Not-in-kind approach to remote monitoring in CO2 refrigeration systems

EU GREEN WEEK 2021 PARTNER EVENT

ZERO POLLUTION #EUGreenWeek
for healthier people and planet
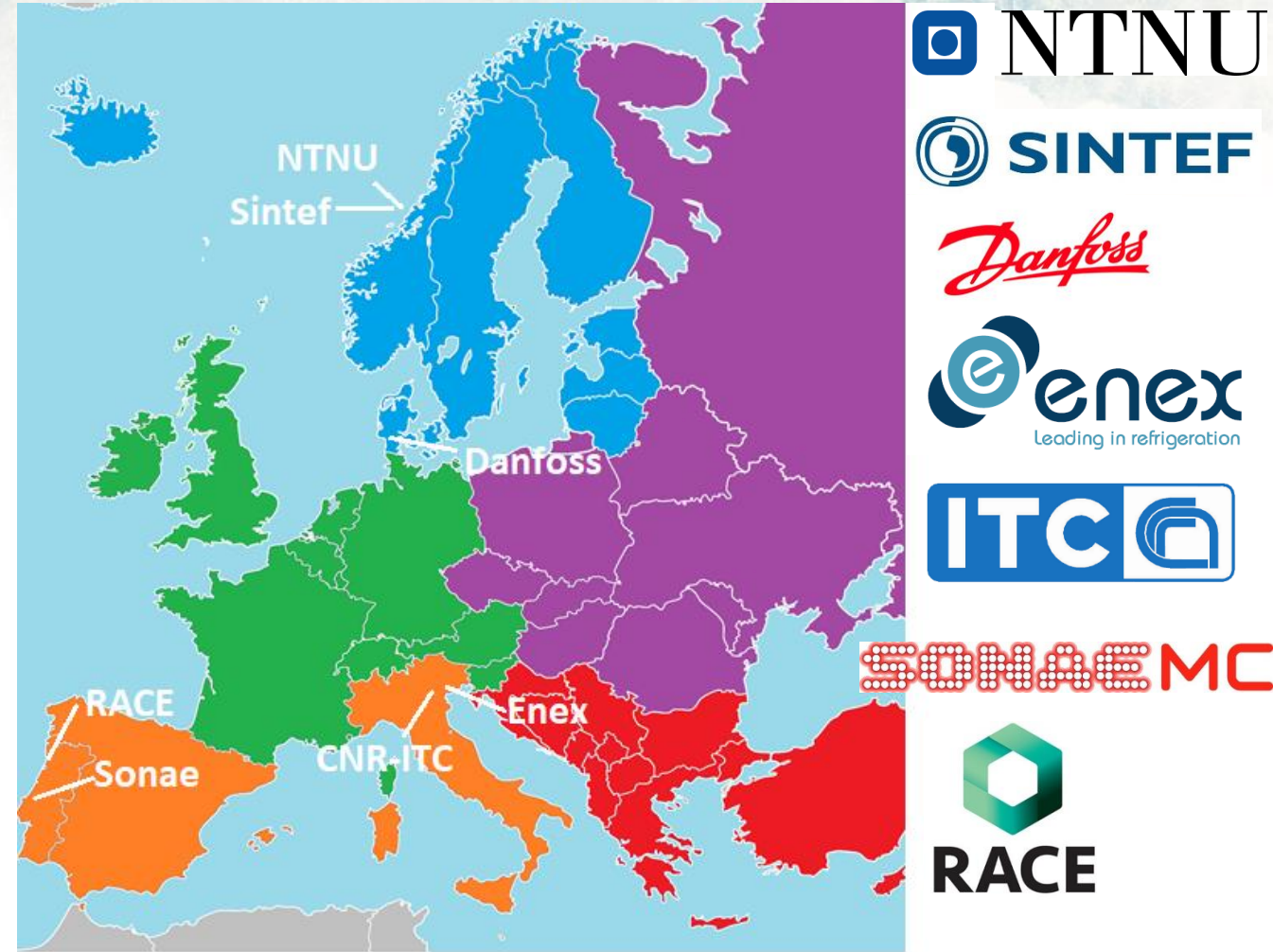
multi PACK

ITC

# Outline

- The MultiPACK H2020 Project

- 1$^{st}$ MultiPACK demosite: integrated Supermarket in Italy

- Performance evaluation

- Considerations on performances benchmarking


- Refrigerant flow measurement

# The MultiPACK Project

- EU funded Horizon 2020 Project (Grant number 723137)

- Duration: 48 months

- Partners: NTNU (coordinator), Sintef, Danfoss, Enex, CNR-ITC, Sonae, RACE
  *partners are present in all the links of the value chain from initial innovation to the actual end user*

- Main focus areas:

  - **Supermarkets**

  - High energy demanding buildings

    (hotel, gyms, etc.)

# What is a MultiPACK unit for Supermarkets?

- A **fully integrated** unit providing Refrigeration, Heating and Air Conditioning based on **Carbon Dioxide** as the refrigerant

- **Heat Pump** functionality

- **Cooling and dehumidification**

- Suitable for **South European Climate**, thanks to **Parallel Compression**, **Overfed Evaporators**, **Ejectors** for vapour pre-compression and liquid recirculation

- **Scalable** and **adaptable** to different load ratios and HVAC design

- Fully instrumented for **performances monitoring**

# What are MultiPACK objectives for Supermarkets?

- Build up **confidence** for standardised integrated cooling & heating packages

- Demonstrate technical feasibility, reliability and serviceability

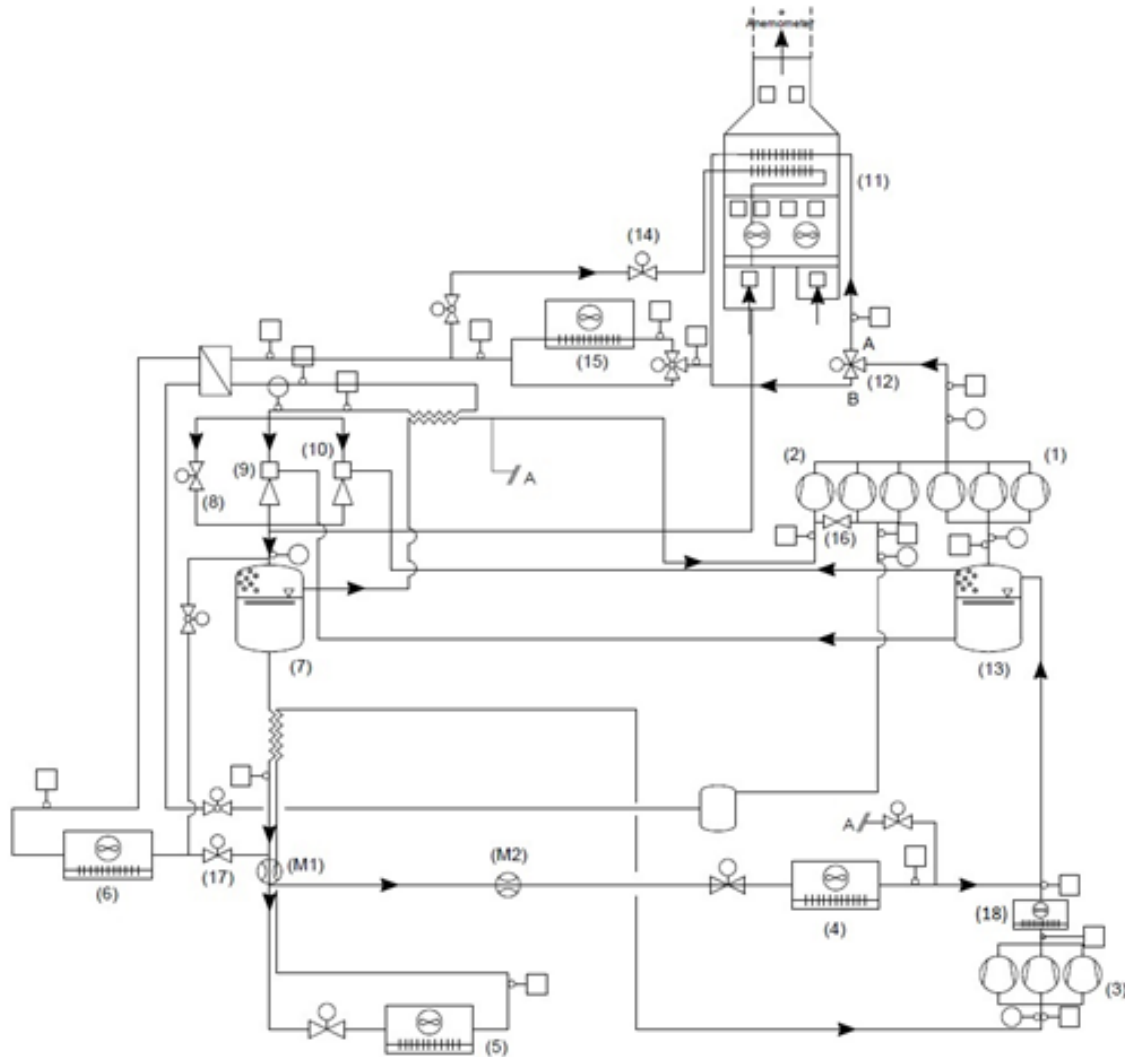- Demonstrate **energy performances** in **South European Climate**

**How?**

- Installing 3 fully instrumented demo sites

**Where?**

- **Portugal** and **Italy**

# The MultiPACK unit in central Italy



- Nominal capacity 50kW MT, 20 kW LT, 75 kW AC, 110 kW Heating
- Based on a **booster concept** with parallel compression
- Expansion work recovery via **multiejector** system
- Minimised superheat
- Integrated direct air **heating, cooling and dehumidification** with **AHU**
- Heat Pump functionality
- Fully instrumented for performances monitoring

# Measurement instruments
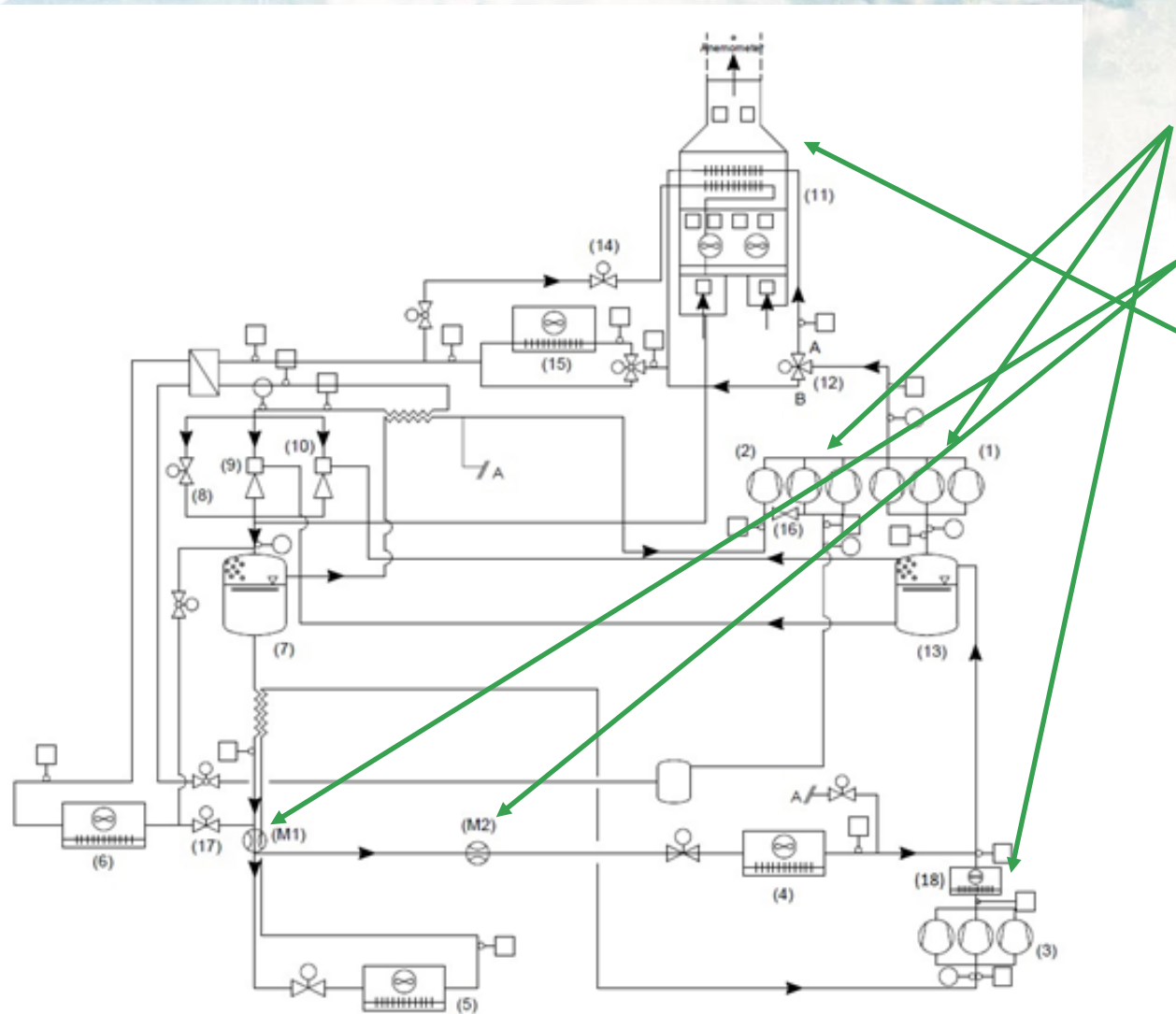


- Power input to compressors racks (MT, LT, Aux, Total)
- Refrigerant mass flow MT, MT+LT
- Air flow, T and RH in and out from AHU

- Pressure and temperature for key points state definition
- Components status

# Performance evaluation

## First law approach

$$COP_{tot} = \frac{\dot{Q}_{MT} + \dot{Q}_{LT} + \dot{Q}_{AC} + \dot{Q}_{H}}{P_{MT} + P_{LT} + P_{Aux}}$$
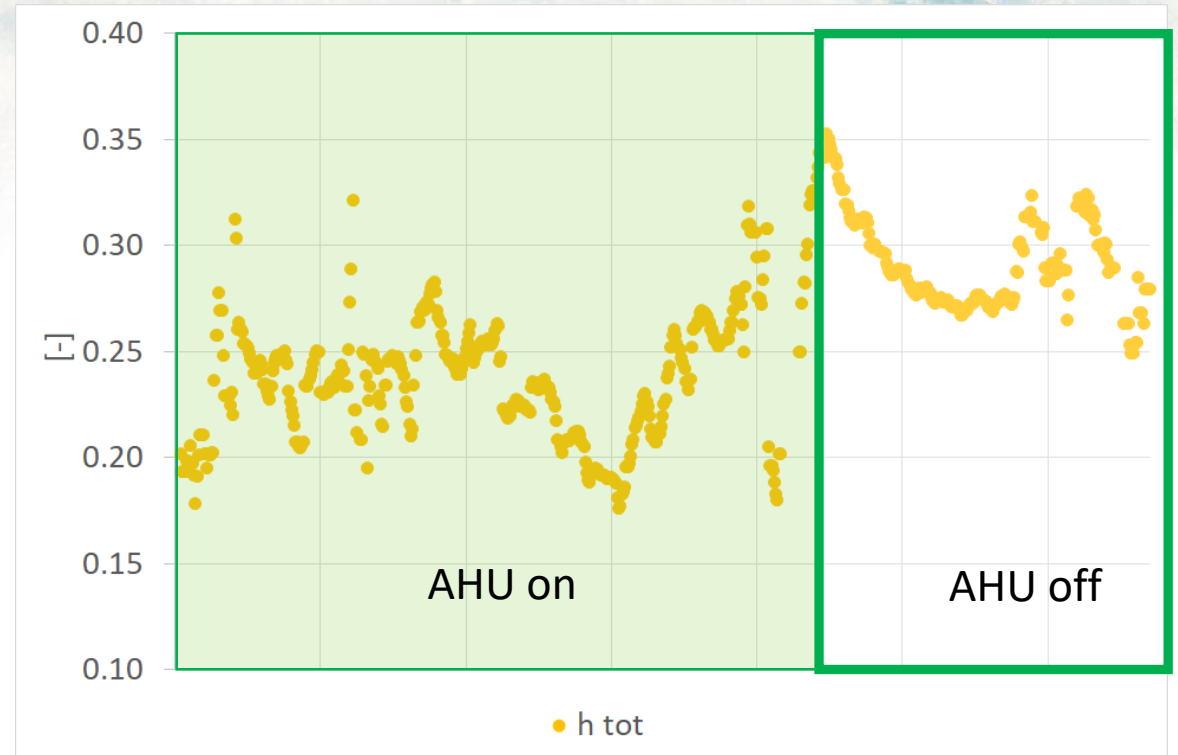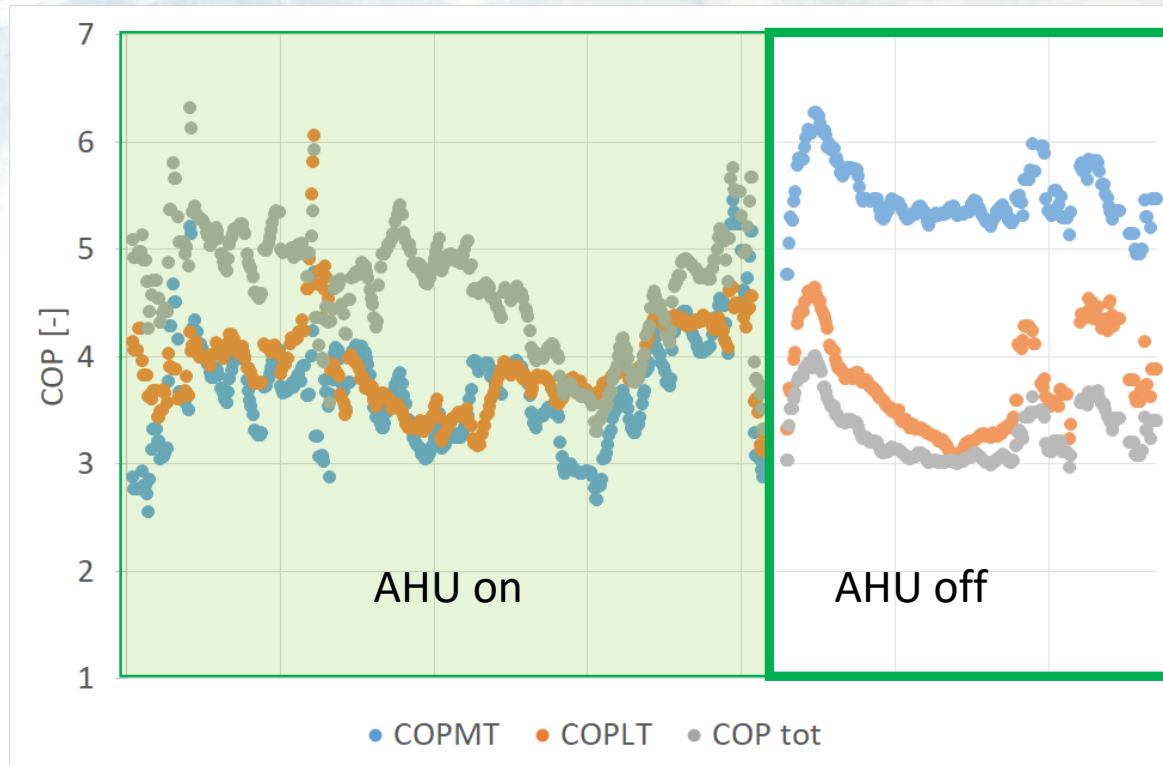
$$COP_{MT} = \frac{\dot{Q}_{MT} + (\dot{Q}_{LT} + P_{LT} - \dot{Q}_{ds})}{P_{MT} + P_{Aux}}$$
n.a. if $(\dot{Q}_{H} > 0 \wedge P_{Aux} > 0)$

$$COP_{LT} = \frac{\dot{Q}_{LT}}{P_{LT}}$$

Easier evaluation in energy terms

# Performance evaluation (winter)



22-23 December 2018
AHU on (heating) during the day

# Performance evaluation

## Second law approach

$$\eta_{tot} = \frac{P_{C,MT} + \dot{P_{C,LT}} + P_{C,AC} + P_{C,H}}{P_{MT} + P_{LT} + P_{Aux}} =$$

$$\frac{\dot{Q}_{MT}\left(\frac{T_{amb}}{T_{MT,ref}} - 1\right) + \dot{Q}_{LT}\left(\frac{T_{amb}}{T_{LT,ref}} - 1\right) + \dot{Q}_{AC}\left(\frac{T_{amb}}{T_{AC,ref}} - 1\right) + \dot{Q}_{H}\left(1 - \frac{T_{amb}}{T_{H,ref}}\right)}{P_{MT} + P_{LT} + P_{Aux}}$$

Requires reference values for $T_{MT,ref}$, $T_{LT,ref}$, $T_{AC,ref}$, $T_{H,ref}$
Assumed as 273.15 K, 251.15 K, 299.15 K and 294.15 K

# Performance evaluation

$$LR = \frac{\dot{Q}_{MT}}{\dot{Q}_{LT}}$$

| - | - | 22/12/2018 | 22-23/12/2018 | 12/12/2018 | 12-13/12/2018 |
|---|---|---|---|---|---|
| $T_{amb}$ | (°C) | 14.5 | 14.2 | 10.6 | 9.9 |
| $T_{evMT}$ | (°C) | -4.6 | -5.0 | -4.9 | -5.1 |
| $T_{evLT}$ | (°C) | -31.3 | -30.2 | -30.4 | -30.9 |
| $T_{evaux}$ | (°C) | 2.6 | - | -0.8 | - |
| $p_{gc}$ | ($10^5$ Pa) | 70.3 | 55.8 | 77.3 | 53.7 |
| $Q_{MT}$ | (kW) | 35.0 | 24.2 | 31.4 | 22.4 |
| $Q_{LT}$ | (kW) | 13.4 | 19.4 | 16.9 | 14.5 |
| $Q_H$ | (kW) | 30.9 | - | 49.3 | - |
| LR | (-) | 2.6 | 1.2 | 1.9 | 1.5 |
| $COP_{MT}$ | (-) | 2.7 | 5.3 | 3.2 | 6.3 |
| $COP_{LT}$ | (-) | 3.8 | 3.7 | 4.0 | 4.1 |
| $COP_{tot}$ | (-) | 3.6 | 3.3 | 4.4 | 4.0 |
| $\eta_{tot}$ | (-) | 0.20 | 0.29 | 0.23 | 0.27 |

# Performance evaluation-preliminary summer data
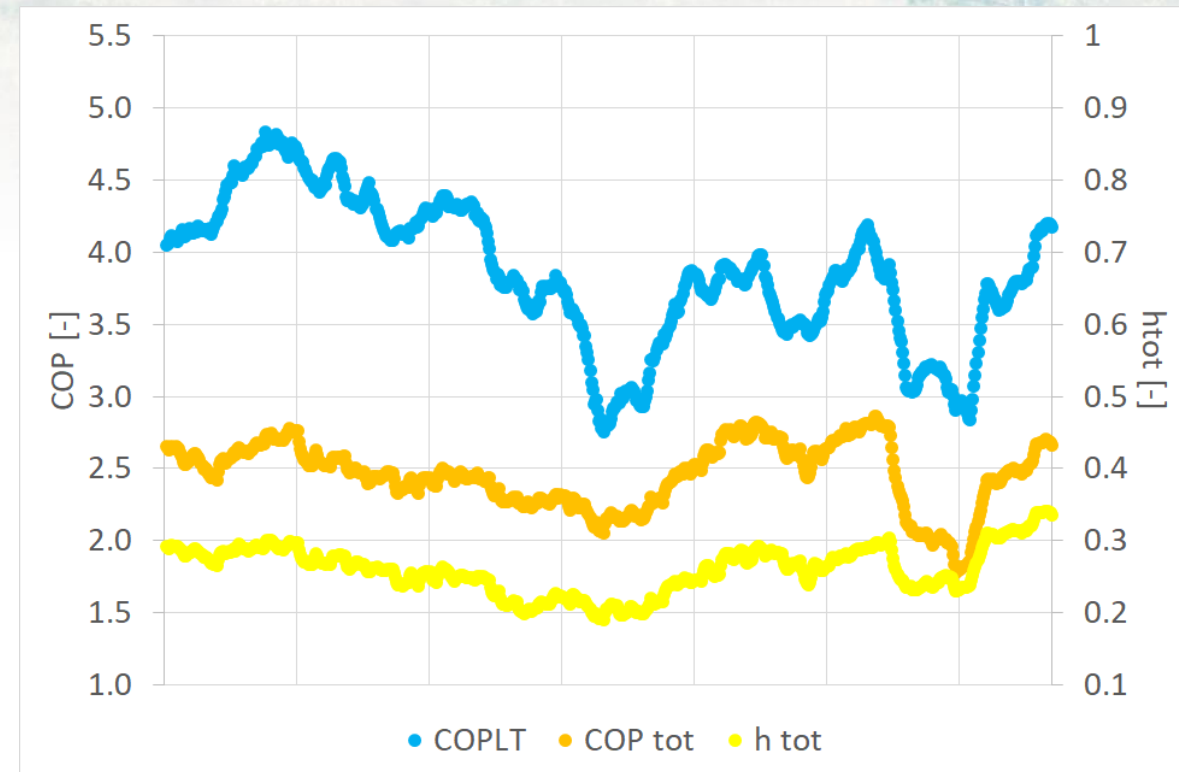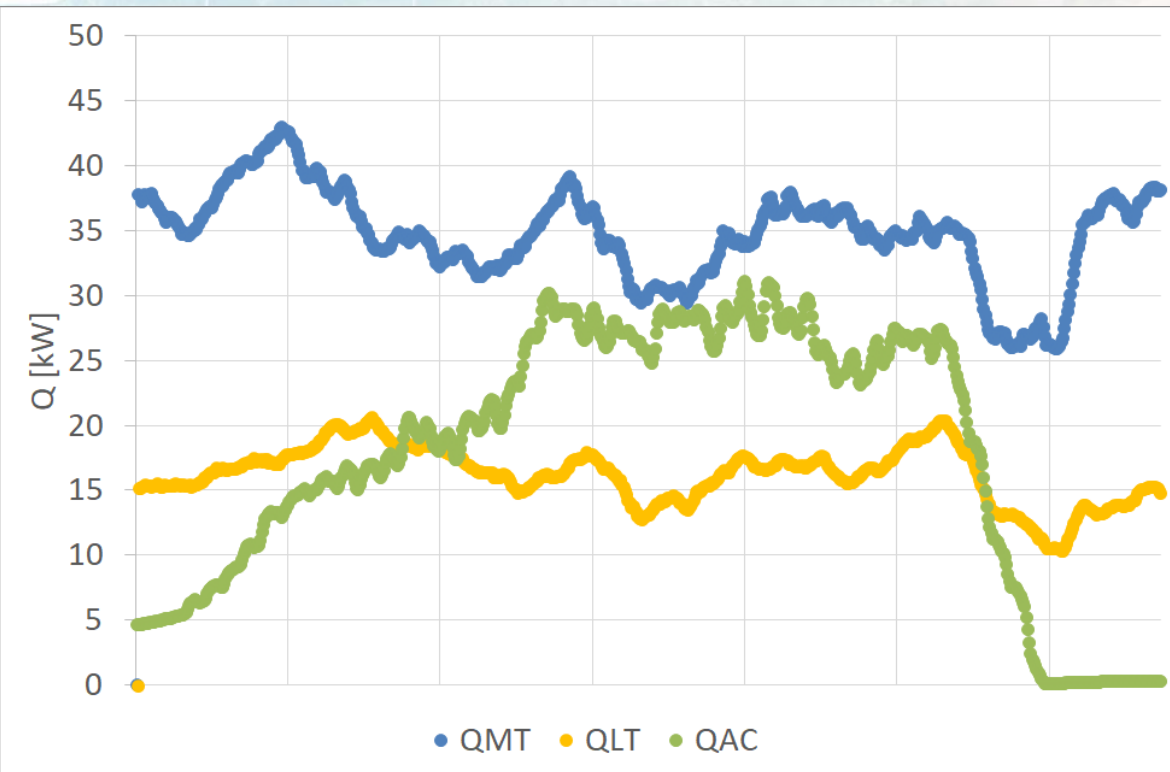


21-22 July 2019
AHU on (cooling)

# Performance evaluation

- Both 1st and 2nd law approach require loads measurements, i.e. refrigerant flow measurement (not affordable values by direct simple calculation in complex systems)

- Flow meters installation is not common practice in commercial refrigeration

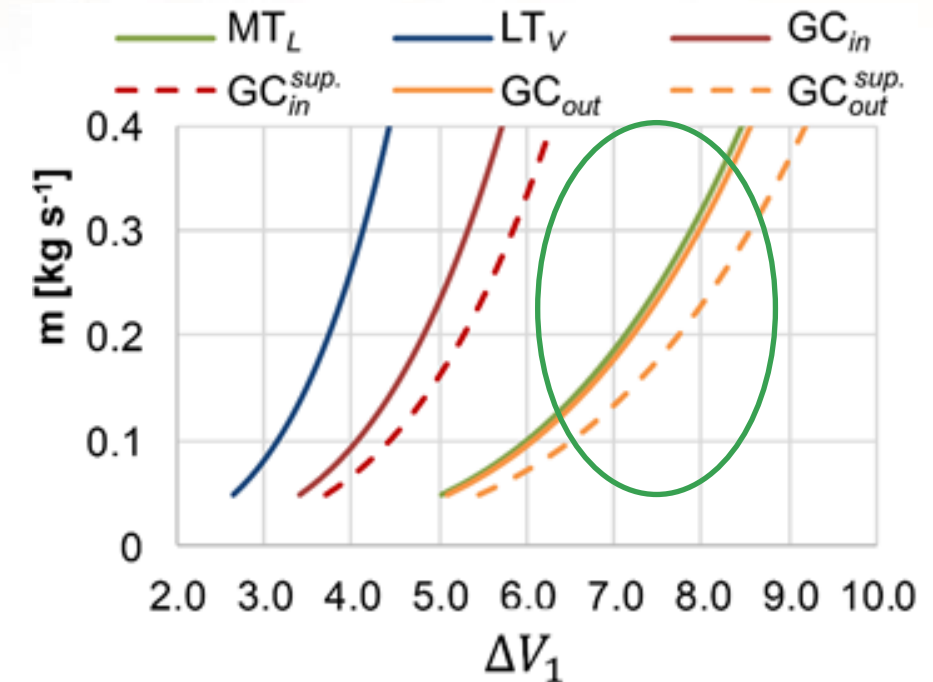- Objectives: low cost, reliable, good accuracy meter, to be extensively installed in supermarkets

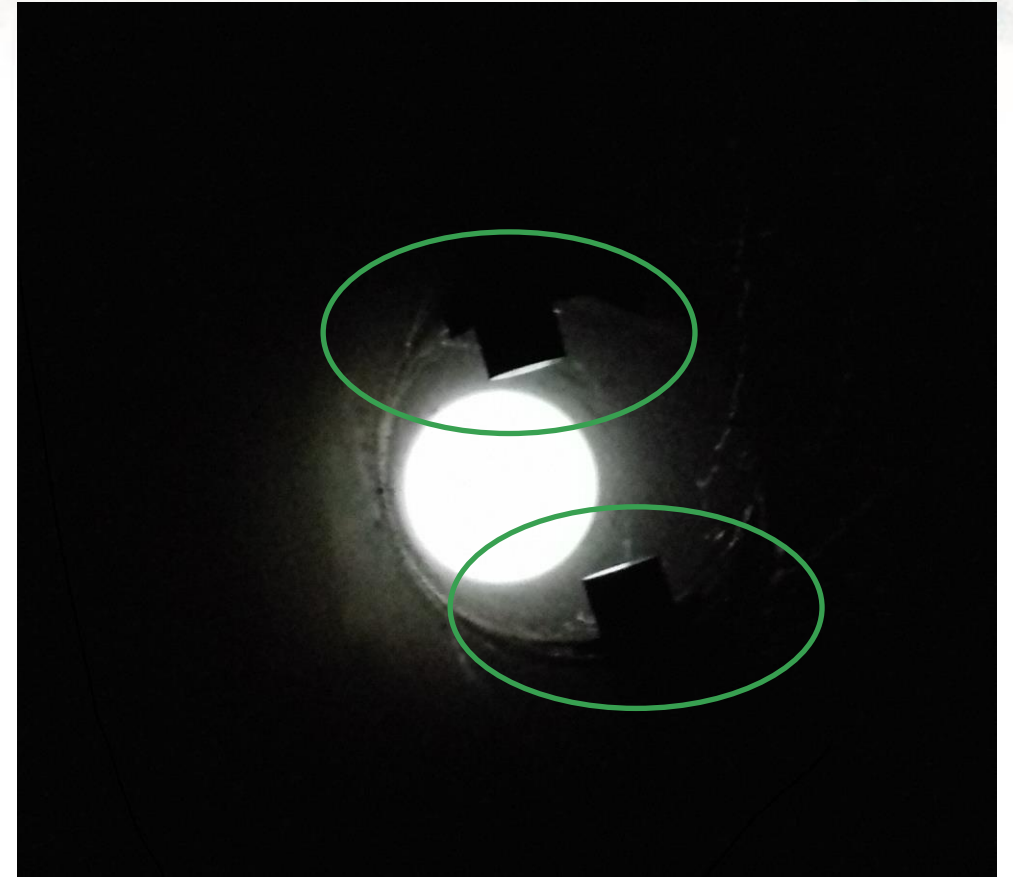# In-house flow meter
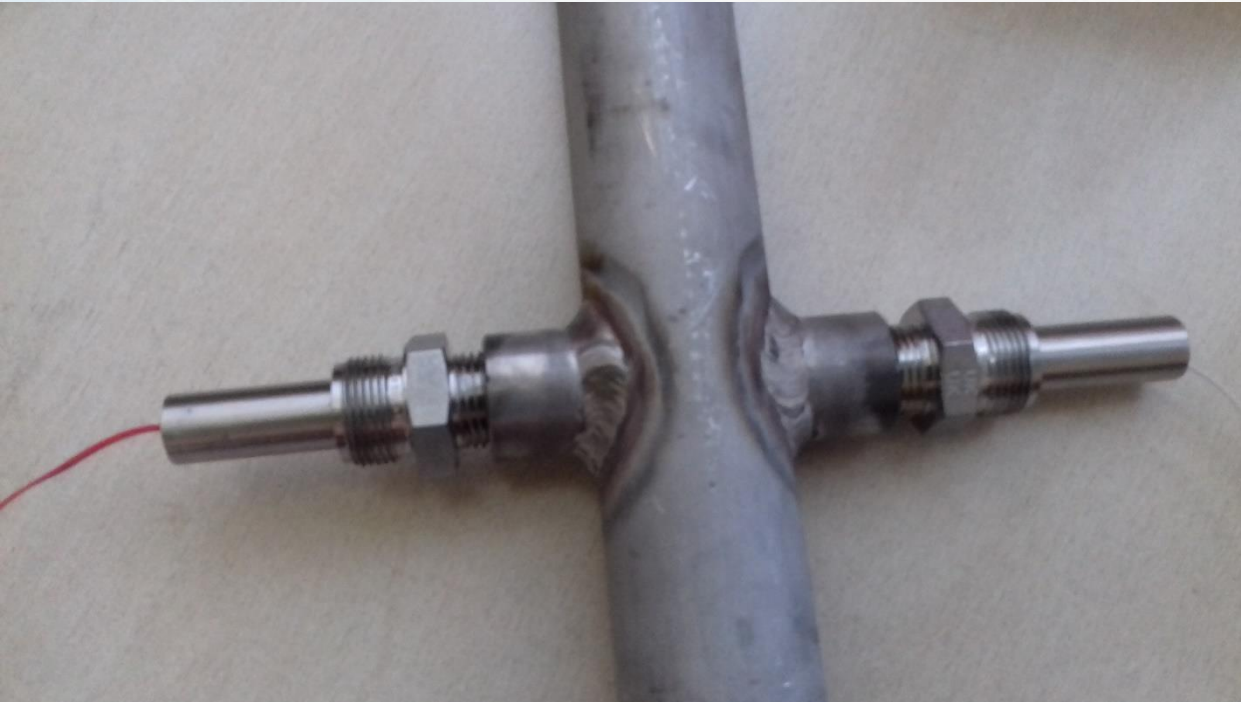
- Based on hot wire anemometer principle
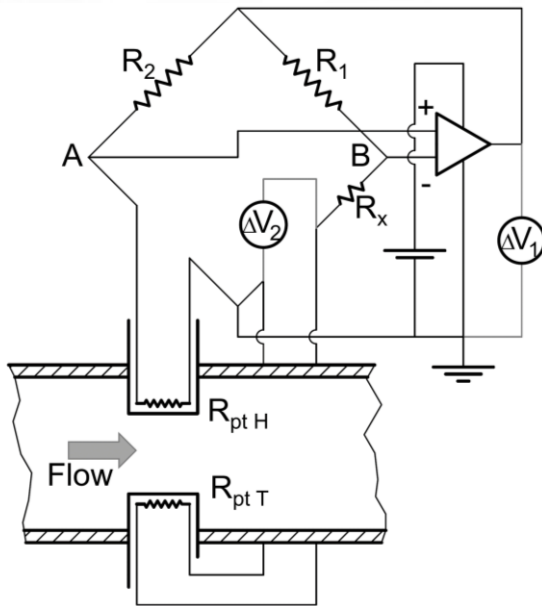


| Resistor | Nominal Resistance |
|----------|--------------------|
| $R_1$ | 500 $\Omega$ |
| $R_2$ | 50 $\Omega$ |
| $R_x$ | 15 $\Omega$ |
| $R_{ptH}$ | 100 $\Omega$ |
| $R_{ptT}$ | 1000 $\Omega$ |

- Expected performance

# First prototype

# Conclusions

- The MultiPACK H2020 Project

- 1st MultiPACK demosite: **integrated Supermarket** in Italy

- Challenge in **performance measuring**

- Challenge in **performance benchmarking**

- **First or second law** analysis

- **Refrigerant mass flow measurement** is anyhow required for performance evaluation

Thank you!

Silvia MINETTO
silvia.minetto@itc.cnr.it

**EU GREEN WEEK 2021 PARTNER EVENT**