exchange area, thermo-physical properties of the floor	•Improve the sleeping environment of pigs in general pig houses •Satisfy the special thermal comfort demands of lactating houses	Large thermal inertia, slow cooling speed, low energy utilization efficiency
Water-cooled pad	Water temperature, water flow, heat exchange area, thermo-physical properties of the pad	•Excellent temperature uniformity, fast thermal response •Facilitating dynamic regulation •Suitable for the lactating house	High production costs
Radiant cold panel	The tube spacing, the temperature difference between the ambient air and the inlet water, and the height of the canopy	•Relieves heat stress of pigs in hot and humid weather •Suitable for the lactating house	•High relative humidity in the equipment due to insufficient ventilation •Dirty equipment will reduce the frequency of pigs lying in the equipment

Drip/sprinkle and ventilation cooling



Water dripped on the neck area of the sow, which has a high blood volume. Heat conduction between water droplets and skin and evaporation of water reinforced by forced ventilation enhances heat dissipation in the sow This cooling terminal solves the problem of different thermal comfort zones for sows (18–22 °C) and piglets (28–32 °C) in the lactating house. (Dong et al., 2001)

Pad-fan cooling system

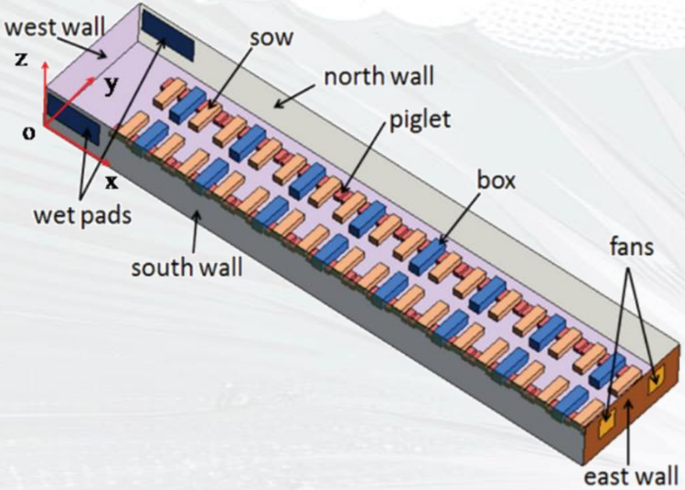
Animal/Type of Facility	Cooling Technology	Climatic Parameters		Main Effect on Physiological/ Performance Markers
		Uncooled Room	Cooled Room	
Lactating sows/concrete building with open air inlets	Fogging system	AT 27.8 °C RH 49.8% THI 75.3	AT 25.7 °C RH 68.4% THI 74.5	Decrease of respiratory rate
Lactating sows/open side walls building	Evaporative pads with forced ventilation	AT 26.2 °C RH 69.8% AV 0.1 m/s	AT 24.1 °C RH 79.5% AV 3.25 m/s	Decrease of respiratory rate and skin surface temperature

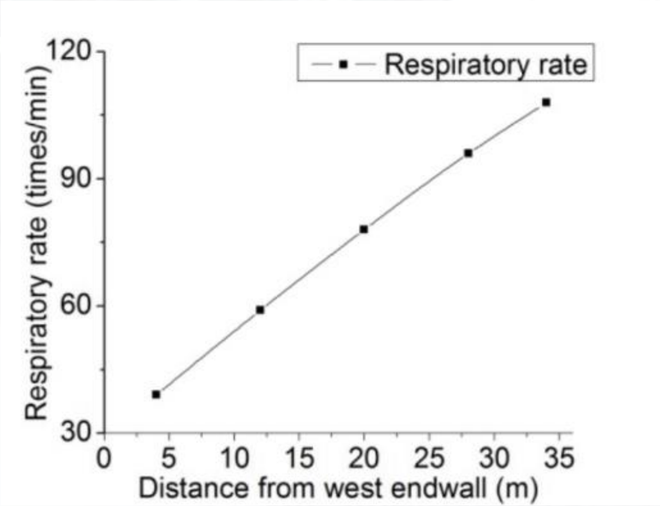
(Godyń et al., 2020)

Impact of cooling methods on climatic and physiological parameters in pigs.
AT—air temperature, RH—relative humidity, THI—thermal humidity index, AV—air velocity.

HYGROTHERMAL CONDITIONS IN A FARROWING ROOM

Two wet pads as air inlets and two exhaust fans as outlets

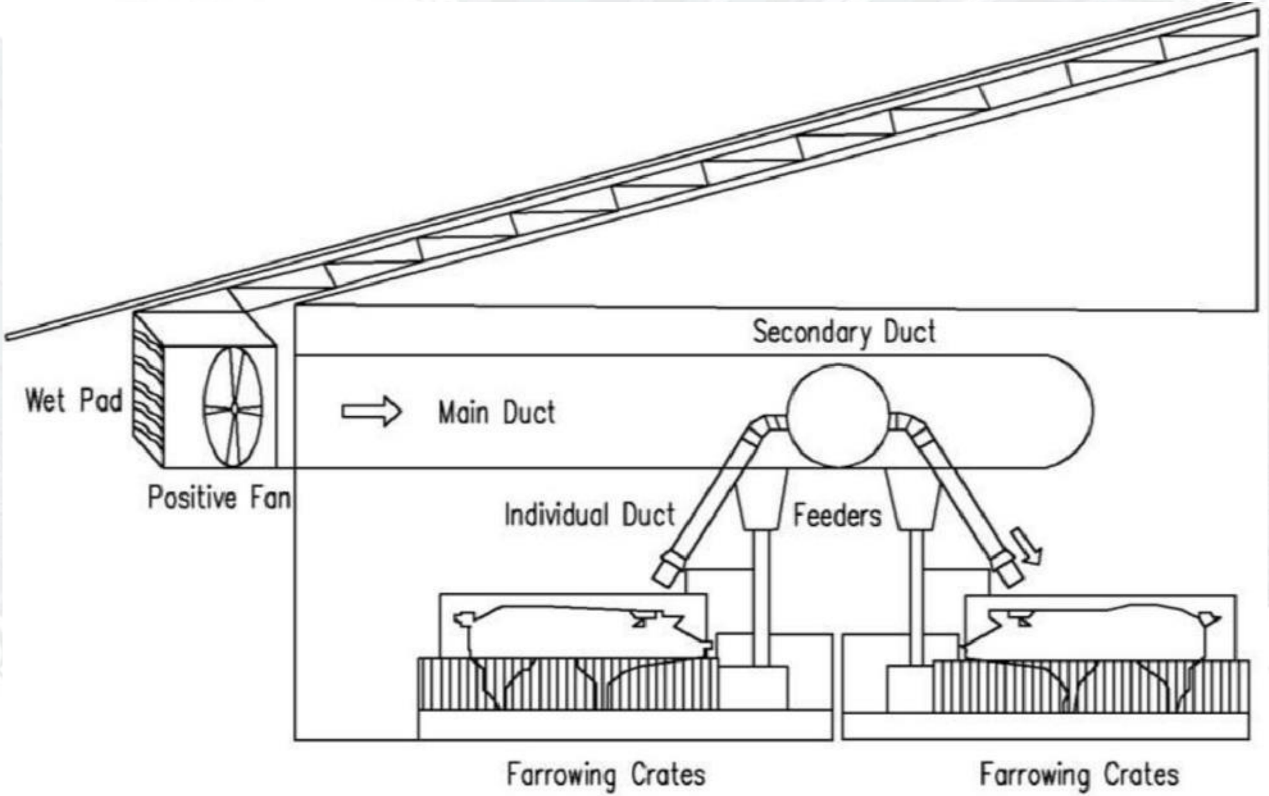




This wet-pad cooling system is not sufficient to provide optimum hygrothermal conditions for the sows and piglets because of the heterogeneity of air velocity, temperature, and relative humidity.

(K. Wang et al., 2014)

Positive pressure fan and pad: the “snout cooling system”



(Perin et al., 2016)

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RES4LIVE

ENERGY SMART LIVESTOCK FARMING
TOWARDS ZERO FOSSIL FUEL CONSUMPTION

Project Overview

Intensive Livestock Farming is one of the most **energy consuming** sub-sectors of agriculture, mainly based on fossil fuels use

Electricity and thermal energy is required to cover strongly diversified energy demand

More sustainable livestock production and de-fossilising energy needs in husbandry facilities emerge as **crucial aspects within EU**

Horizon 2020

01/10/2020 – 30/09/2024

17 Partners from 8 EU countries

www.res4live.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No.101000785

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Project Overview – Introduction

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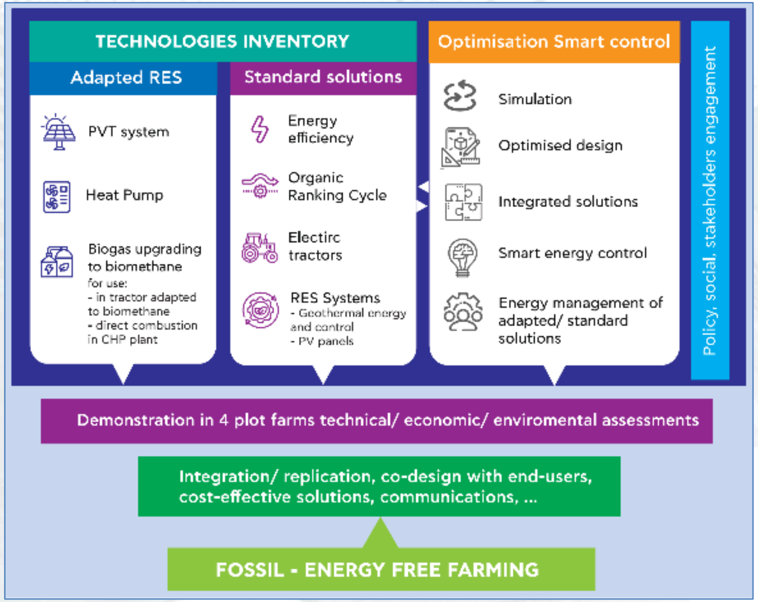
ENERGY SMART LIVESTOCK FARMING TOWARDS ZERO FOSSIL FUEL CONSUMPTION



100% replacement of fossil energy in intensive livestock farming sector utilizing Renewable Energy Sources (RES)

- A **combination of technologies and solutions** will be installed and evaluated in 4 livestock farms

Market integrated, cost-effective & case-sensitive RES solutions towards fossil-free livestock farming

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Italian Pilot farm

GOLINELLI
AZIENDA AGRICOLA

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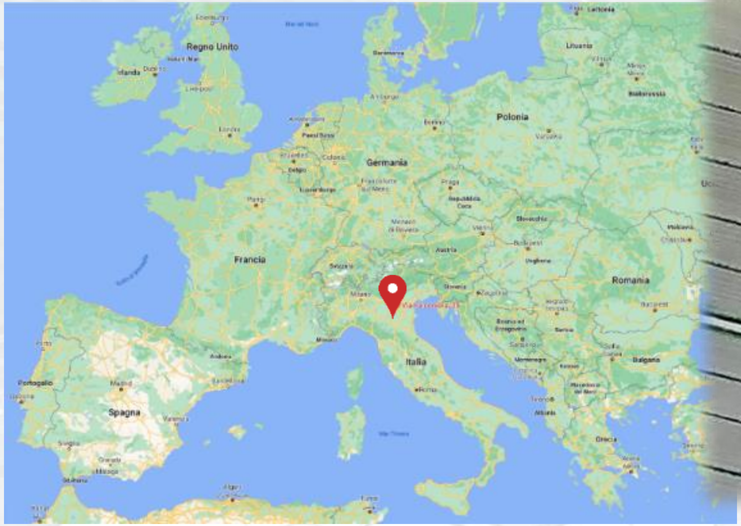
- Via Falconiera, 35 – 41037 MIRANDOLA (MO) -Italy



- amministrazione@agricolagolinelli.it

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Pig farm

500 sows

2500 weaners

A variable number of hogs

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INTEGRATED RES SYSTEM: PVT-BTES-DSHP

in nursery barn (high energy demand)

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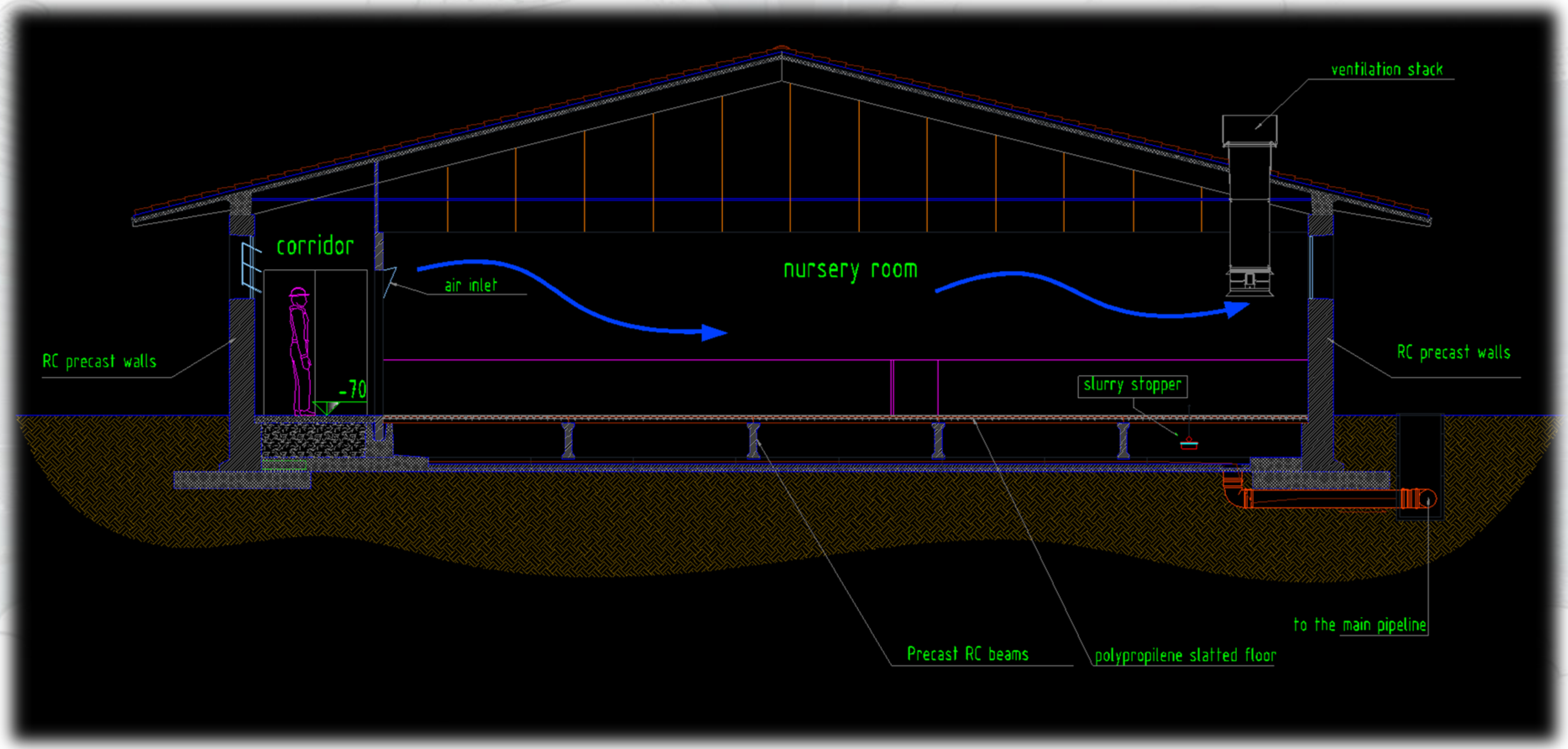
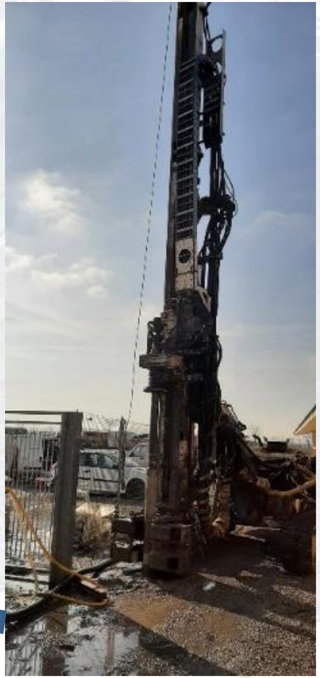


Integrated RES system



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Finishing the BTES field

- The area is fully accessible again
- The connections can be inspected
- Measuring underground T, every m up to 25m

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Heat pump connected to geothermal storage

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- East side

- NE corner

- NW corner

- Heat pump on the West side

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SMART MONITORING SYSTEMS

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Sensors network

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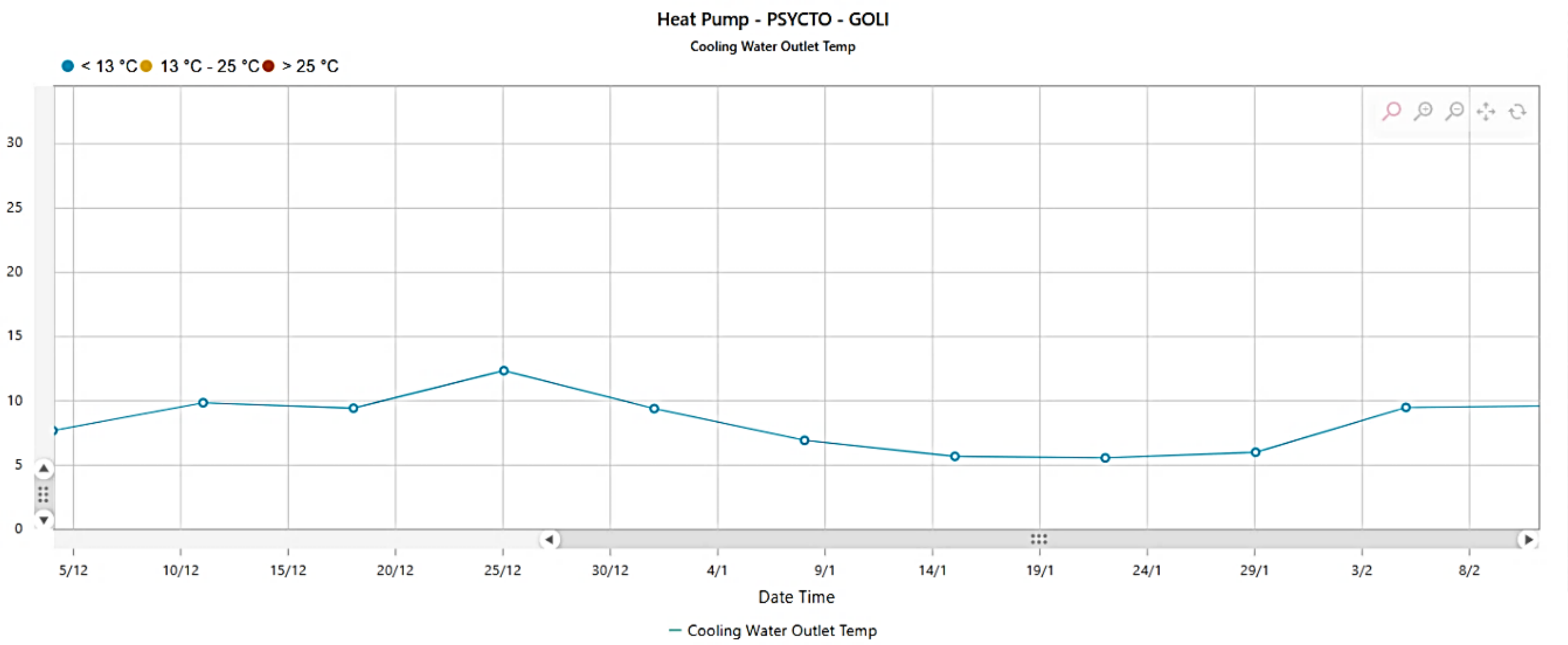
Potential cold storage



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RETROFITTING OF OLDER PIG BARN TO INCREASE COOLING PERFORMANCE

INITIAL STATE

34 windows of 2.8 m x 0.8 m, with steel single-layer frames and 4 mm thick glass surfaces. thermal transmittance assessed 5.9 W/m2K

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Retrofitting hog barn

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TOWARDS ZERO FOSSIL FUEL CONSUMPTION

- **windows with frame in tubular stainless steel, frame and upper counterframe in stainless steel**
- **transparent infill in 16mm thick double chamber alveolar polycarbonate**
- **thermal transmittance of 2 W/m2K, i.e. around one third of the previous situation**

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Retrofitting hog barn

6 gearmotors with limit switch for the mechanical opening

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Smart monitoring and automation control

environmental sensors and actuators

automatic openings based on temperature and air quality parameters.

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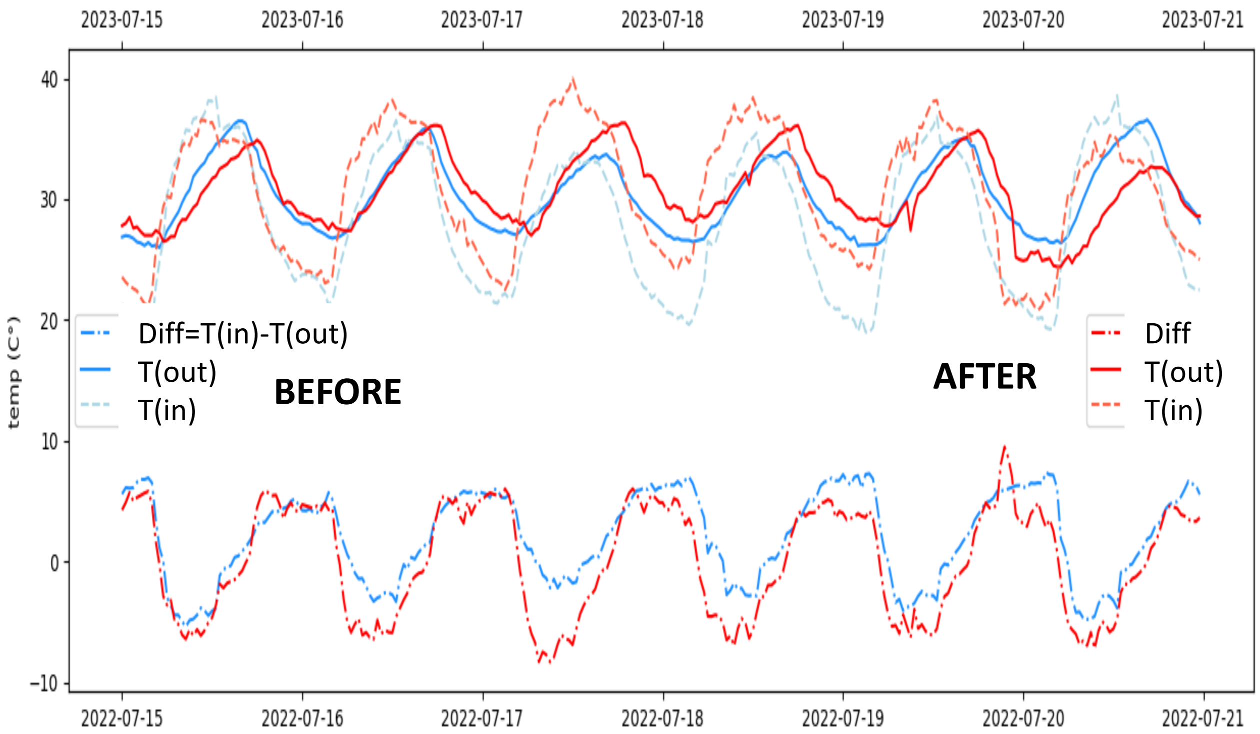
Smart monitoring and automation control

programme under grant agreement No.101000785

Effect of retrofitting on indoor temperature



August 2022:
ΔTHI(in-out) = +1.94 (daily avg)

August 2023:
ΔTHI(in-out) = -2.38

Reduction of daily avg indoor THI = -4.32

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Conclusions

- Only utilizing natural cold sources cannot satisfy the substantial and sustainable demand for energy in large-scale livestock husbandry.
- Evaporative cooling is suitable in dry areas.
- In hot and humid areas where controlling the relative humidity is important, EAHE can provide sufficient fresh air at low temperatures and water.
- Water-cooled pads solve the problem of different thermal comfort zones for sows and piglets in the lactating house through local cooling.
- Combined ventilation with supply and exhaust fans works.
- Integrating ventilation systems with green plants to purify the air and save energy may become a future interest for large-scale pig farms.
- A combination of artificial cold sources such as heat pumps is necessary for the improvement of energy efficiency and sustainability of cooling systems.
- Geothermal heat pumps showed much higher efficiency

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