RES4LIVE

ENERGY SMART LIVESTOCK FARMING TOWARDS ZERO FOSSIL FUEL CONSUMPTION

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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ENERGY SMART LIVESTOCK FARMING
TOWARDS ZERO FOSSIL FUEL CONSUMPTION

Golinelli Farm, Italy (Unibo)

Type something

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Italian Pilot farm

GOLINELLI
AZIENDA AGRICOLA

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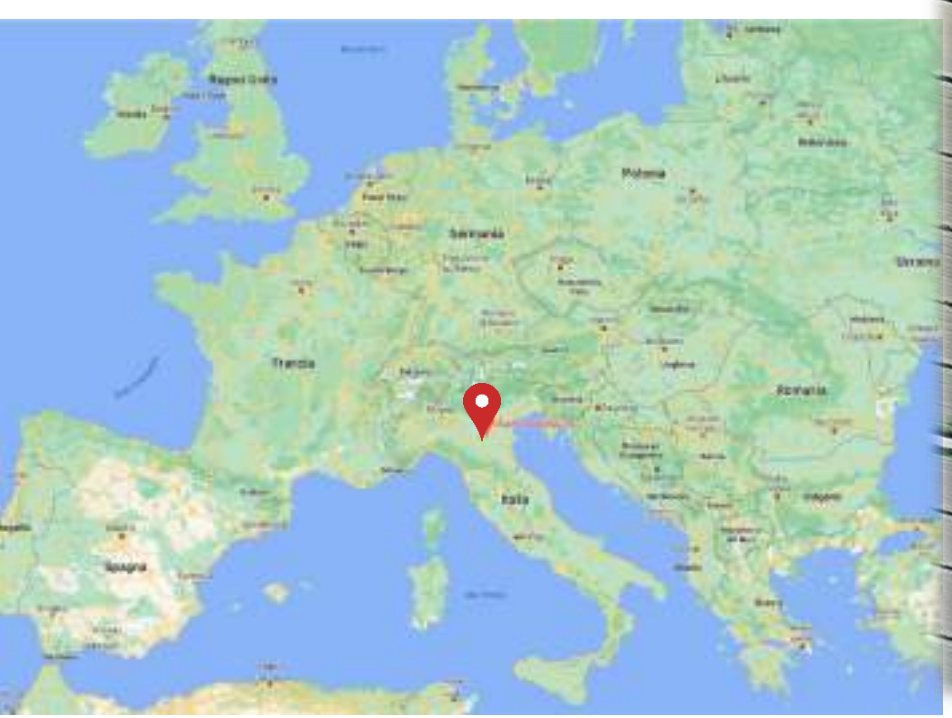
TOWARDS ZERO FOSSIL FUEL CONSUMPTION

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



- amministrazione@agricolagolinelli.it

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Pig farm

- 500 sows; 2500 weaners
- Variable number of hogs
- De-fossilization of nursery barn
- Retrofitting of hog barn

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SMART MONITORING SYSTEMS

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Sensors network

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Monitoring of environmental conditions and energy usages

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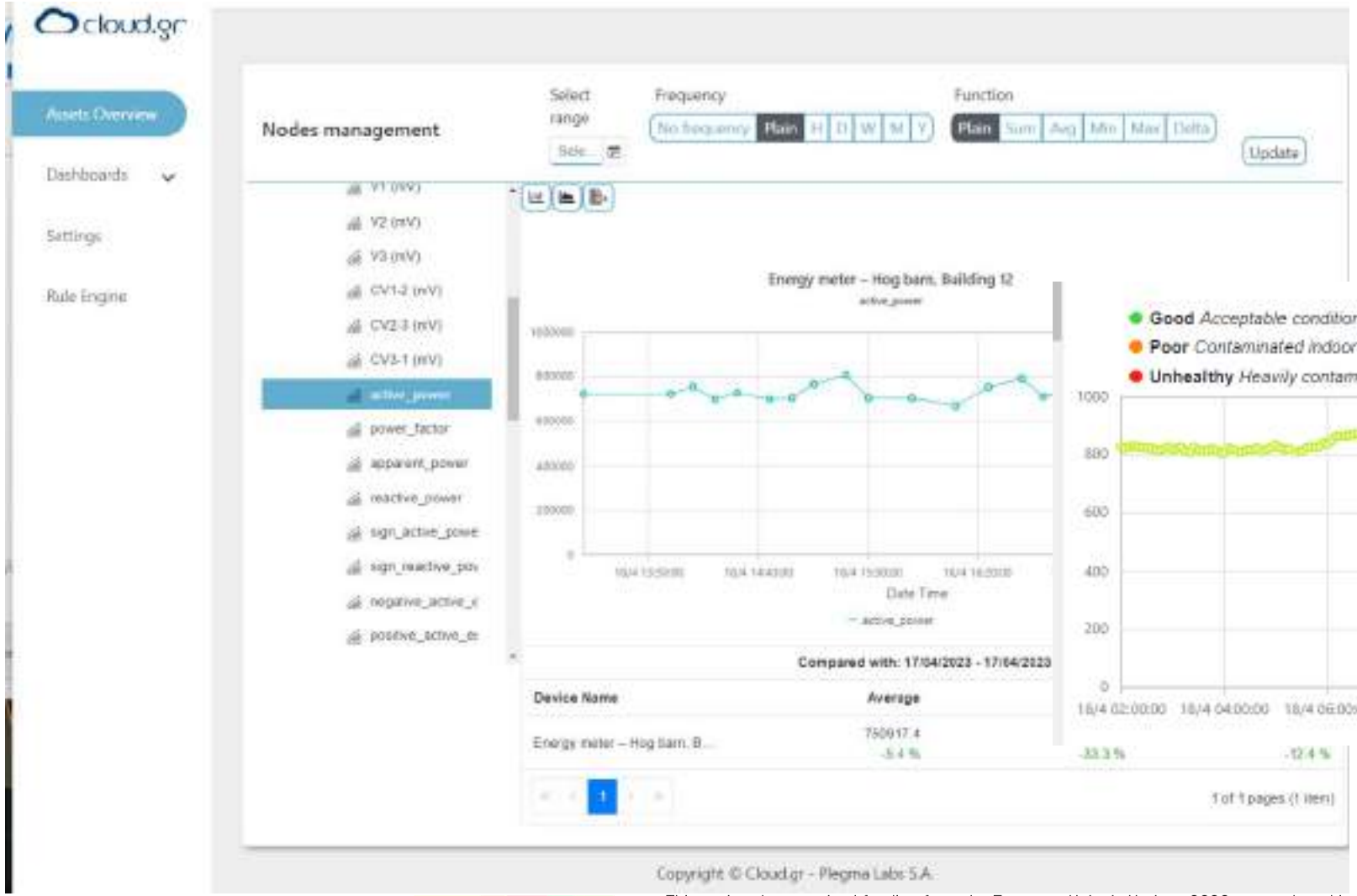

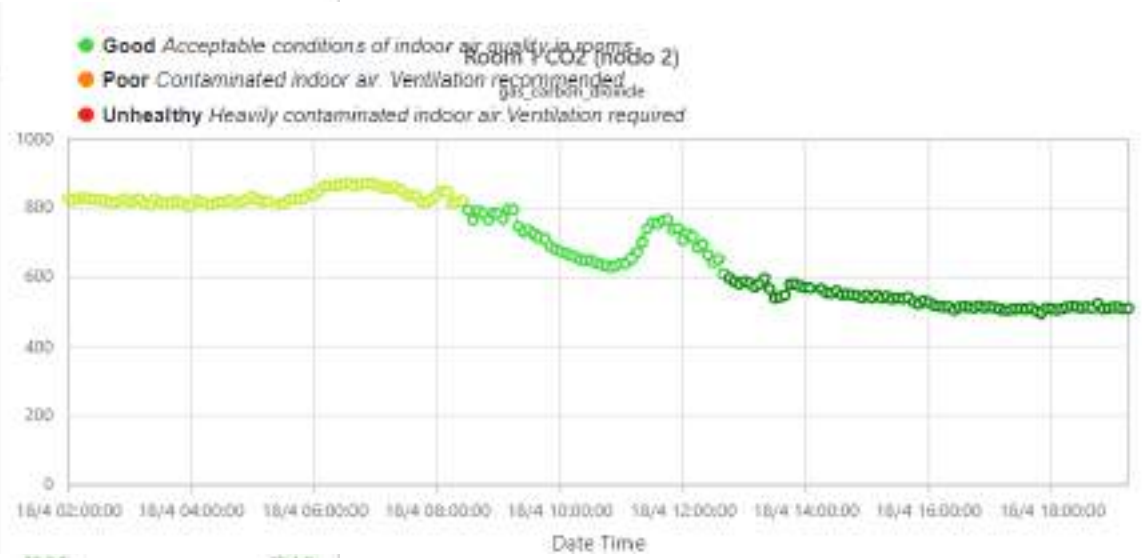

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Dashboard for data analysis

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ENERGY RETROFITTING OF OLDER PIG BARN

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INITIAL STATE

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- 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

- windows with frame in tubular stainless steel
- transparent infill in 16mm thick double chamber alveolar polycarbonate
- thermal transmittance of 2 W/m2K (≈ 1/3)
- 6 gearmotors with limit switch for the mechanical opening

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Smart monitoring and automation control

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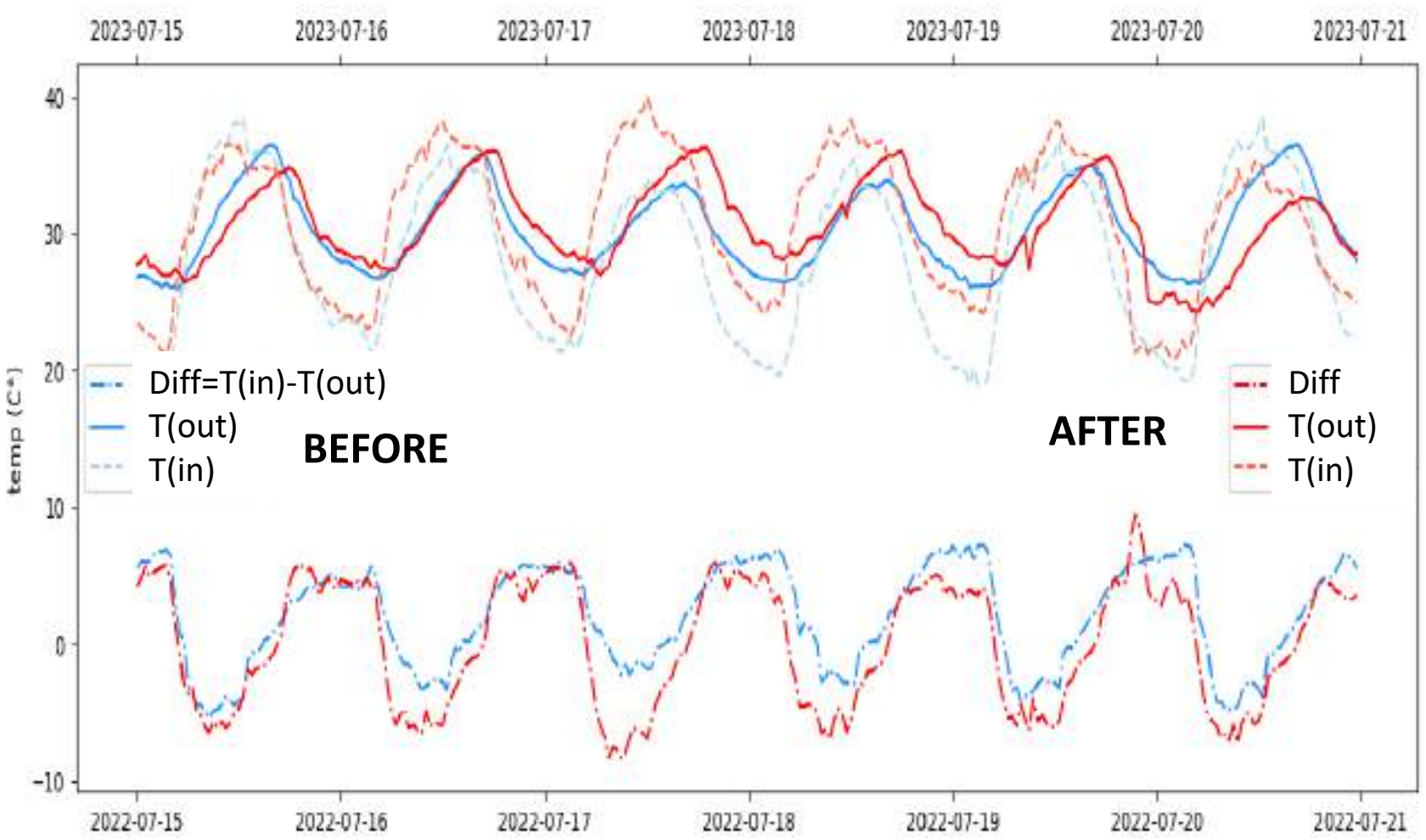
- environmental sensors and actuators
- automatic openings based on temperature and air quality parameters.

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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CO2 before and after

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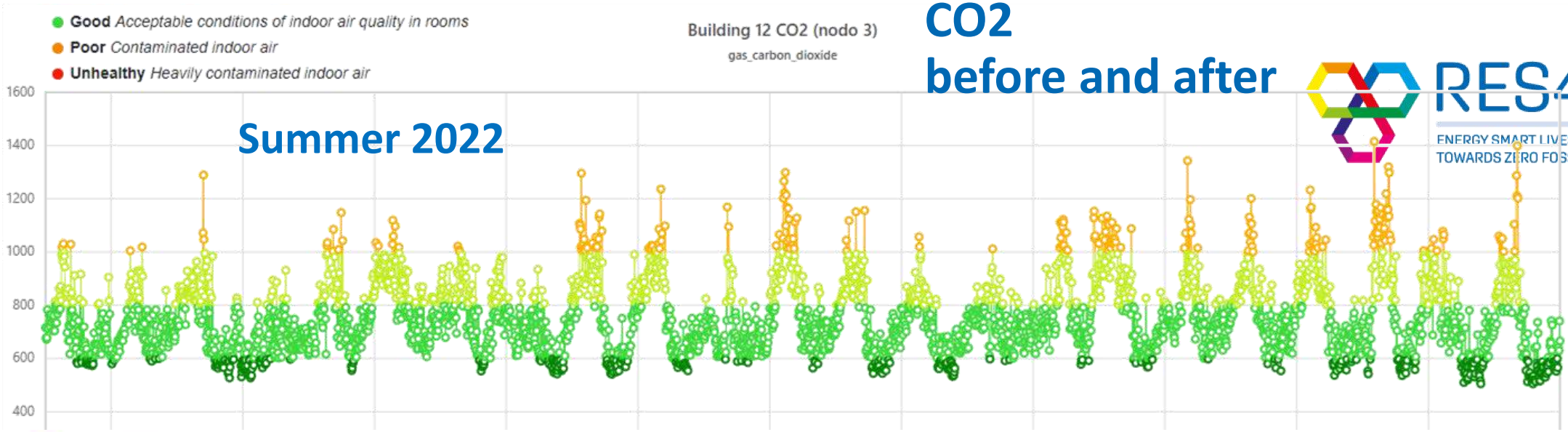

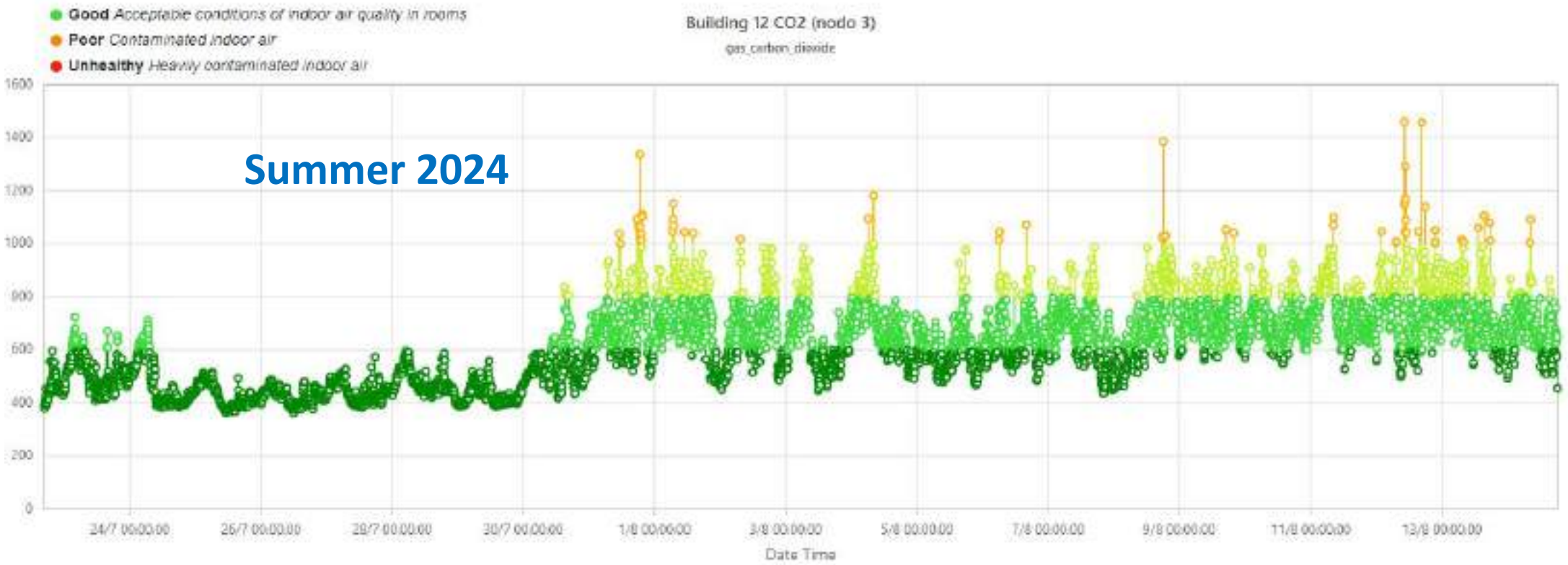

CO2 before and after

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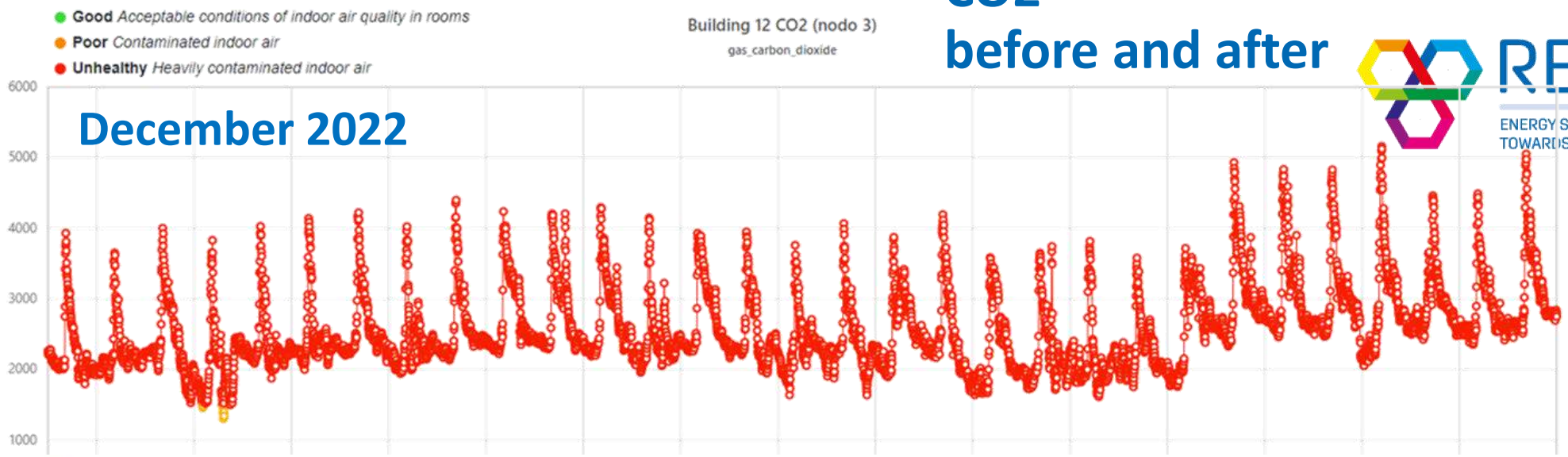

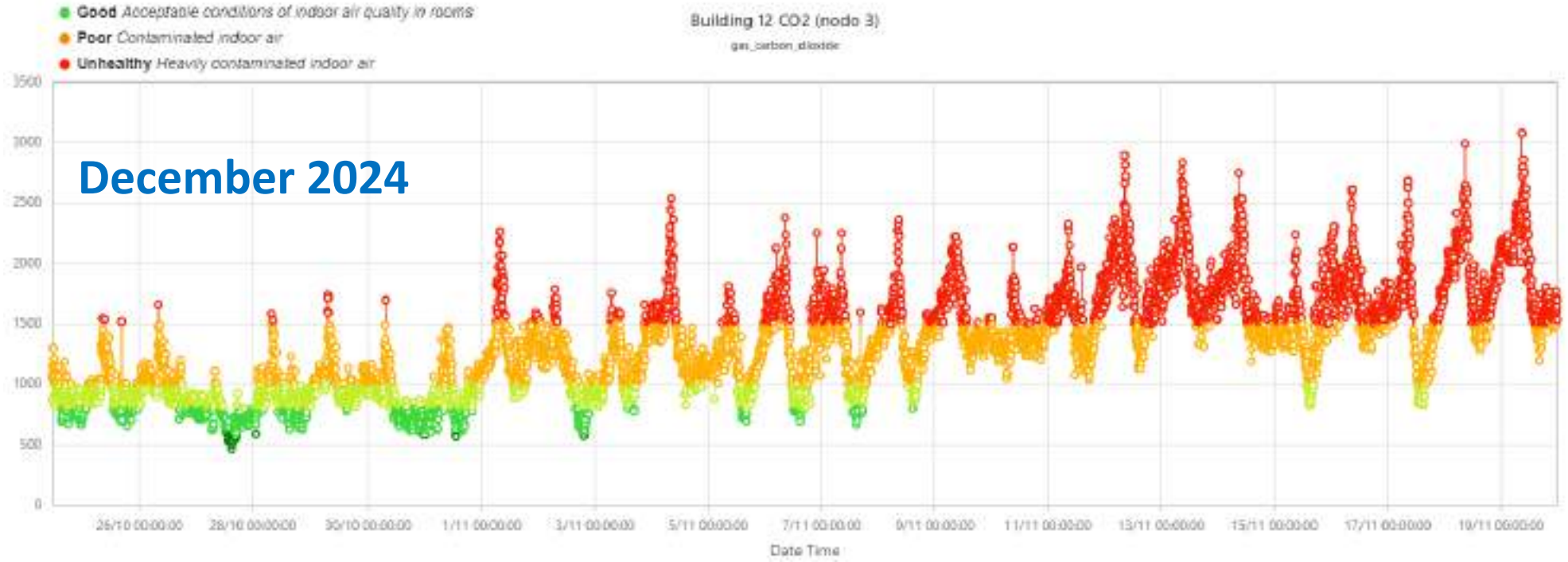

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INTEGRATED RES SYSTEM: PVT-BTES-DSHP

Type something

in nursery barn (high energy demand)

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Integrated RES system

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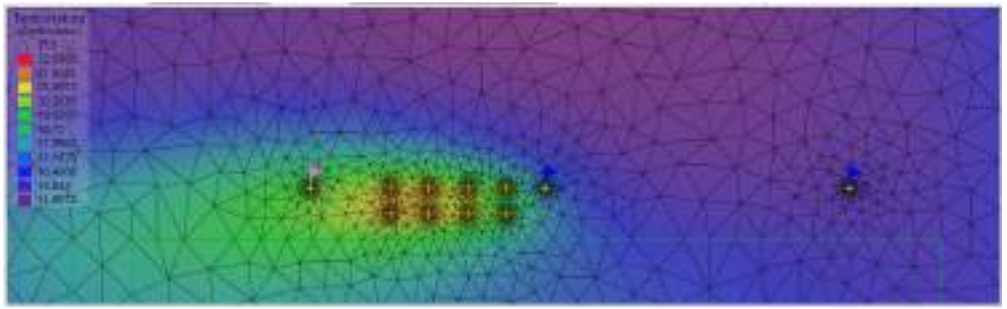

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BTES field

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- The area is fully accessible
- The connections can be inspected
- UNIBO keeps on measuring underground T, every m up to 25m

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PVT installation and setup by MG (April 2023)

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- a 35kW medium temperature heat pump,
- a 24 Samster-SunPro 320W PVT system accompanied with a solar station, to provide electricity (7.68 kW_{el}) and thermal energy (24 kW_{th})
- a smart control system.

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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Energy data analysis: numerical modelling

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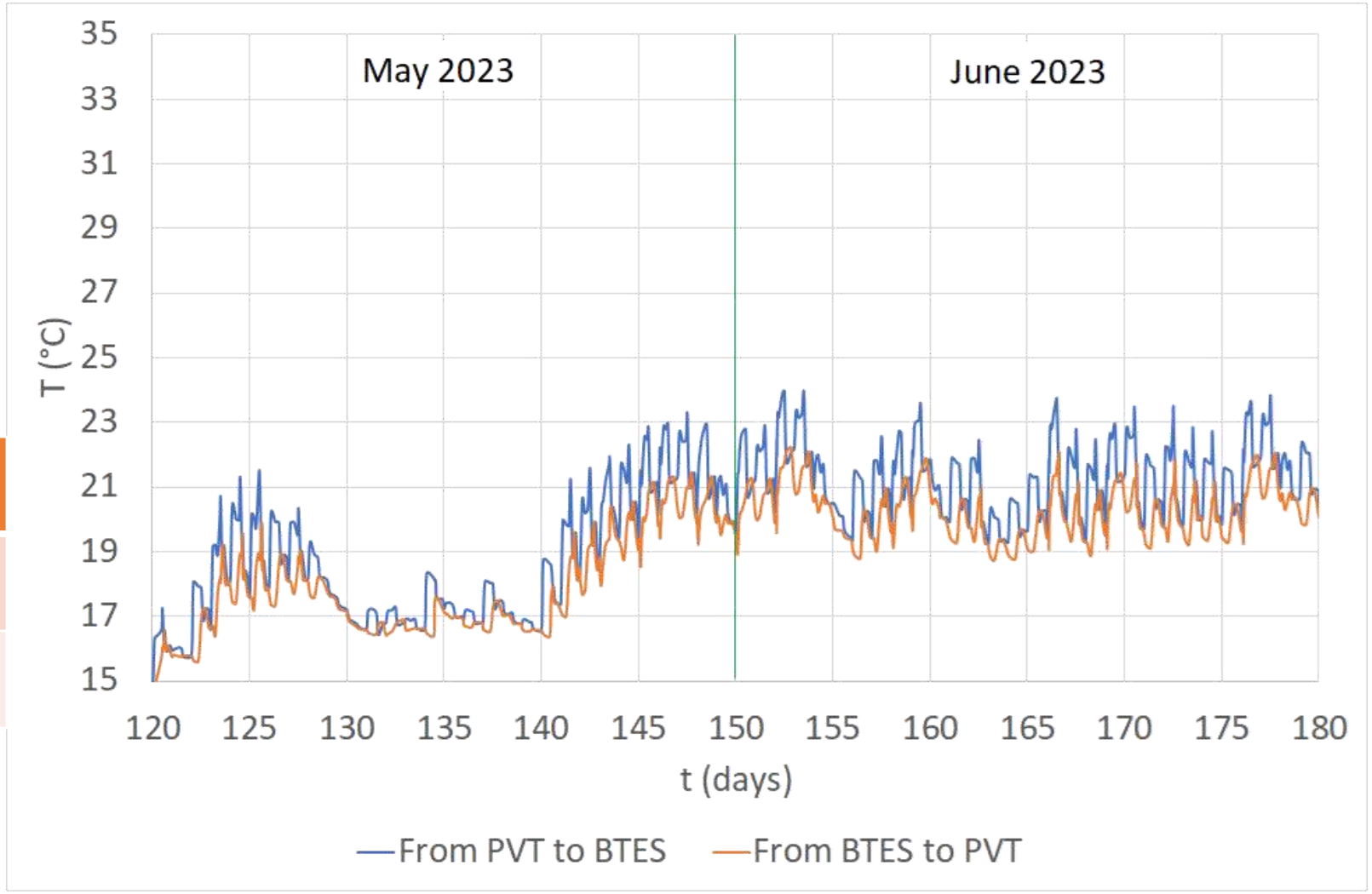
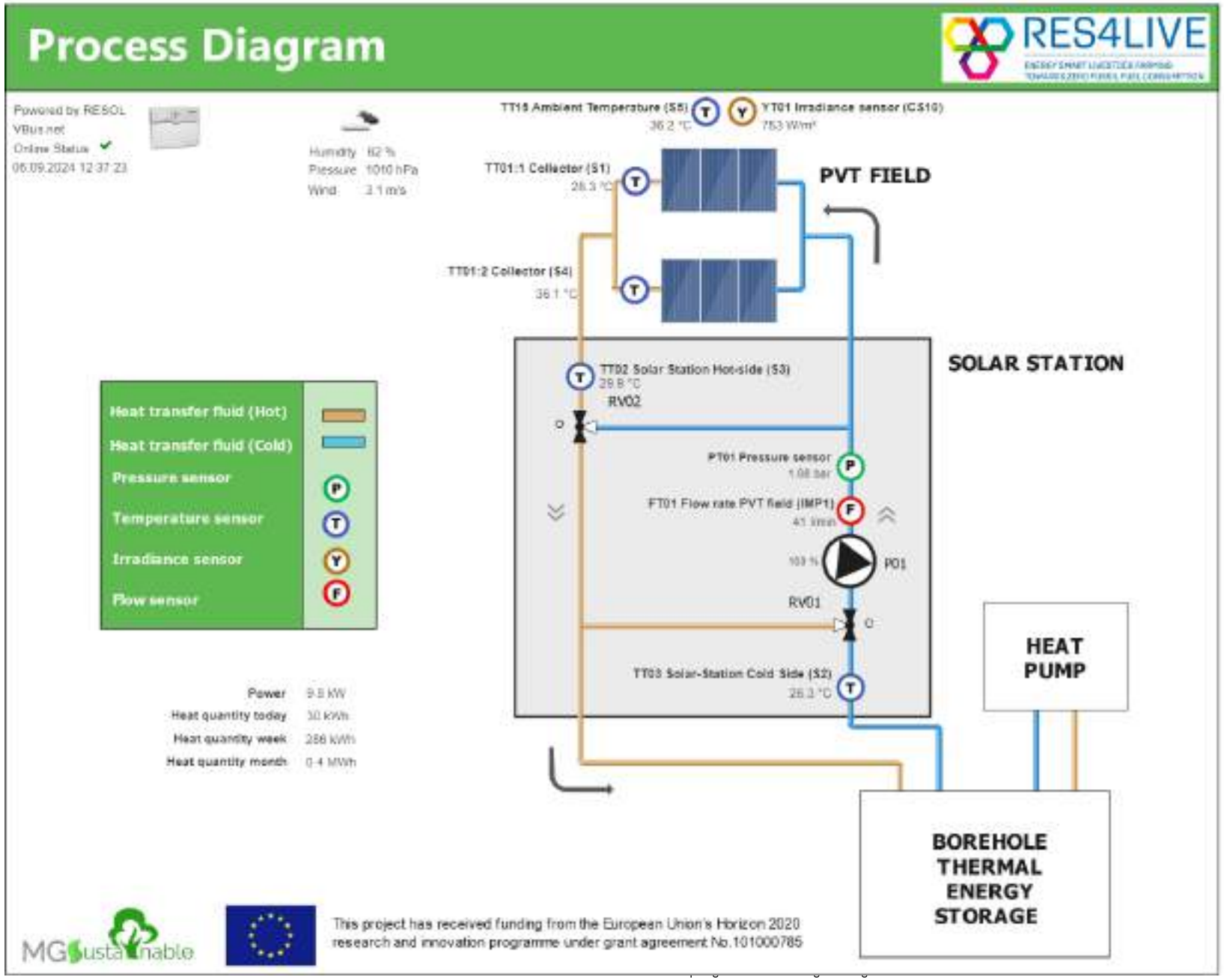
- Numerical temperature curves of the whole BHE array, in injection mode
- Based on energy data measured

Month	Energy (kWh)
May	1807.23
June	2220.27



Process Diagram



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Measurement of boreholes temperature

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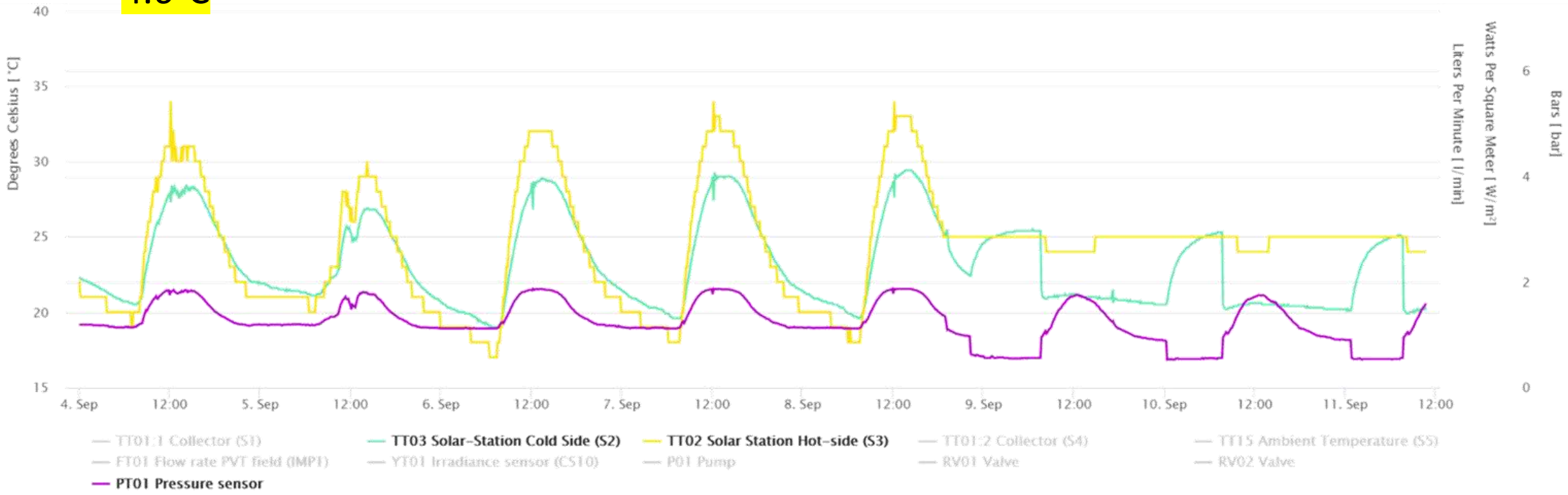
- Average Temperature in 30m borehole in March 2023: 15.9°C (before installation)
- Average Temperature in 30m boreholes on 10 Sep 2023: 20.5 °C
- Increase in TC temperature due to solar heat injection from May to August 2023: 4.6°C



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Energy storage in the ground from PVT: 10-17 April 2024

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• BTES System performance – Irradiance

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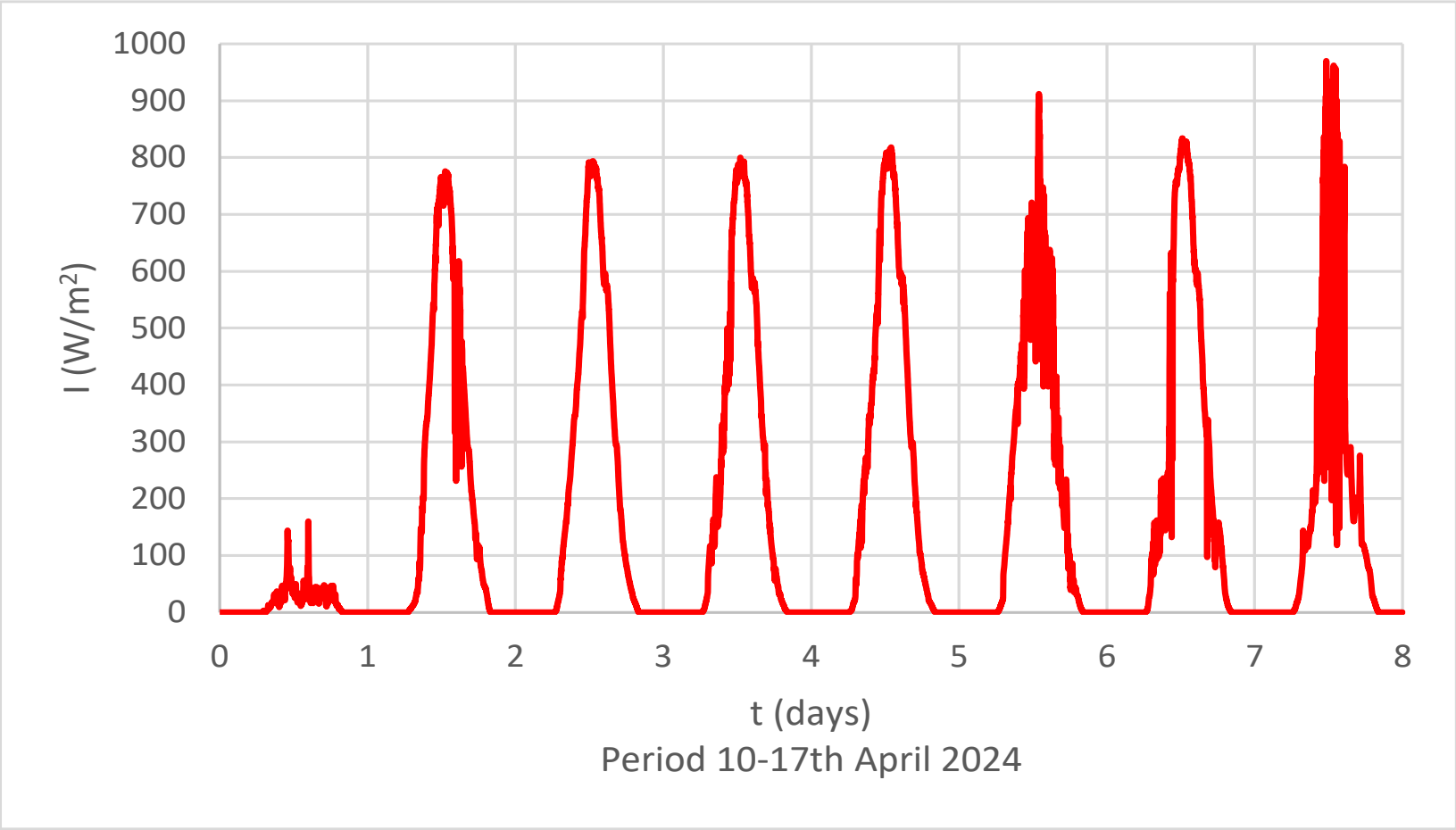
TOWARDS ZERO FOSSIL FUEL CONSUMPTION



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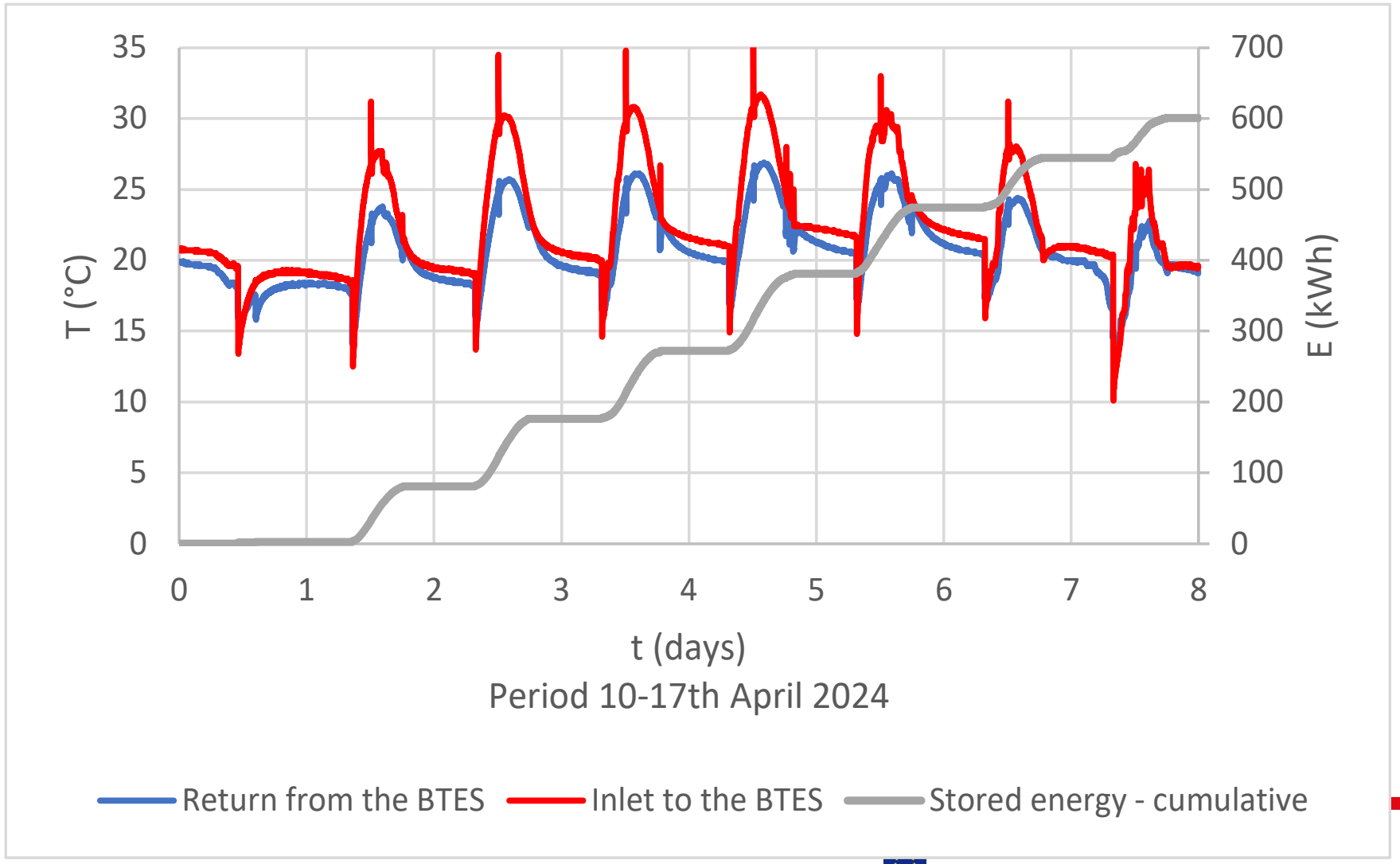
- **BTES System performance – temperature and heat injected**



Energy stored: 600 kWh

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Energy provided to the hallway: 17-25 April 2024

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• System performance – temperature and heat provided

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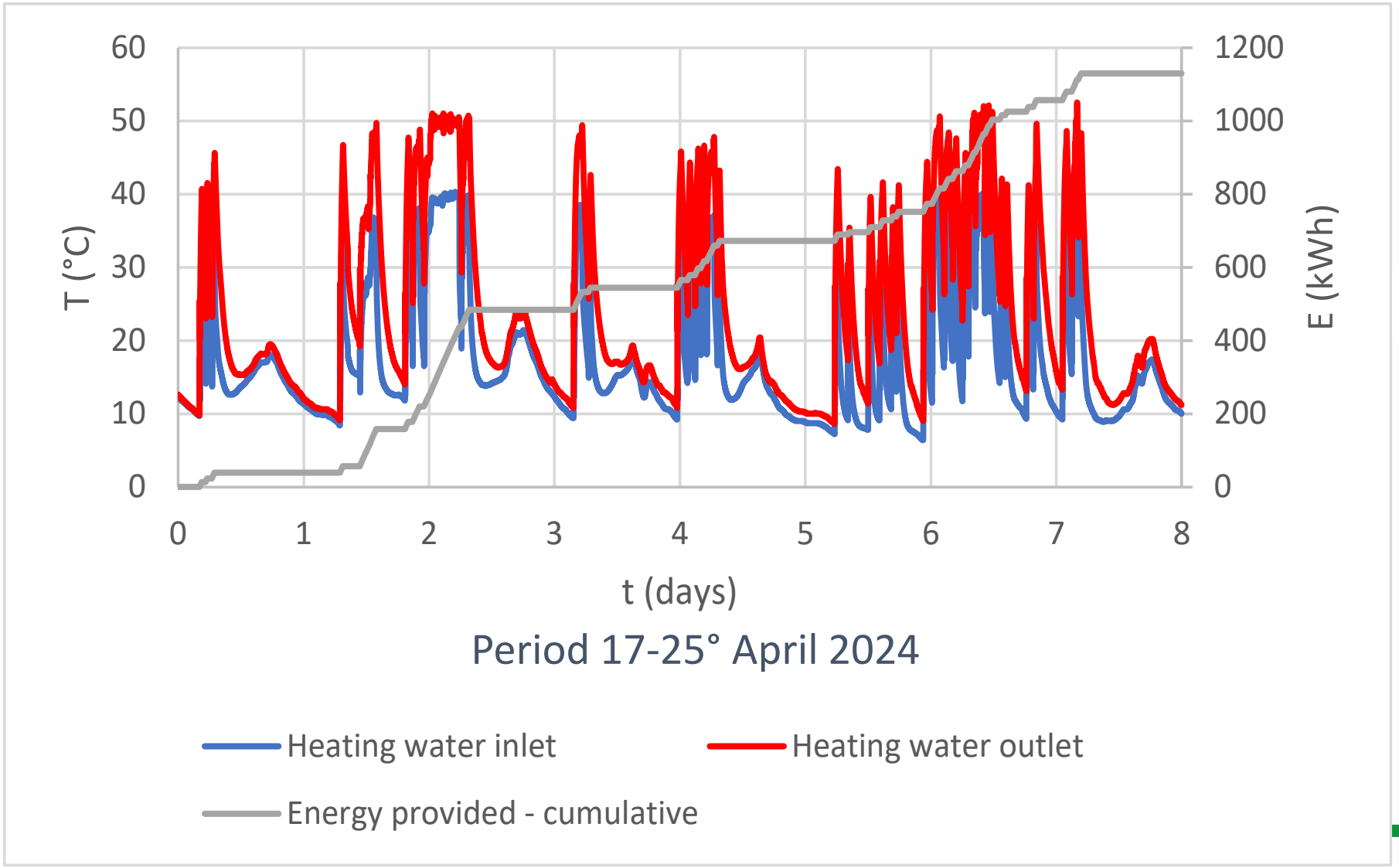
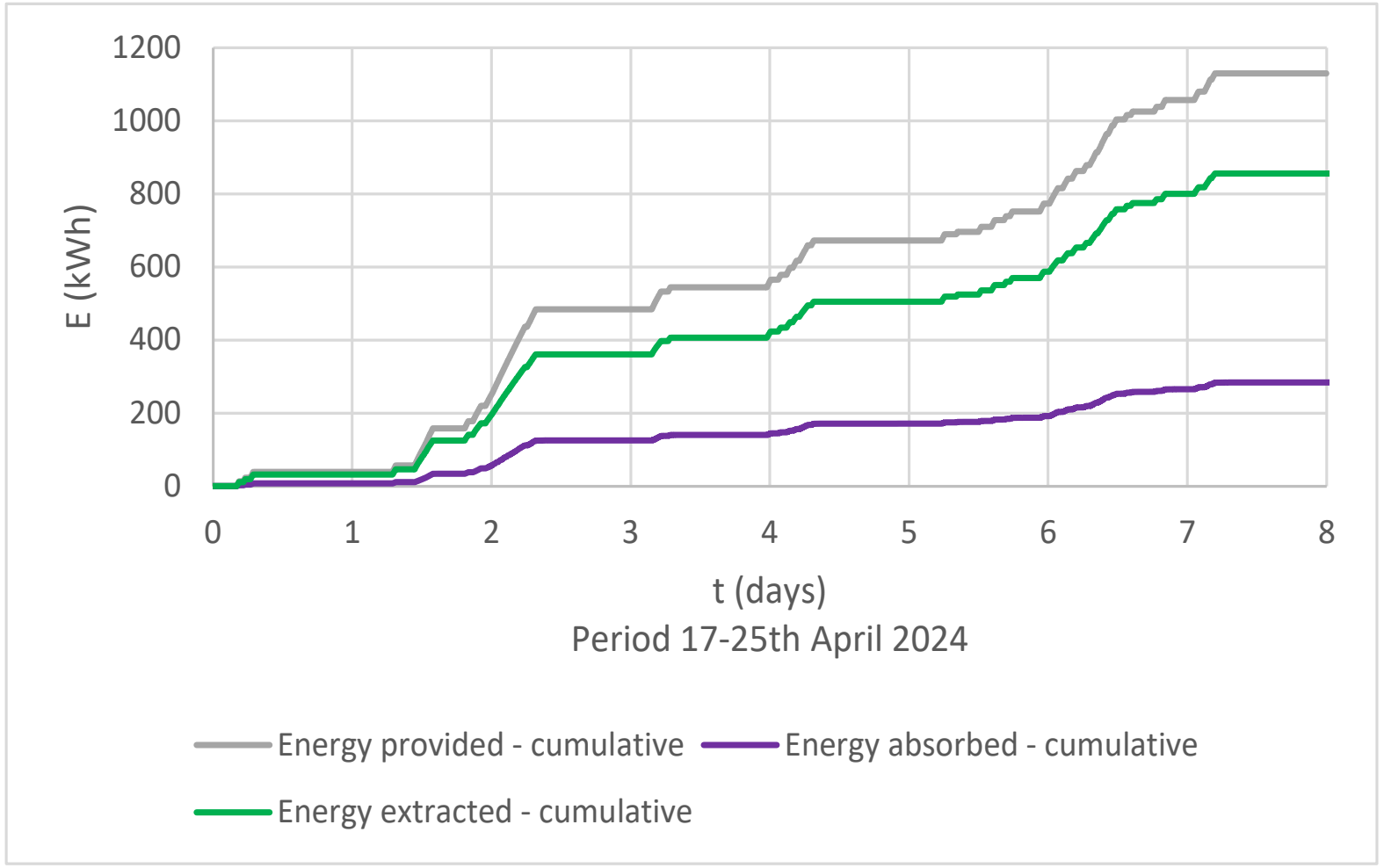
TOWARDS ZERO FOSSIL FUEL CONSUMPTION



Energy provided: 1100 kWh

• System performance – Cumulative energy



Energy provided: 1100 kW

Energy absorbed: 250 kWh

Energy extracted: 850 kWh

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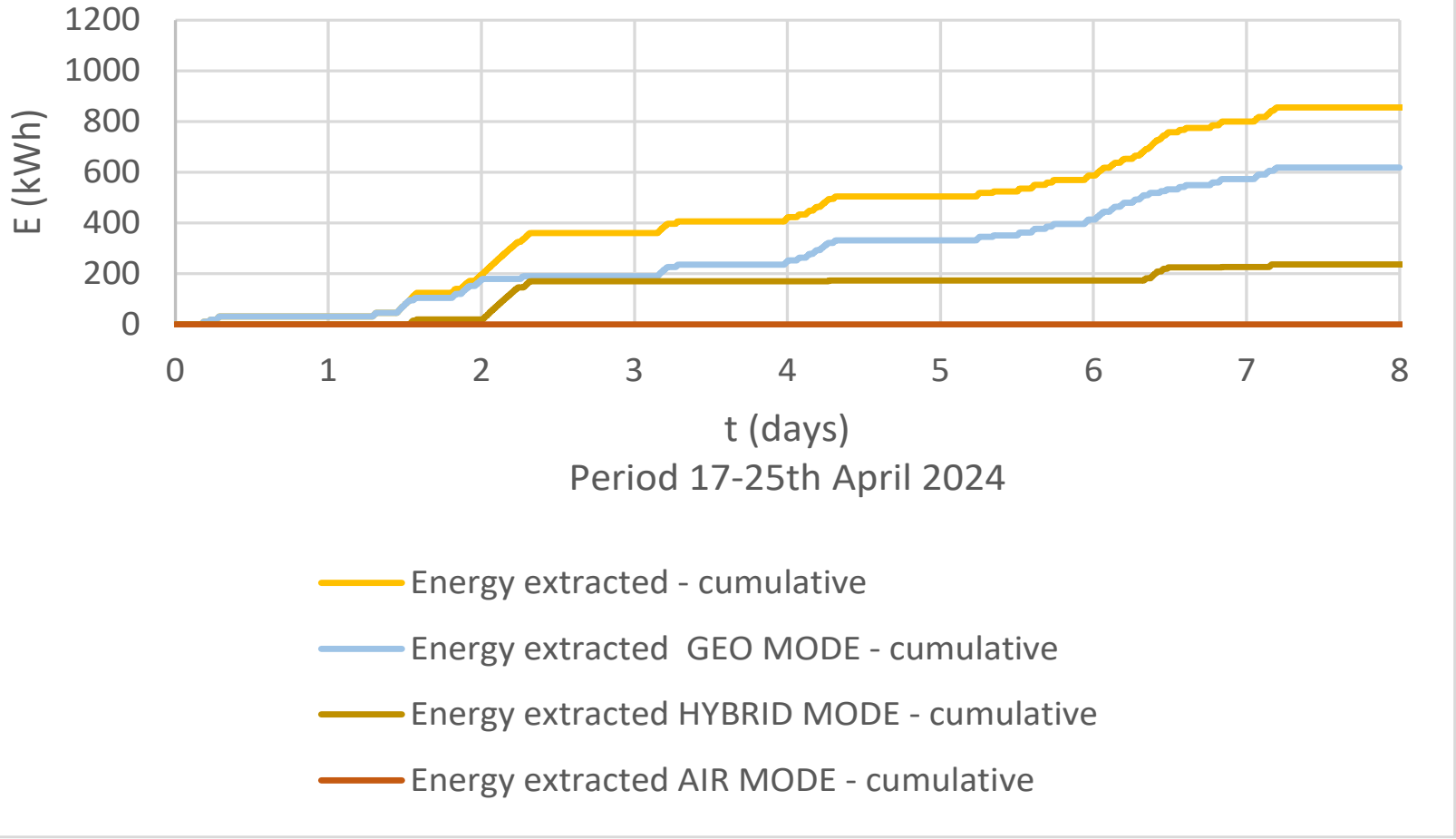
• System performance – Energy sources



	Average COP
GROUND mode	4.67
AIR mode	No activation
HYBRID mode	3.50
TOTAL	4.34

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• System performance – Energy sources in hybrid mode

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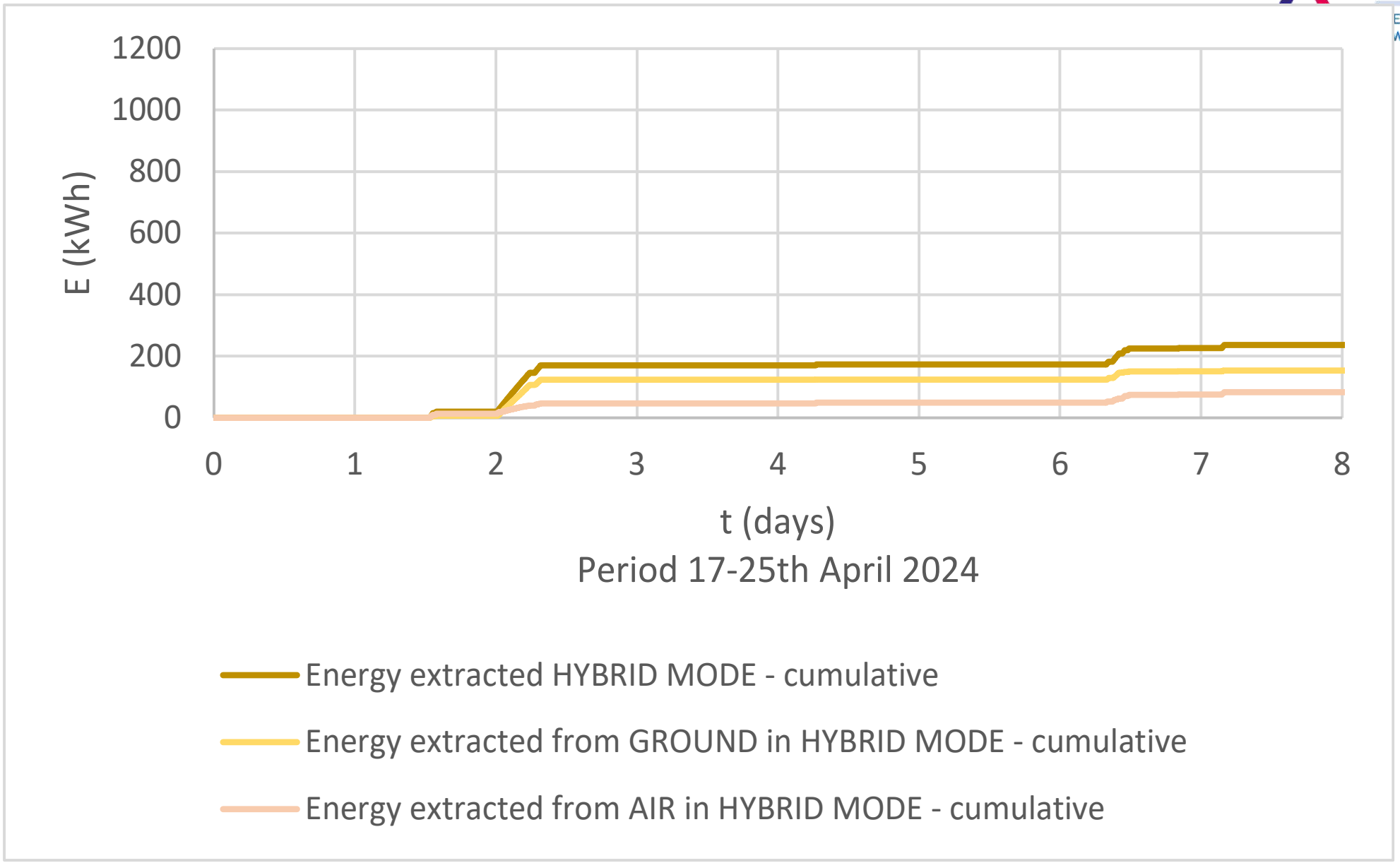
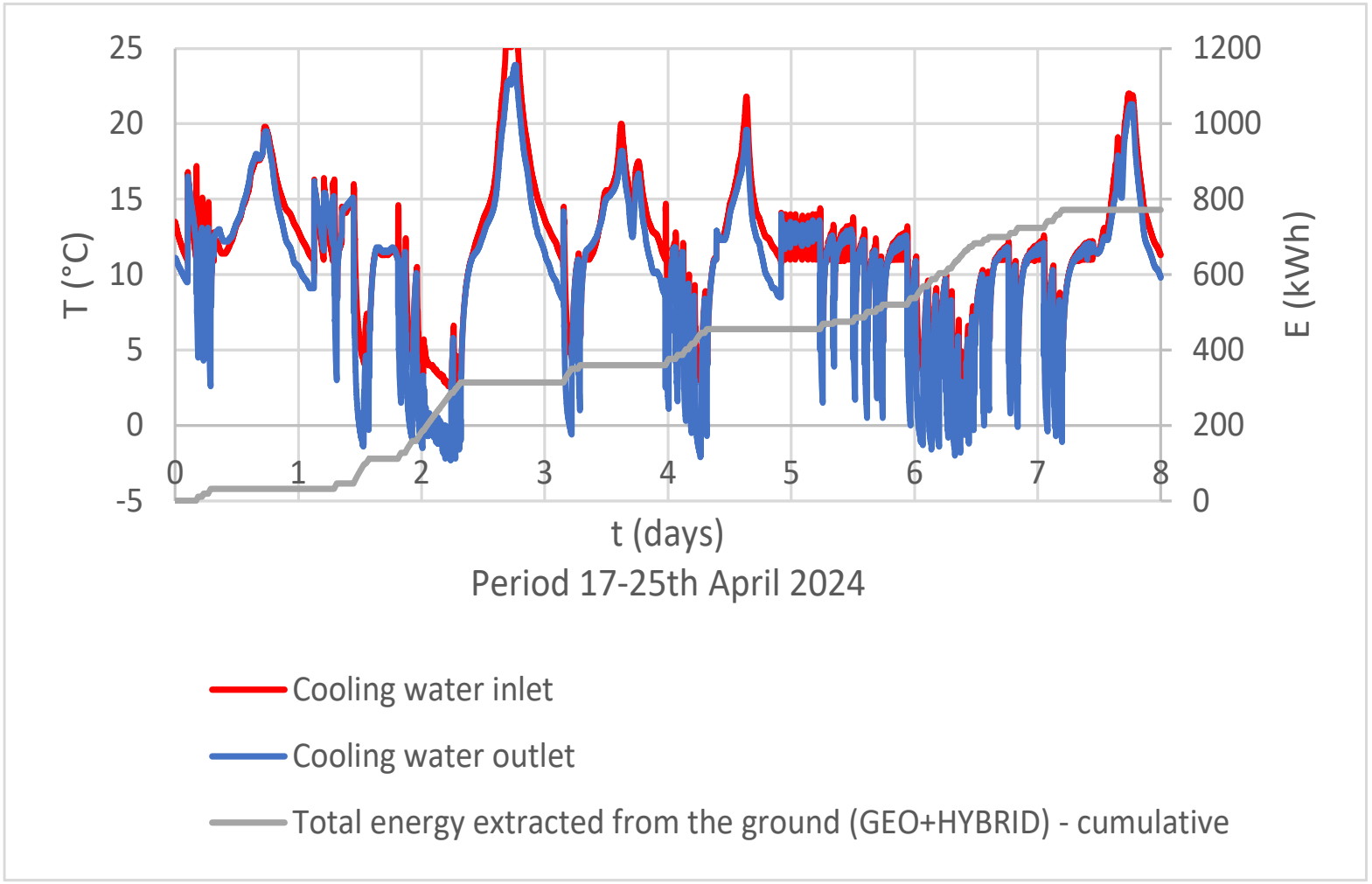


• System performance – Extracted geothermal water



Total energy extracted from the ground: 800 kWh

Minimum temperature: -2°C

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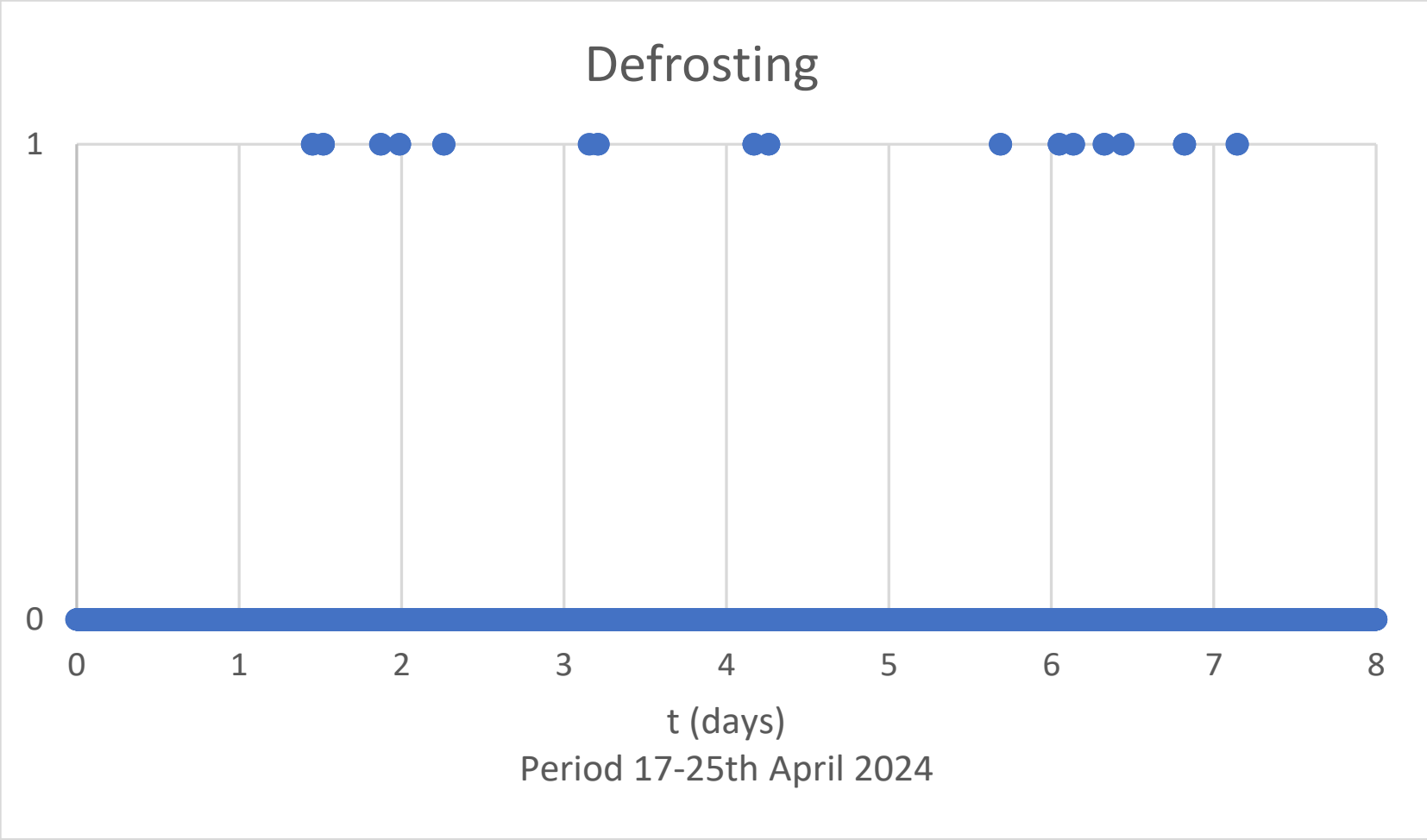
• System performance – Need of defrosting



Defrosting: 8.3% use of fans

Total SPF: 4.02.

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- **System performance**

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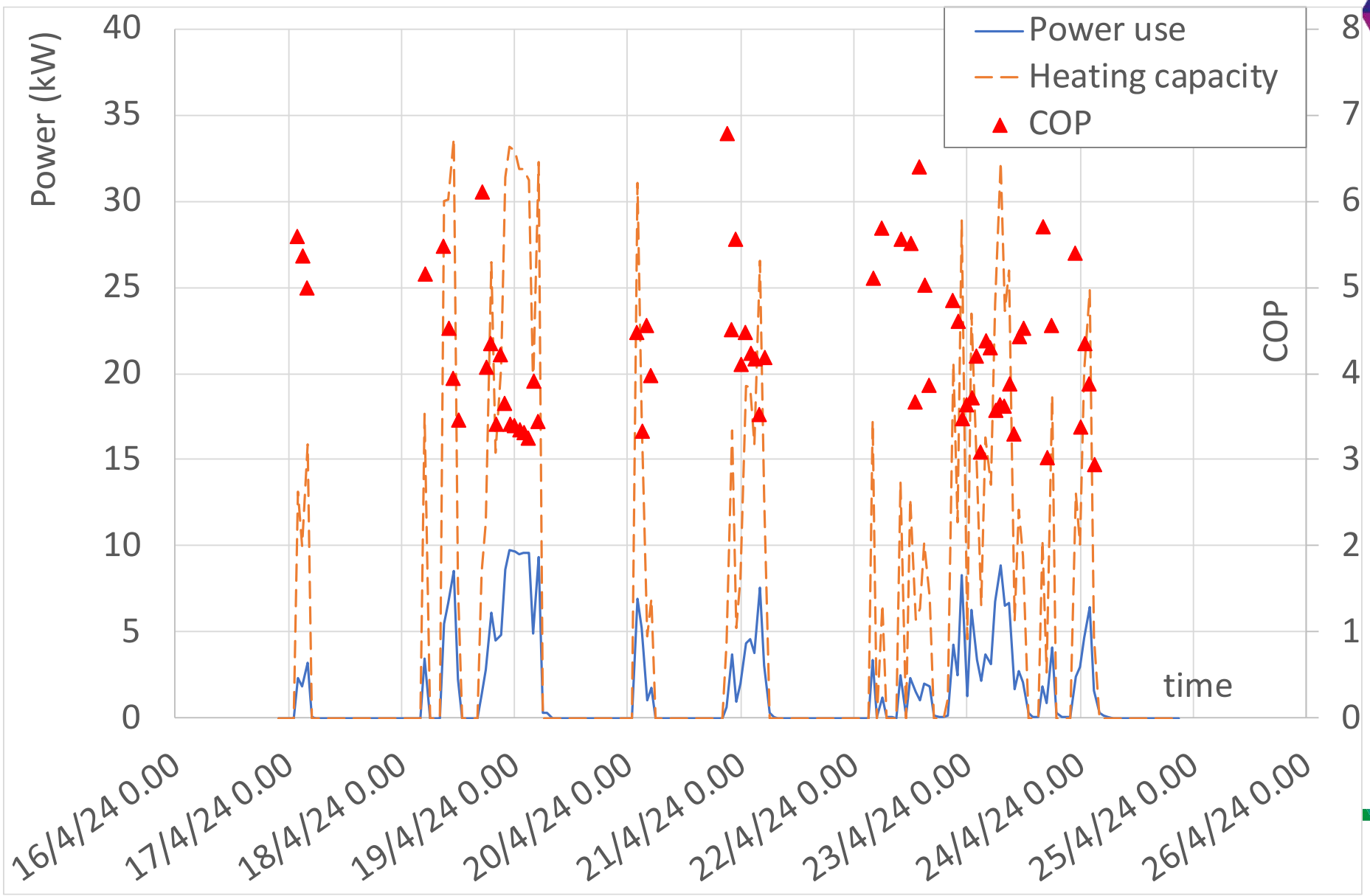
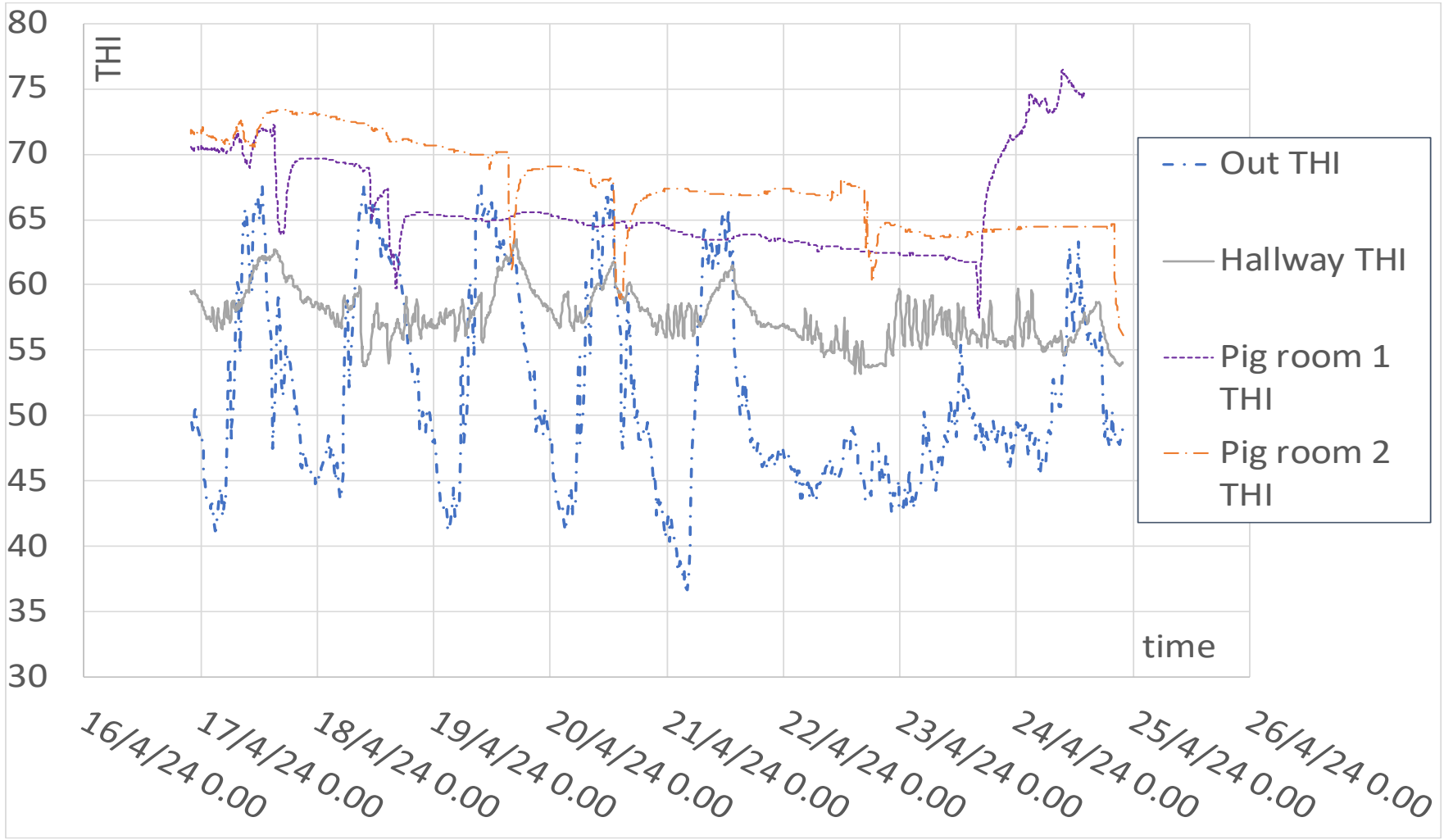


- **Average COP = 4.3**

• THI measured in the monitored indoor spaces and outside the barn



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- The heating system developed proved effective also for the control of humidity conditions in cold season, as it is witnessed by the THI trends in the weaners' rooms, that is substantially kept between 60 and 75.

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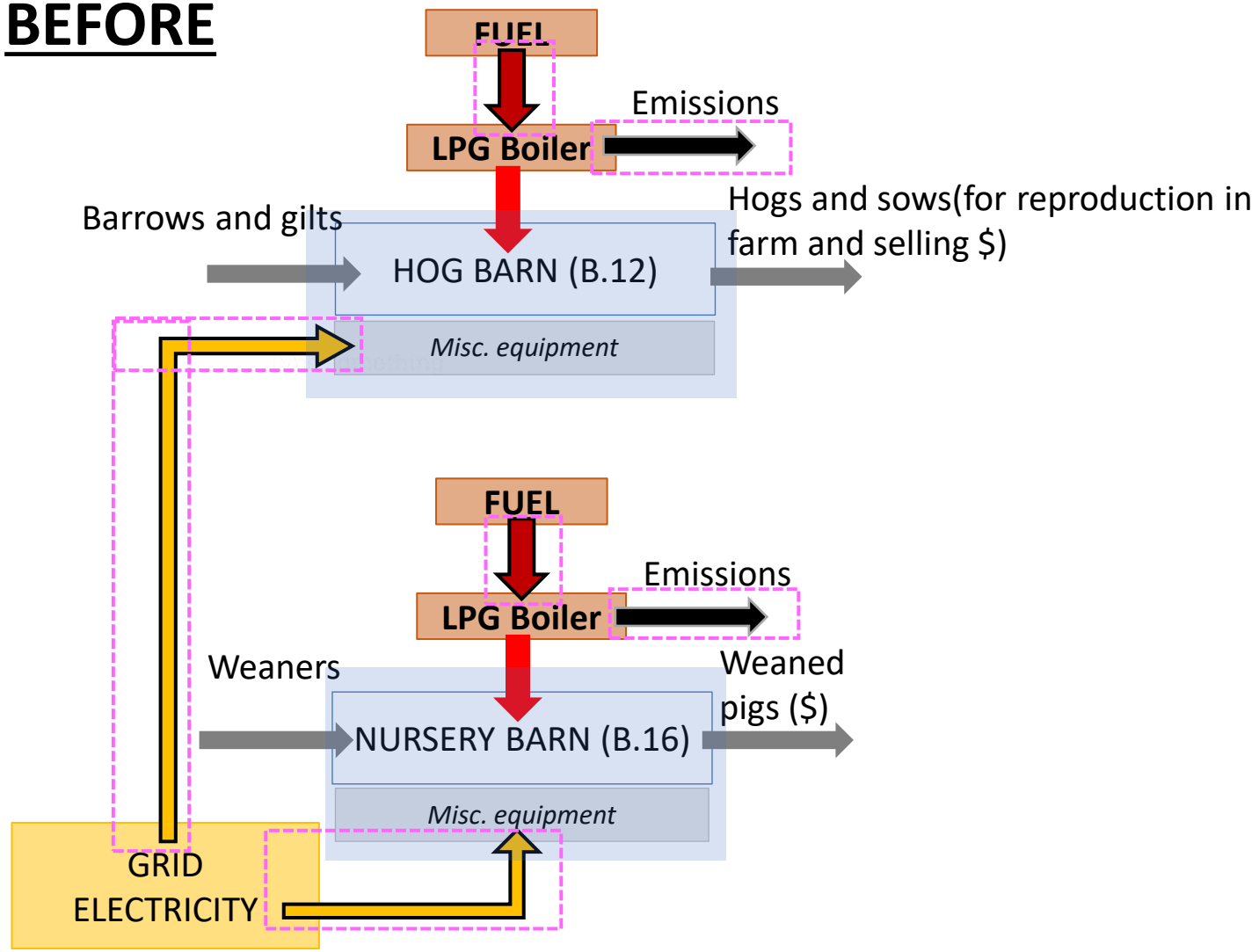
2. GOLINELLI // Swine – Italy (1)

BEFORE



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Legend

1. System boundaries
2. New (RES) system
3. Existing equipment (or a part of it)
4. Product flow
5. Electrical energy flow
6. Thermal energy
7. Electrical energy flow of interest (consumed or produced by our systems)
8. Fuel flow
9. On-farm emissions
10. Fuel, energy, or emission flow to be calculated or measured

2. GOLINELLI // Swine – Italy (2)

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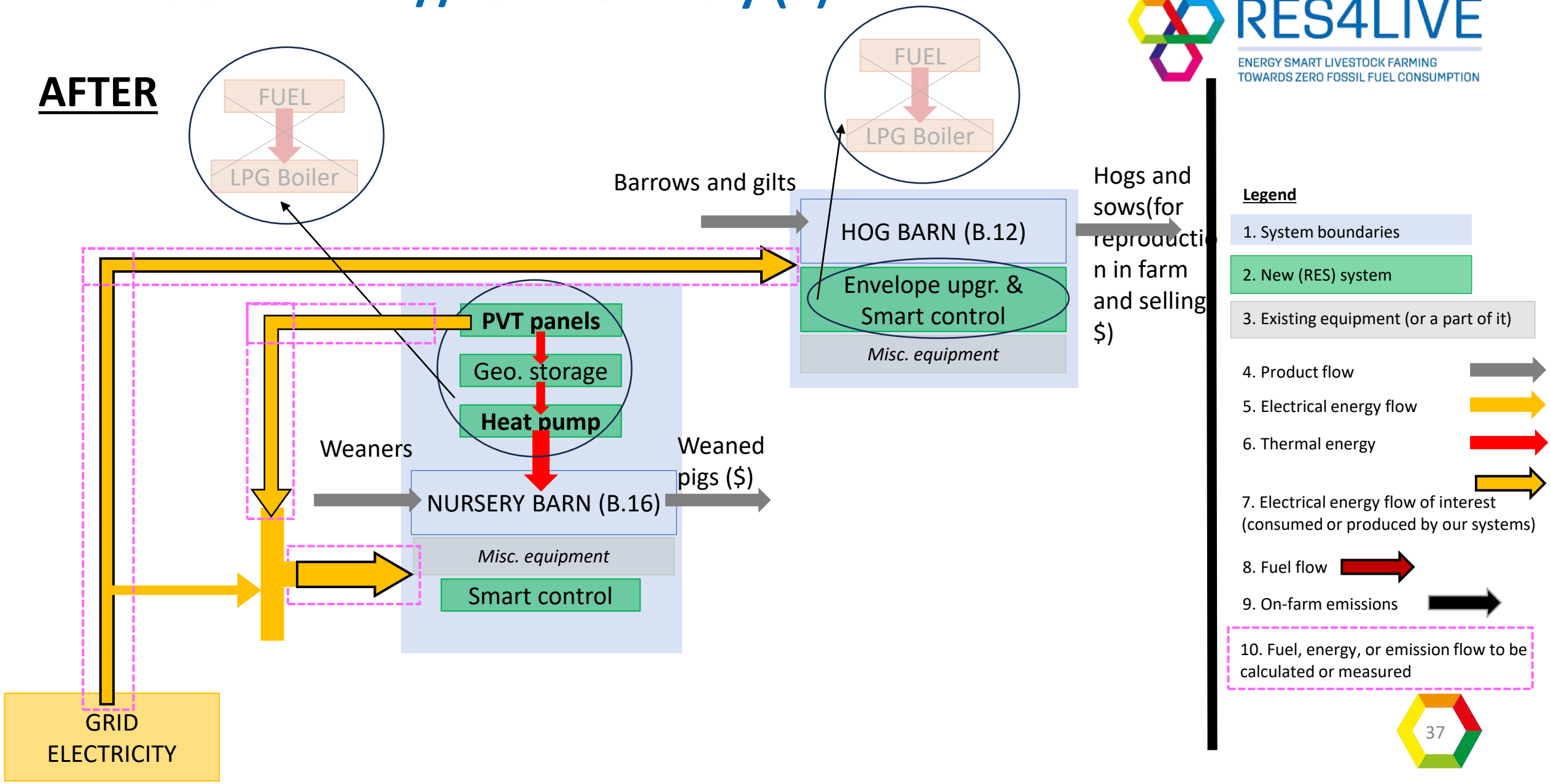
AFTER



Publications and presentations

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TOWARDS ZERO FOSSIL FUEL CONSUMPTION

- S. Benni, C.A. Perez Garcia, M. Bovo, A. Barbaresi, F. Tinti, P. Tassinari, D. Torreggiani. **A Renewable Energy Based Solution for Heating Livestock Buildings: Design and Realization of a Case Study**. The 6th CIGR International Conference 2024, May 19 - 23, 2024, Jeju International Convention Center (ICC JEJU), Jeju, Korea
- Murali, D., Acosta-Pazmiño, I.P., Loris, A., García, A.C., Benni, S., Tinti, F., Gomes, J. **Experimental assessment of a solar photovoltaic-thermal system in a livestock farm in Italy** (2024) Solar Energy Advances, 4, art. no. 100051.
- Benni, S., Tinti, F., Bovo, M., Barbaresi, A., Torreggiani, D., Tassinari, P**. An Integrated Renewable Energy Plant with Smart Monitoring System for Sustainable Farming** (2023) 2023 IEEE International Workshop on Metrology for Agriculture and Forestry, MetroAgriFor 2023 - Proceedings, pp. 547-552.
- Tinti F., Tassinari P., Rapti D,. Benni S., 2023. **Development of a pilot borehole storage system of solar thermal energy: modelling, design and installation**, Sustainability, 15 (9), art. no. 7432, DOI: 10.3390/su15097432.
- S. Benni, M. Ceccarelli, A. Barbaresi, M. Bovo, F. Tinti, M. Agrusti; P. Tassinari, D. Torreggiani, **A pilot system to replace fossil energy with renewable sources in pig barns**, in: Biosystems Engineering Towards the Green Deal, 2022, pp. 163 - 163 (BIOSYSTEMS ENGINEERING TOWARDS THE GREEN DEAL. Improving the resilience of agriculture, forestry and food systems in the post-Covid era, Palermo, 19-22/09/2022)
- S. Benni, A. Barbaresi, F. Tinti, M. Bovo, D. Torreggiani, E. Santolini, P. Tassinari**, Decarbonizing livestock structures: retrofit of a pig barn using renewable sources,** in: Proceedings of the XX CIGR World Congress: Sustainable Agricultural Production - Water, land, Energy and Food, 2022, pp. 1 - 2 (The XX CIGR World Congress 2022 - Sustainable Agricultural Production, Kyoto, 5-9 Dec 2022)
- F. Tinti, D. Rapti, R. Caputo, C. A. Perez Garcia, M. Ceccarelli, E. Santolini, S. Benni, **Investigations and modelling for a practical application of borehole thermal energy storage,** in: Geosciences for a Sustainable Future - Proceedings, 2022, pp. 1 - 1 (Geosciences for a Sustainable Future, Torino, 19-21 Sep 2022)

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