An integrated renewable energy system for the decarbonization of a laying hens farm in Central Greece


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AIIA Mid-Term Conference – Padova 17-19 June 2024

Biosystems engineering promoting resilience to climate change

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PSYCTOTHERM
MARINE REFRIGERATION & AIR CONDITIONING

THERMODRAFT
SUSTAINABLE BOUNDLESS INNOVATION

Energy use in livestock buildings

Intensive livestock systems

- Feed 1.3 billion people
- Animal-derived food

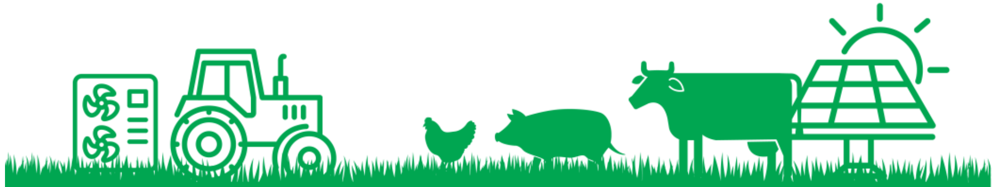
- High energy consumption
- Mainly rely on fossil fuels
- High GHG emissions

The European Green Deal

- Higher energy efficiency
- Decarbonization
- Climate resilience
- Improved animal welfare

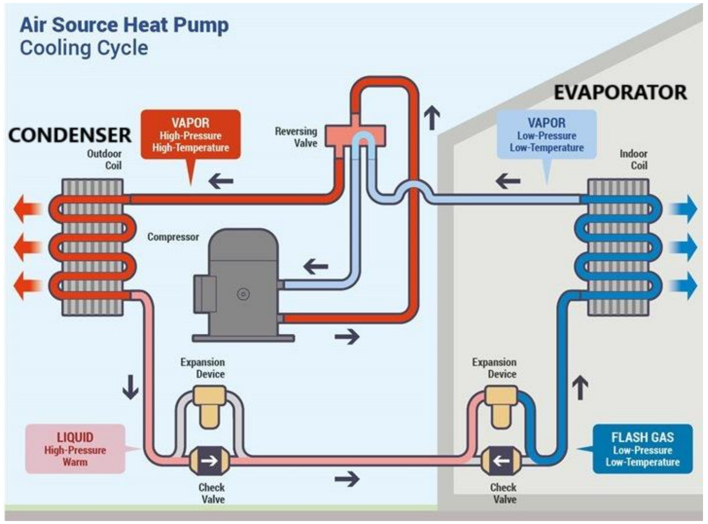
The RES4LIVE project

RES4LIVE
ENERGY SMART LIVESTOCK FARMING
TOWARDS ZERO FOSSIL FUEL CONSUMPTION



Introducing market integrated, cost-effective & case-sensitive Renewable Energy Sources solutions towards fossil-free livestock farming

Use of heat pumps in livestock buildings through an experimental approach



Objective:

Analyzing the actual performance of a heat pump integrated in a livestock house to understand the potential of this technology in increasing the sustainability of livestock systems.

The case study: the AUA hen house

The hen house of Agricultural University of Athens (AUA):

- Education & Research
- 45 m^2 of floor area
- Capacity for ~400 hens
- 3-tier enriched colonies
- Founded in 1950s

Refurbishment

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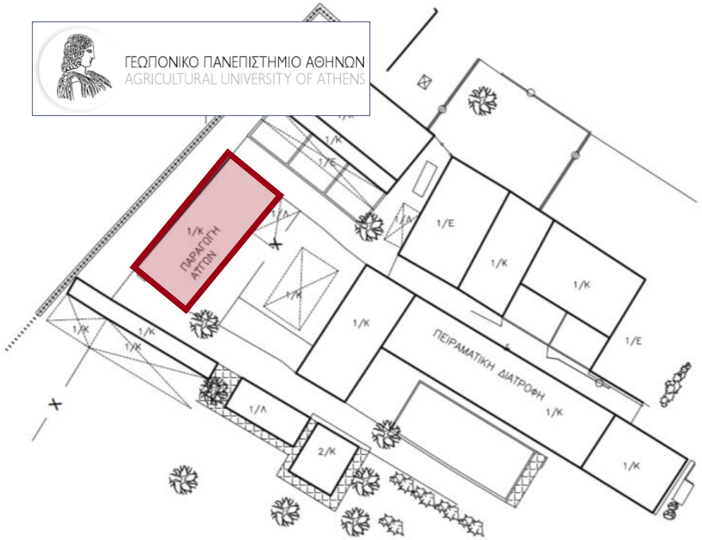


The case study: the Heat Pump (HP)

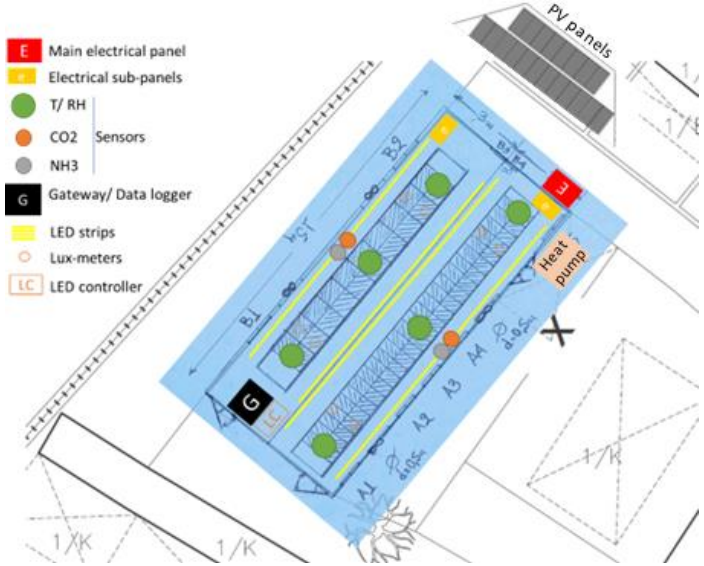
Main features of the HP:

- Air-to-air HP, screw-type compressor
- 10 kW of nominal cooling capacity (R407C)
- Heat recovery system
- Auxiliary fans + water pumps
- Integration with a 9 kW_p photovoltaic system

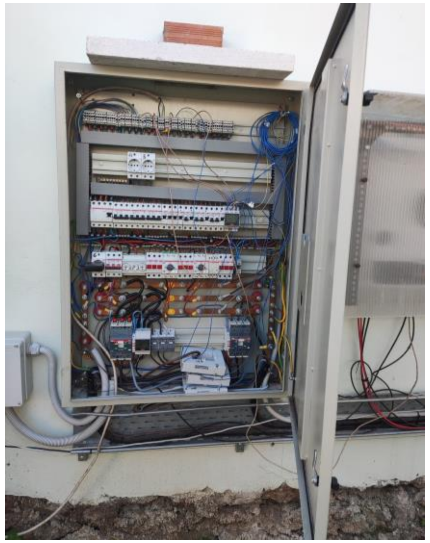
The acquired dataset

Monitored parameters:

- Indoor air temperature and relative humidity
- Gas concentrations (CO_2 and NH_3)
- PV power generation
- Power consumption
- Refrigerant pressures



Power consumption { Inlet fan, Exhaust fan, Dry cooler fan, Water pumps, LEDs



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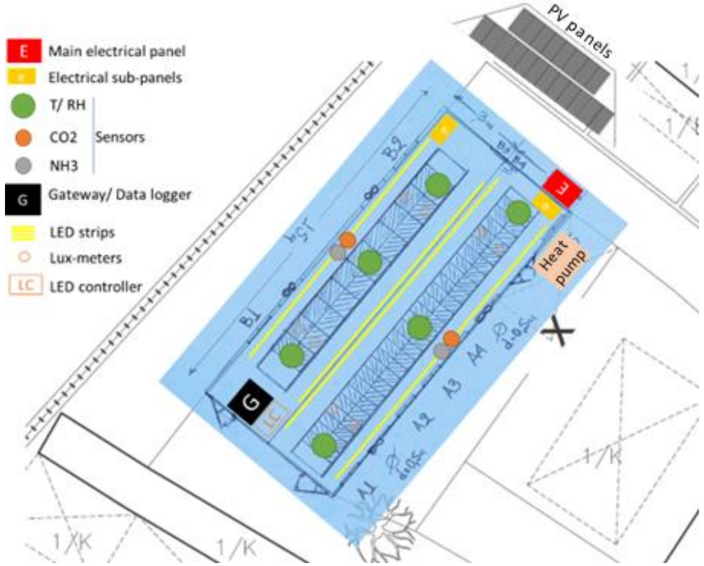
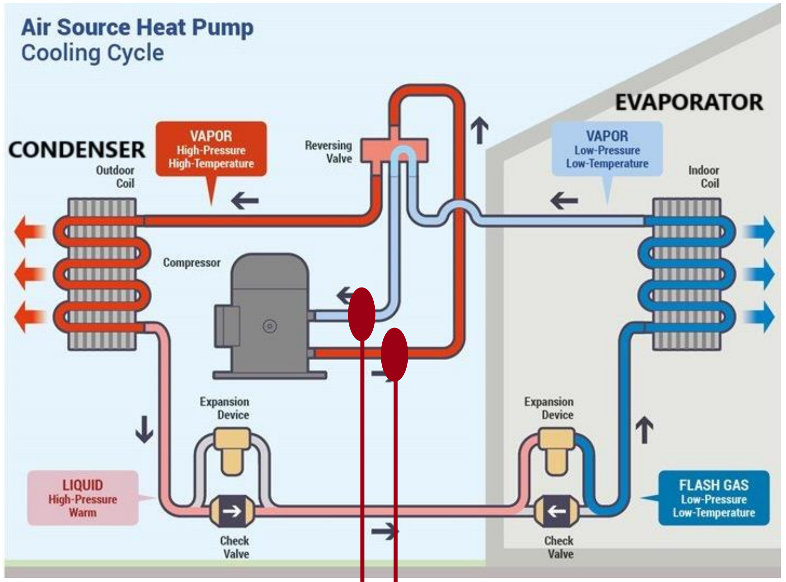
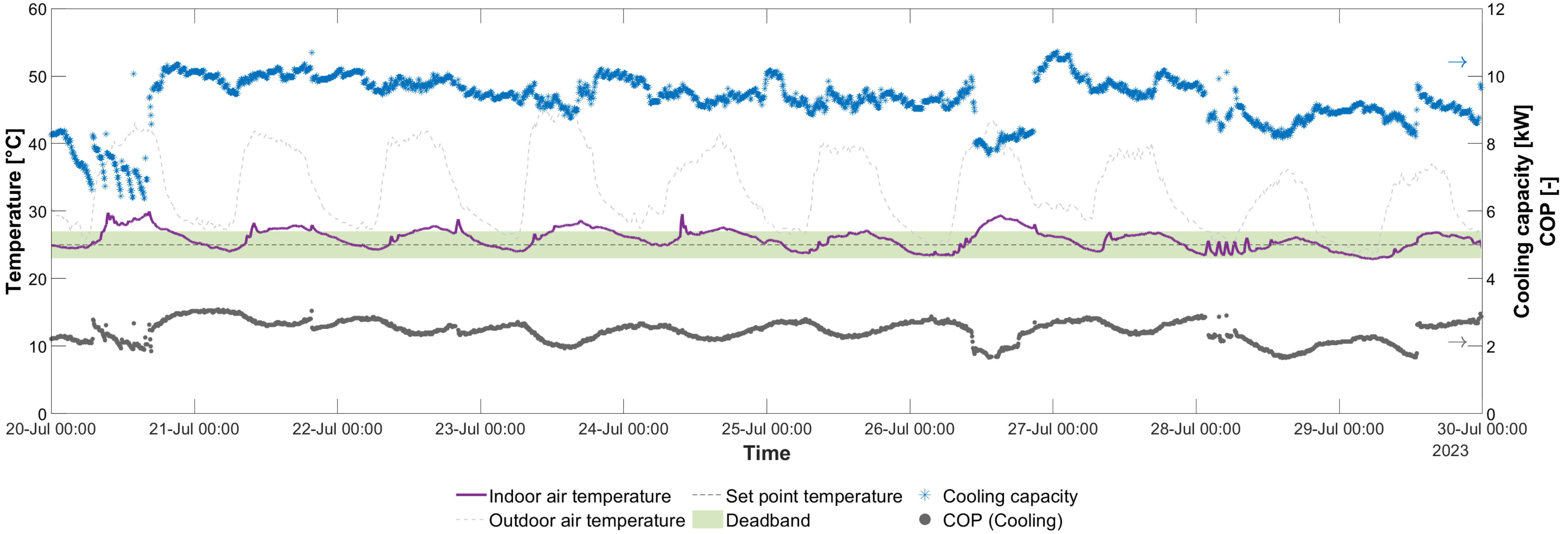




Refrigerant pressures $\xrightarrow{y = f(X)}$ Refrigerant temperatures $\xrightarrow{y = f(X)}$

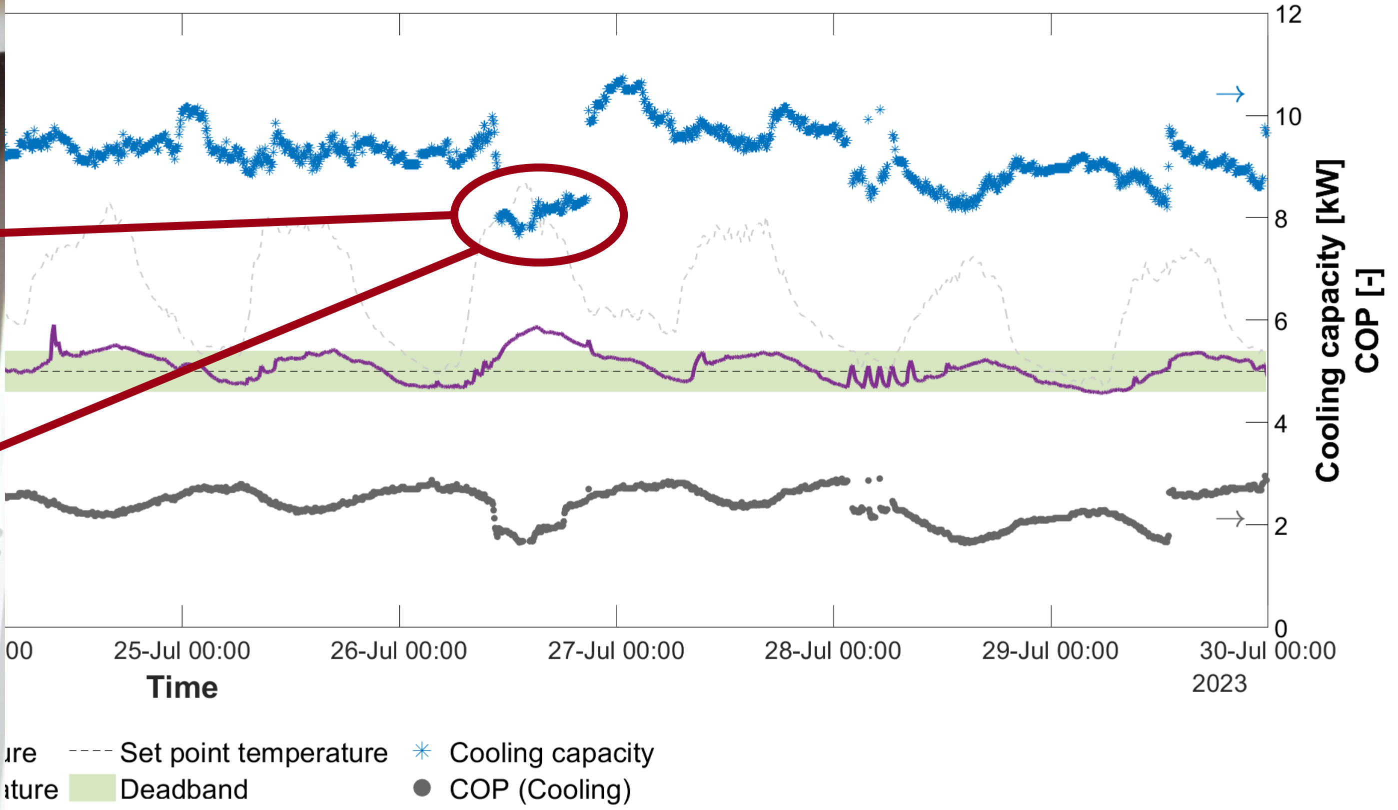
- Power input
- Cooling capacity
- Heating capacity
- COPs

Results: HP operation during summer

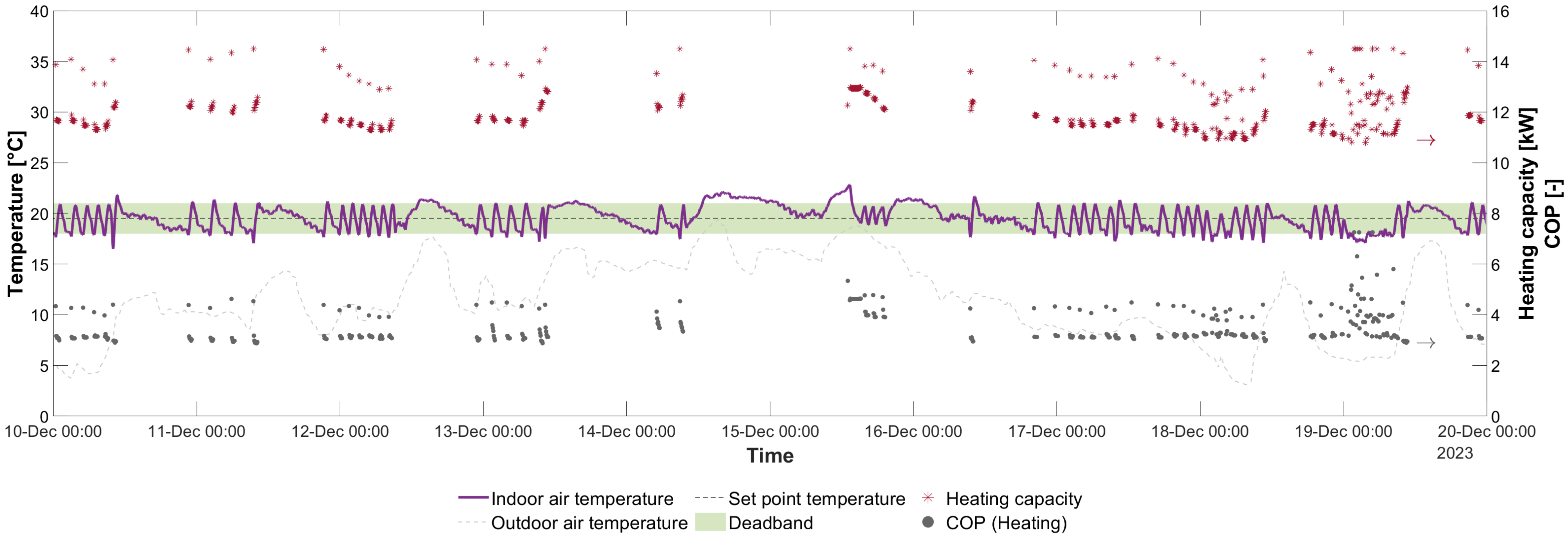


- Acceptable indoor air temperature even during heat waves
- Undersized cooling capacity: extreme weather + adult birds
- Suboptimal defrost cycle programming

Results: HP operation during summer

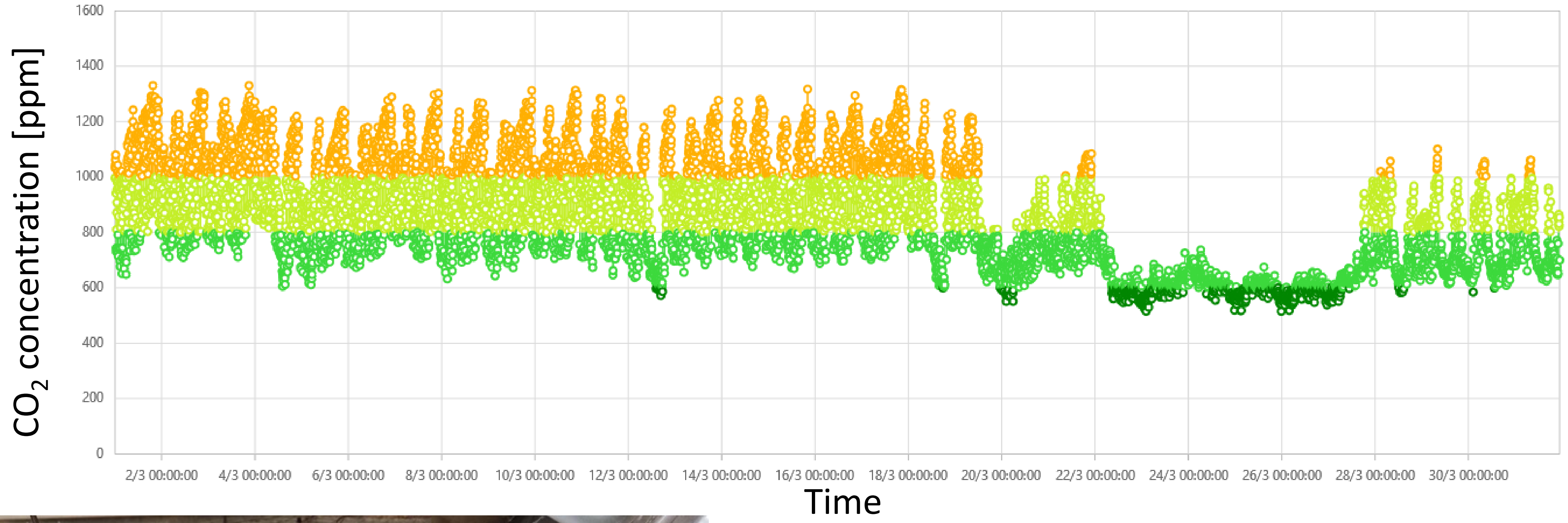


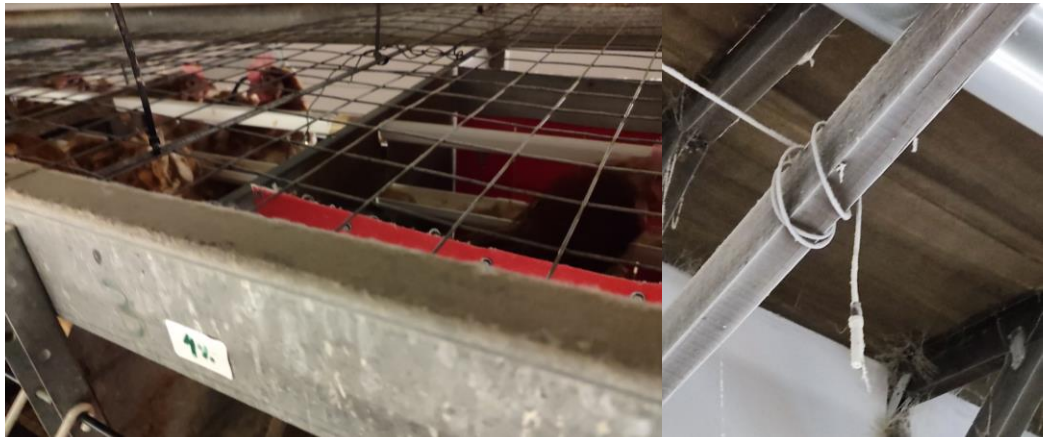
Results: HP operation during winter



- Indoor air temperature mostly within the deadband
- Oscillation of indoor air temperature affects HP performance
- COP always exceeded 3

Results: Indoor Air Quality

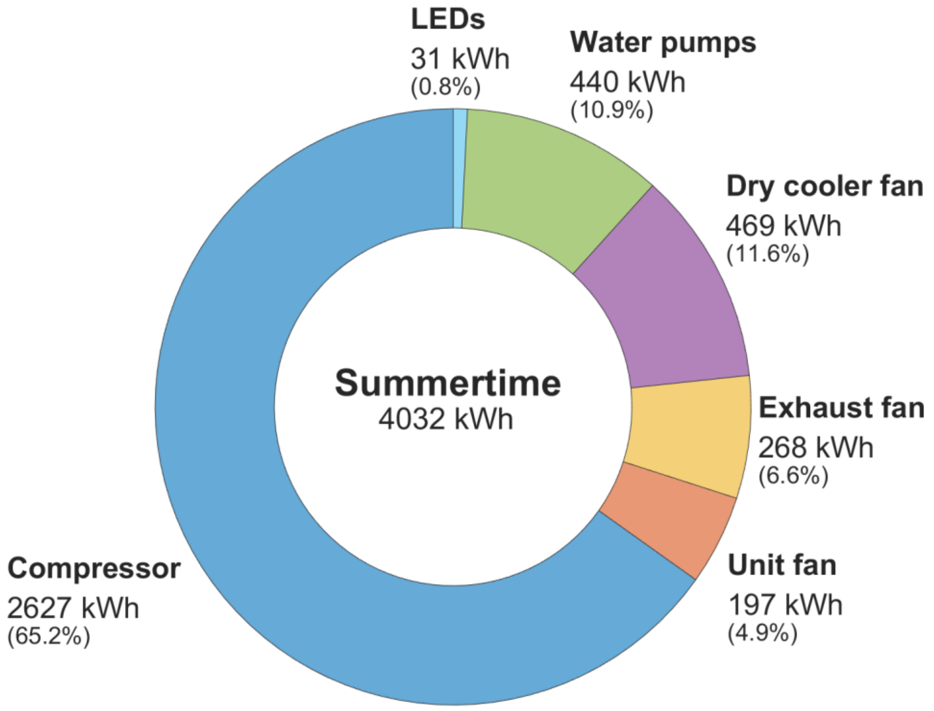


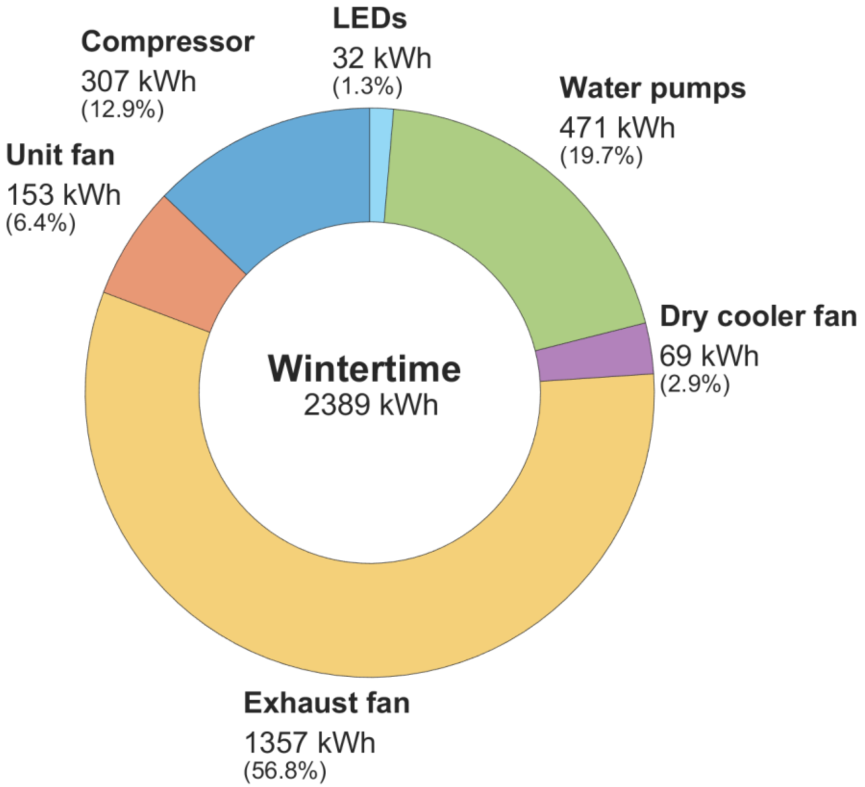


- CO_2 may represent an issue in commercial farms
- High concentration of particulate (dusty environment)

→ **Need to identify solutions**

Results: energy consumption





- Analyses over 30 days
- Higher energy consumption in summer: compressor operation
- Greater exhaust fan during wintertime

Results: RES integration

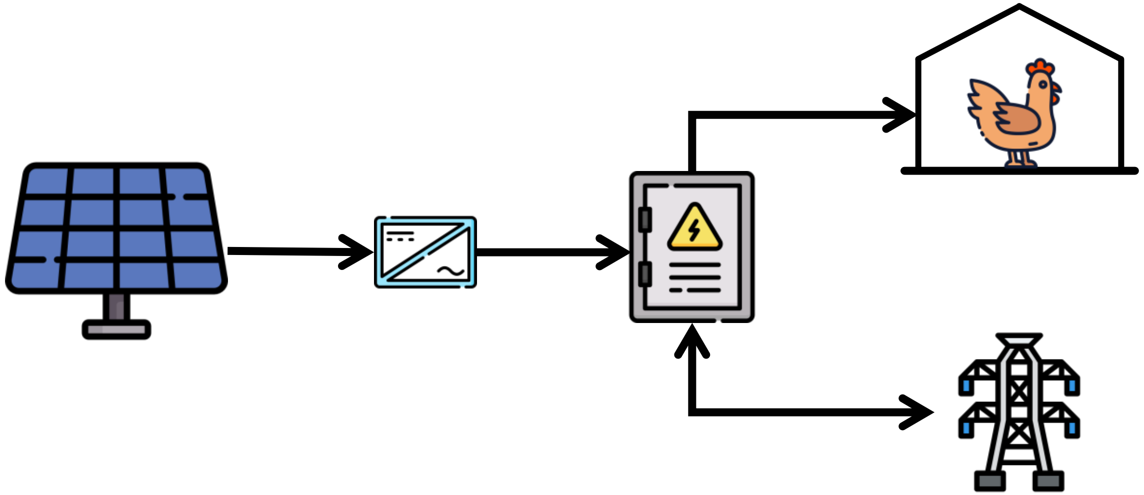
Summer (30 days):

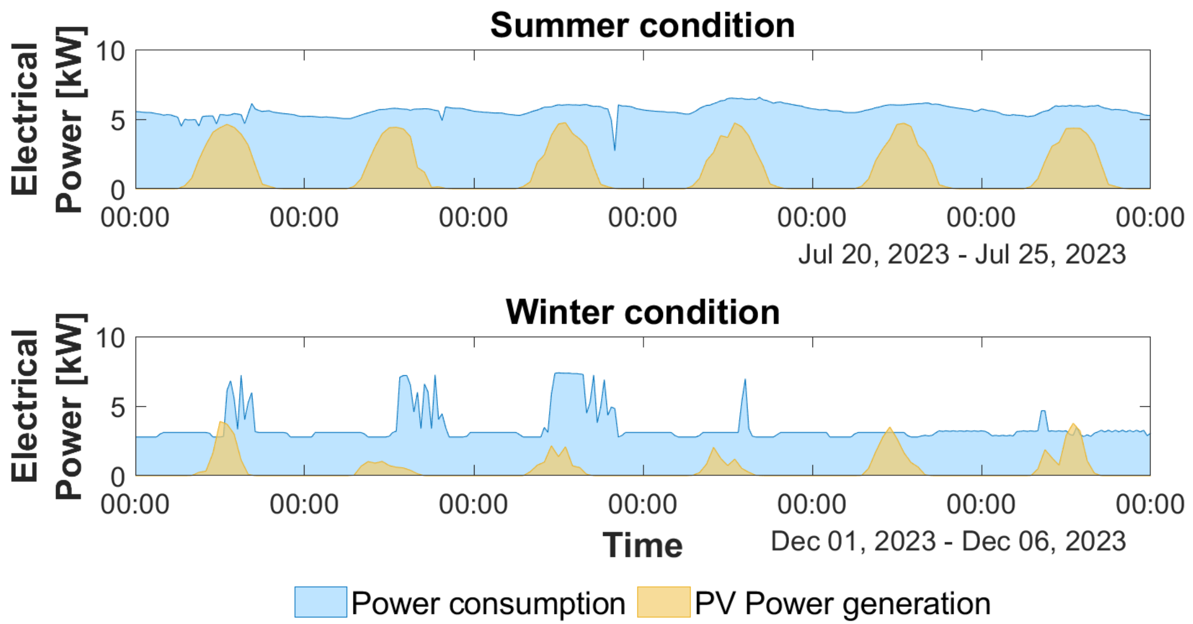
- 909 kWh generated from PV
- 22.5% of Self-Sufficiency
- 99.7% of Self-Consumption
- Avoided GHGs: 688 $kg_{CO2\text{-}eq}$

Winter (30 days):

- 483 kWh generated from PV
- 20.2% of Self-Sufficiency
- 85.6% of Self-Consumption
- Avoided GHGs: 314 $kg_{CO2\text{-}eq}$

Calculations performed considering Greek national energy mix.





Results: RES integration

Summer (30 days):

- 909 kWh generated from PV
- 22.5% of Self-Sufficiency
- 99.7% of Self-Consumption
- Avoided GHGs: 688 $kg_{CO2\text{-}eq}$

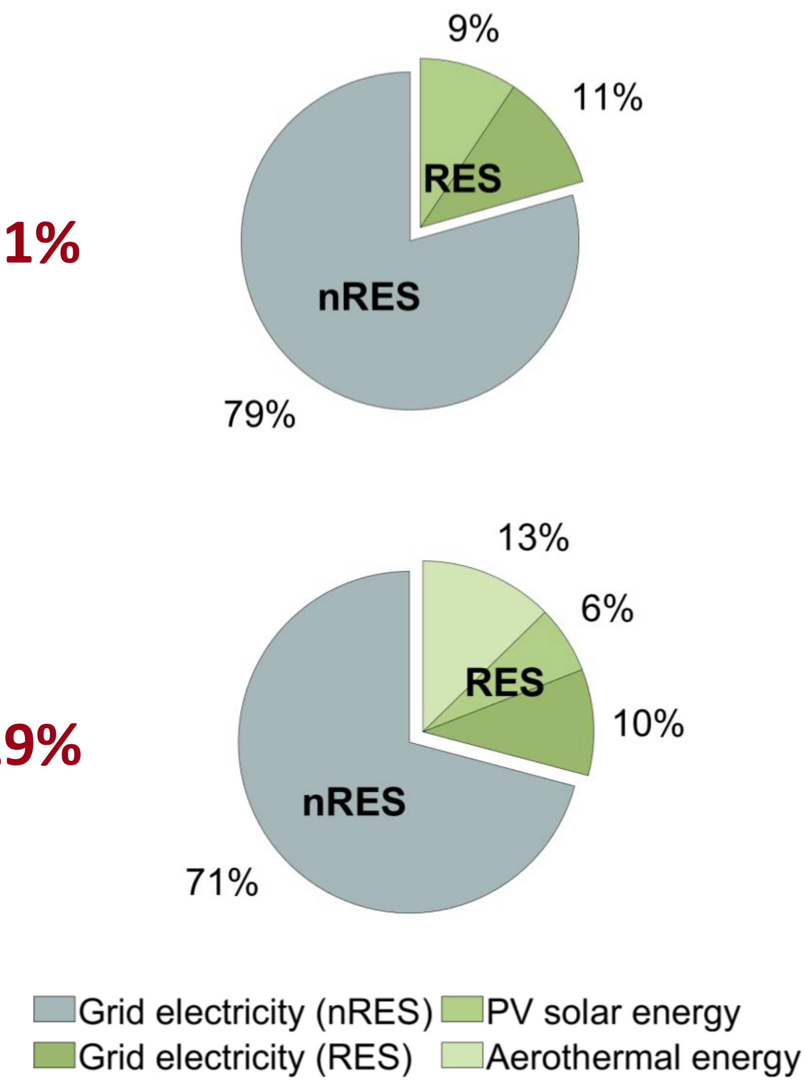
$$RER = \frac{1999\ kWh_p}{9700\ kWh_p} = 21\%$$

Winter (30 days):

- 483 kWh generated from PV
- 20.2% of Self-Sufficiency
- 85.6% of Self-Consumption
- Avoided GHGs: 314 $kg_{CO2\text{-}eq}$

$$RER = \frac{1876\ kWh_p}{6440\ kWh_p} = 29\%$$

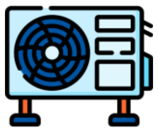
Primary energy



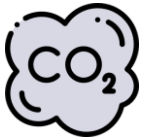
Calculations performed considering Greek national energy mix.

Conclusions

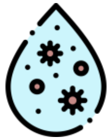
The heat pump maintained the adequate indoor air temperature for hen farming, even in presence of **heat waves**.



The heat pump operation was satisfactory, with a **SCOP** of 2.4 in summer and 3.7 in winter, respectively.



The integration with a PV system avoided the emissions of around **1000 $kg_{CO2\text{-}eq}$** over two months.



The experimental activity pointed out possible issues related to **Indoor Air Quality**.

Acknowledgments

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 101000785.

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Andrea Costantino was supported by a "Juan de la Cierva" Fellowship.

Grant JDC2022-049782-I funded by MICIU/AEI/10.13039/501100011033 and by the European Union NextGenerationEU/PRTR.

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Financiado por la Unión Europea
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