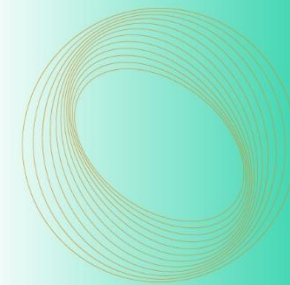




The Business Case Natural Refrigerants



BRUSSELS

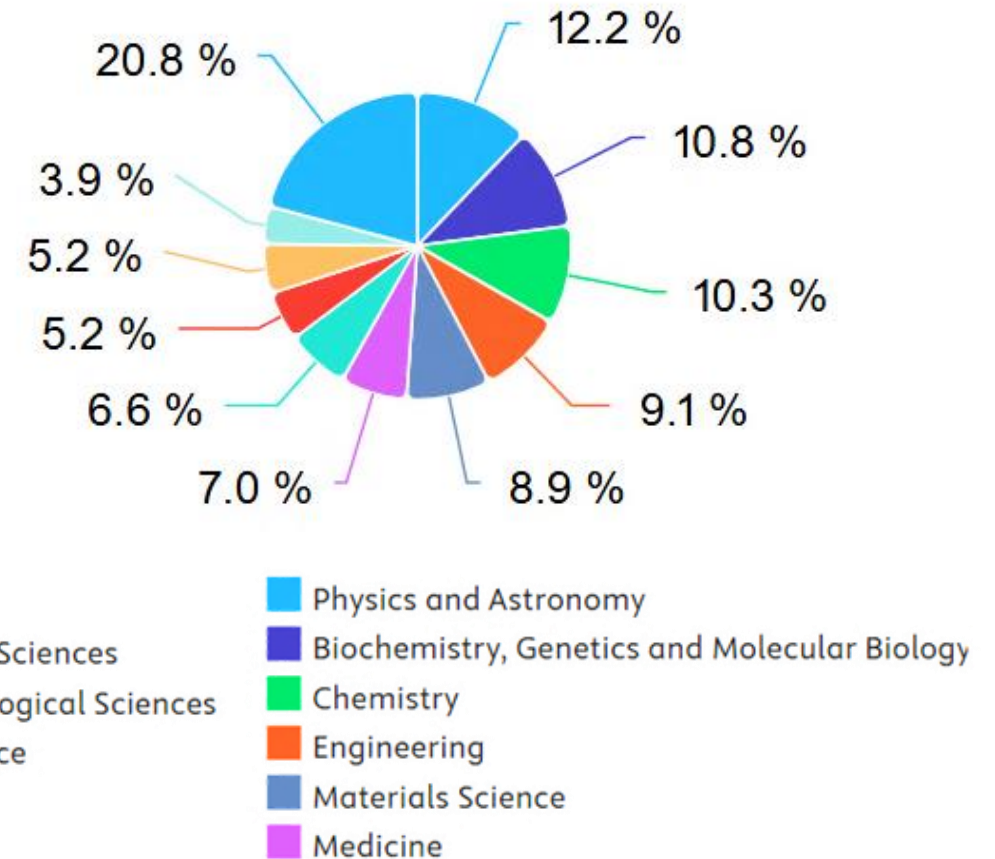
29 Sept. 2026



ATMO.org

National Research Council

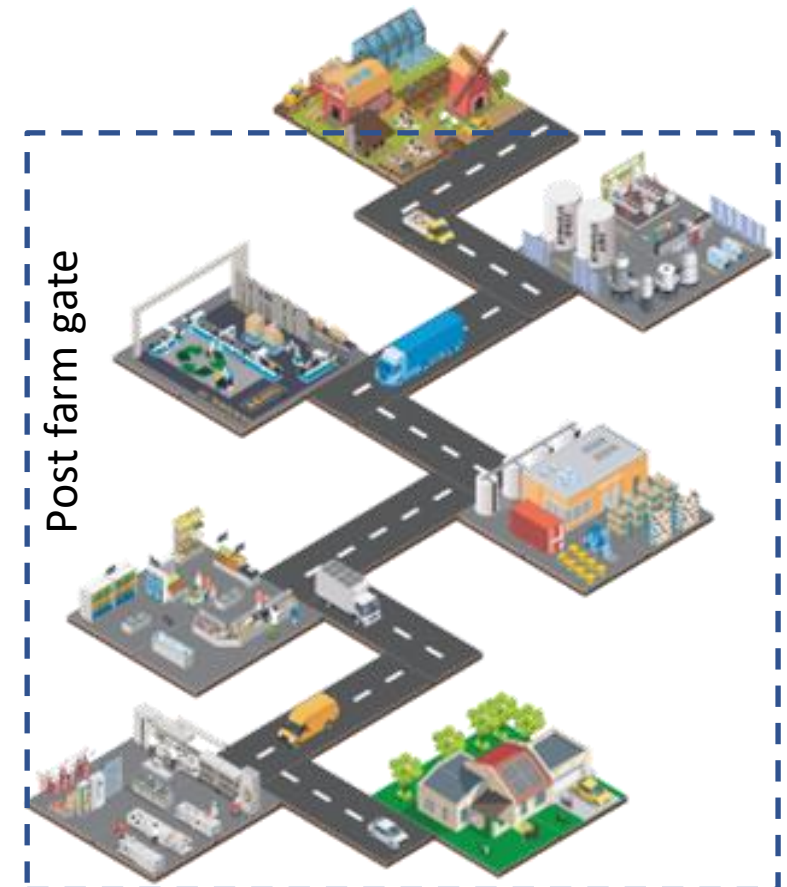
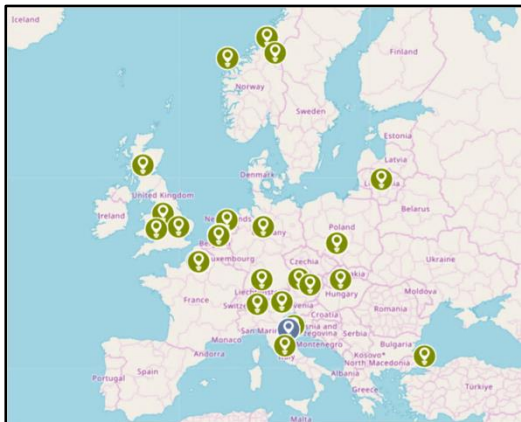
- The **National Research Council of Italy (CNR)** is Italy's largest public research institution. It conducts multidisciplinary scientific and technological research to support innovation, competitiveness, and international collaboration.
- Founded in **1923**
- **88** Institutes, grouped in **7** Departments
- **9 000** employee
- **334 000** scientific paper indexed in SCOPUS (9% in the Engineering area)



ENOUGH PROJECT: European food chain supply to reduce GHG emissions by 2050

- The goal of the **ENOUGH EU H2020** project is to provide tools and methods that support the achievement of climate neutrality in the food sector

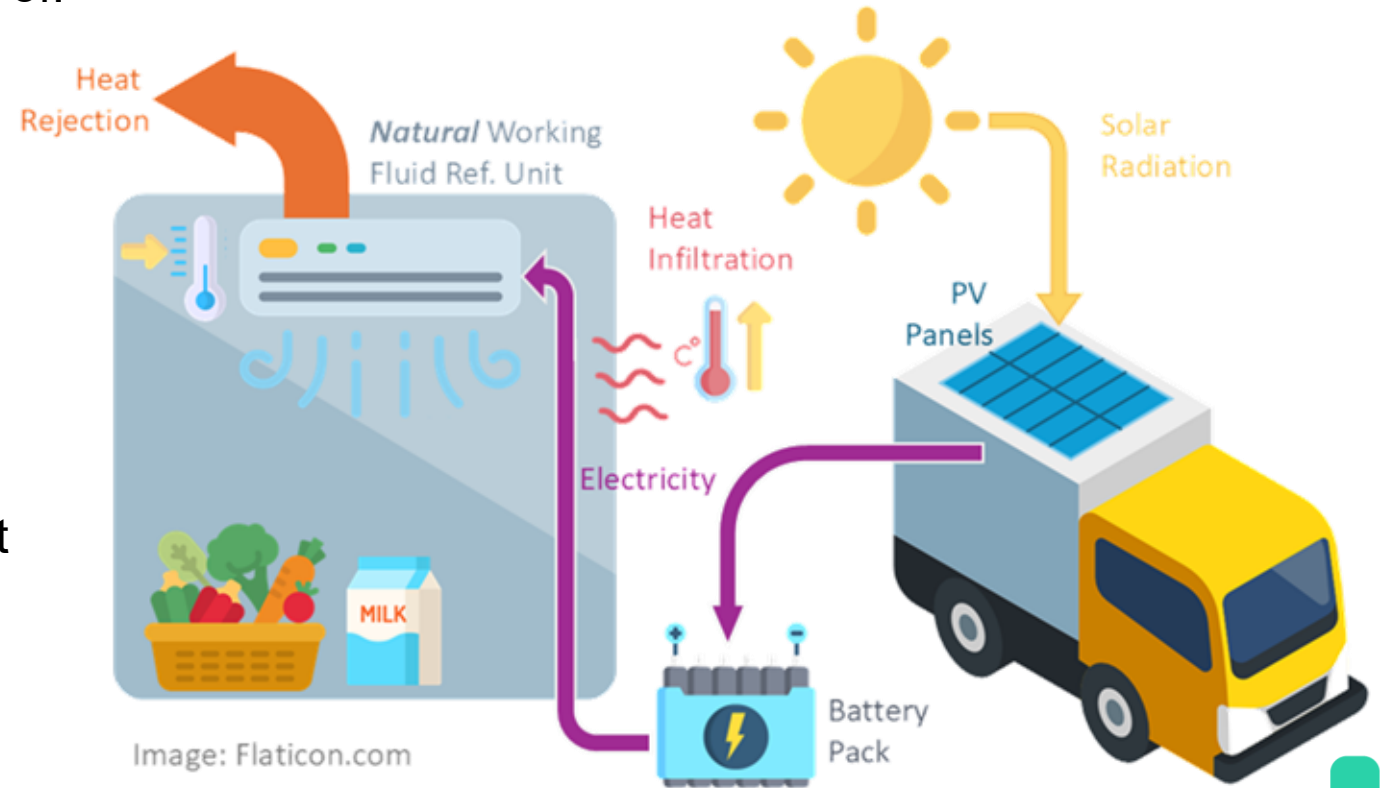
- 2021 – 2025** (4 year)
- 12 Countries**
- 30 Partners**
- 14 Private for-profit entities**
- Emissions evaluation- baseline
- Roadmaps
- Food chain assessment tool
- Demonstration campaign**
- Finance and Business models
- Smart Data Systems
- Policy Briefs, standards, regulations
- Communication, Dissemination, exploitation



Fresh and green delivery (DEMO 7)

- The **Demo 7** focuses on the design and test of:

- eLCV** for food transport;
 - CO₂** refrigeration unit;
 - Full electric;
 - Solar aided battery recharge.
- The unit was designed to operate at ambient temperatures up to **40°C**
- An **ejector** was included to improve performance at high ambient temperatures



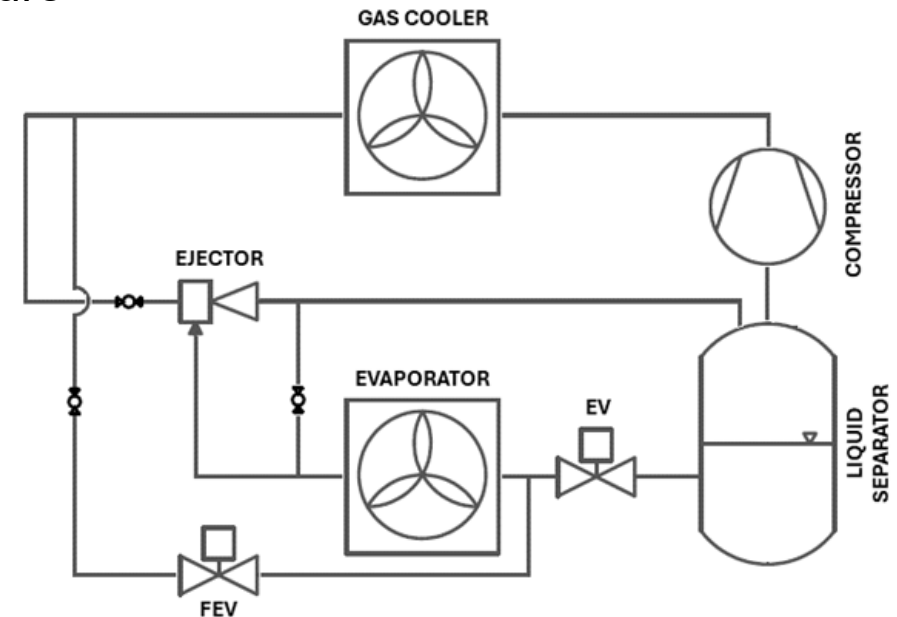
Design steps

- The **ejectors** were designed by Silesian University of Technology
- Refrigeration circuit was conceptually tested in a stationary mockup unit
- The final circuit was then integrated into the TRU prototype



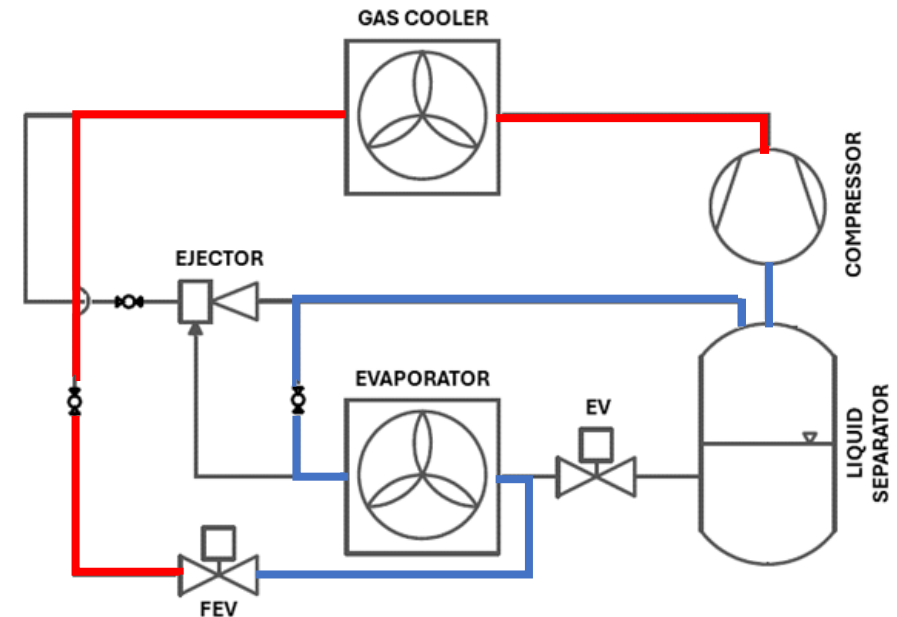
System Schematics

- The system is designed to operate in a **simple-cycle** configuration at low ambient temperature and switch to an ejector configuration at high ambient temperature
- As the ejector geometry is fixed, the **variable speed** compressor the variable-speed compressor is controlled by a dedicated controller to maintain the design high pressure
- Both the high-pressure valve and the valve controlling the ejector lift are set at **fixed position**



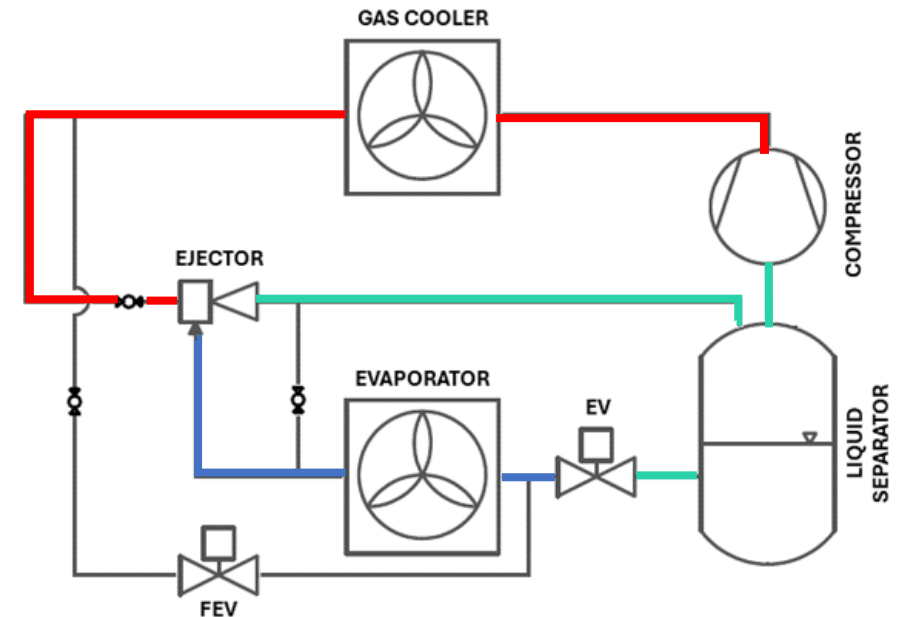
Simple Cycle set-up

- In the **simple cycle** set-up the high pressure is controlled by the compressor speed, against a fixed-orifice expansion valve.
- The liquid separator is in equilibrium with the evaporation pressure, and ensure a **flooded operation** of the evaporator



Simple Cycle set-up

- In the **ejector-cycle** set-up the system operates with three pressure levels.
- The high pressure is still controlled by the compressor speed against the motive characteristic
- The **fixed expansion valve (EV)** create a pressure drop between the evaporation pressure and the liquid separator pressure. The ejector then compresses the flow exiting the evaporator back to the separator pressure level.

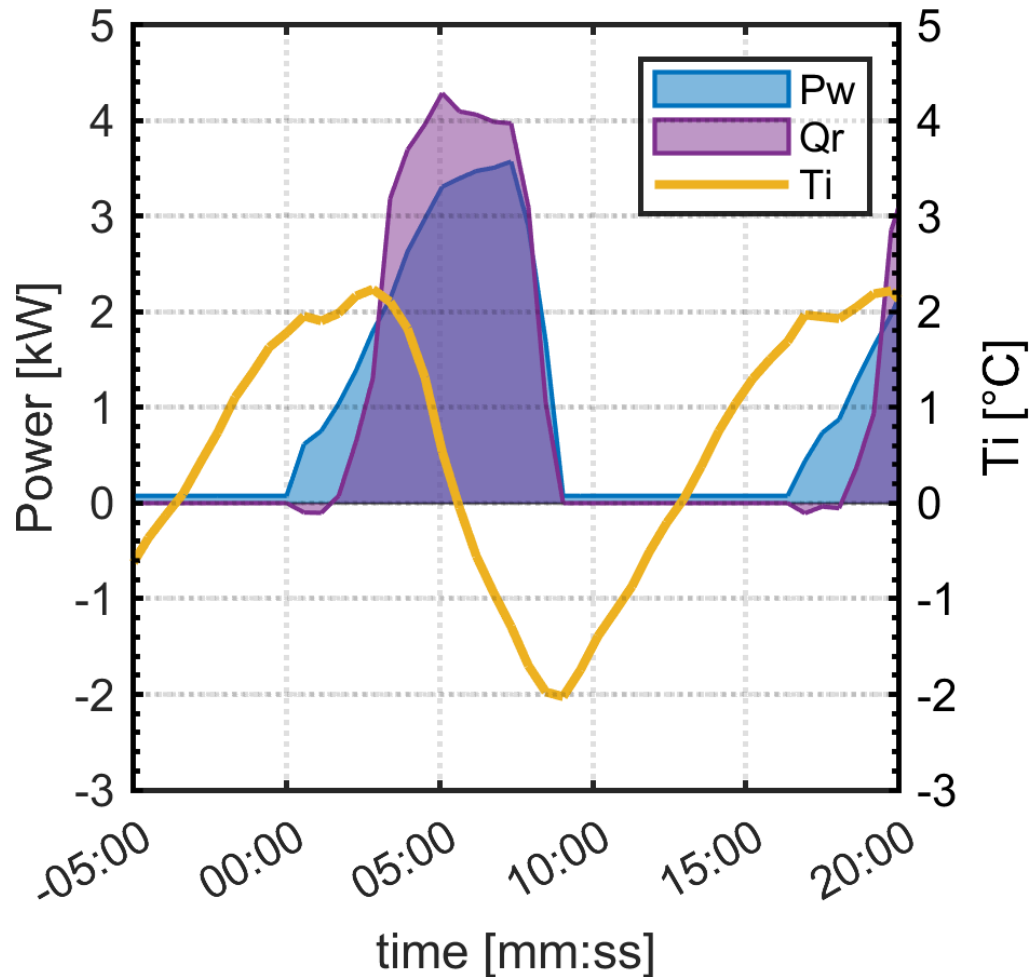


Experimental Test

- Test has been carried out at a **CNR facility in Padua** varying the external temperature while recording the unit performance during the standard **ON-OFF cycling**.
- Ambient temperature: **10, 20, 25, 30, 40°C**
- Internal temperature set point: **0°C (+2K hysteresis)**

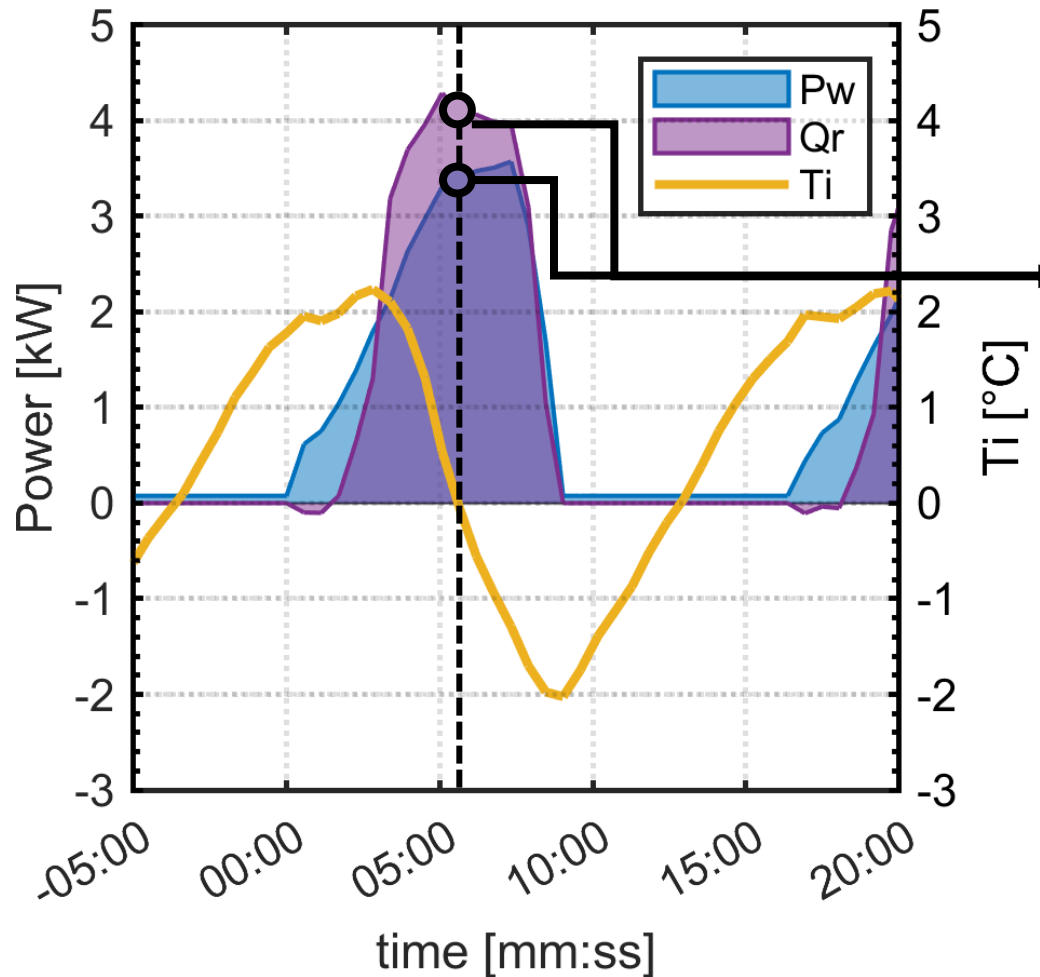


Performances: instantaneous and cycle-averaged



- For each ambient temperature, the insulated box was allowed to reach **steady-state conditions**, enabling the system to operate under **periodic cycling conditions**.
- Data were then **post-processed** to characterize the overall performance

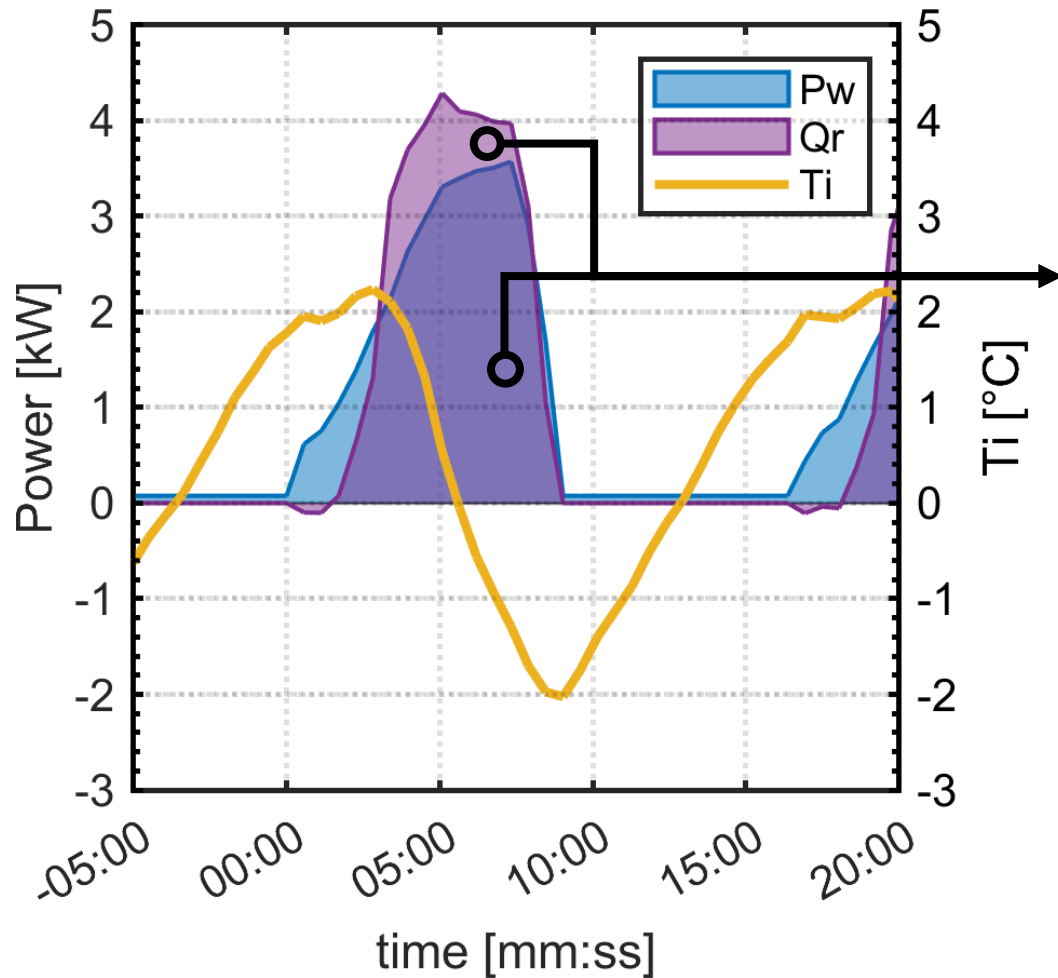
Performances: instantaneous and cycle-averaged



- **Instantaneous** Power consumption and cooling power at set-point temperature

Used to estimate the nominal ($T_i = 0^\circ\text{C}$) cooling power of the unit at different ambient temperatures

Performances: instantaneous and cycle-averaged

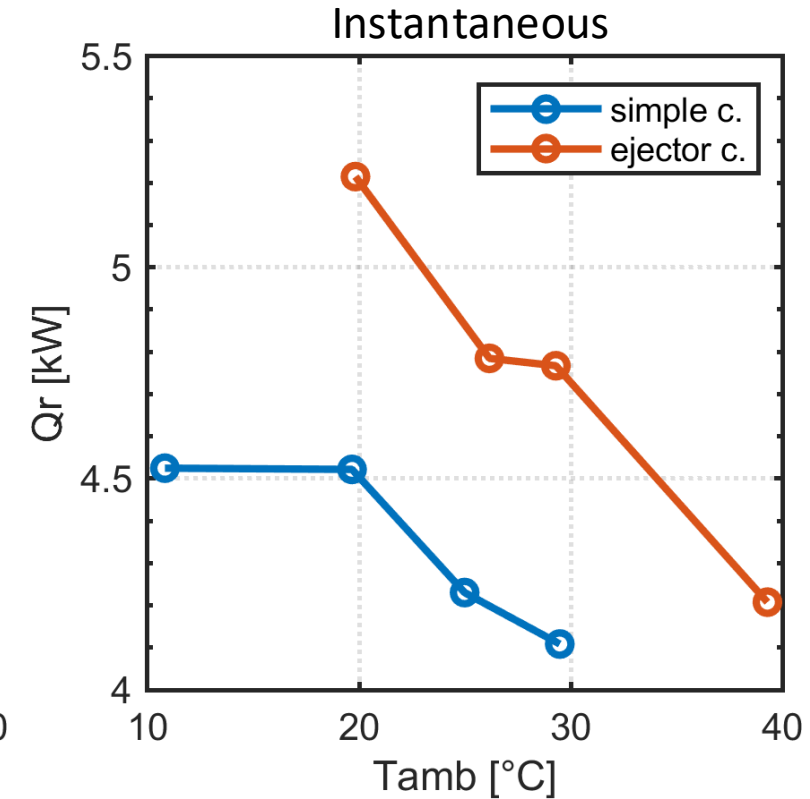
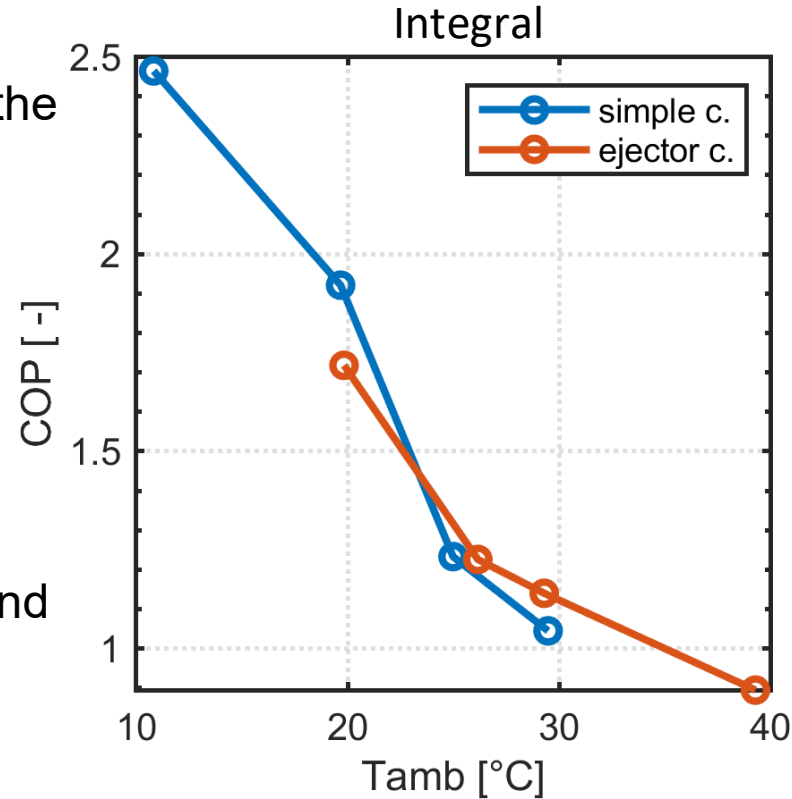


- **Integral** Power consumption and cooling power at set-point temperature

Used to estimate the system Coefficient of Performance according to the actual use of the TRU

Results

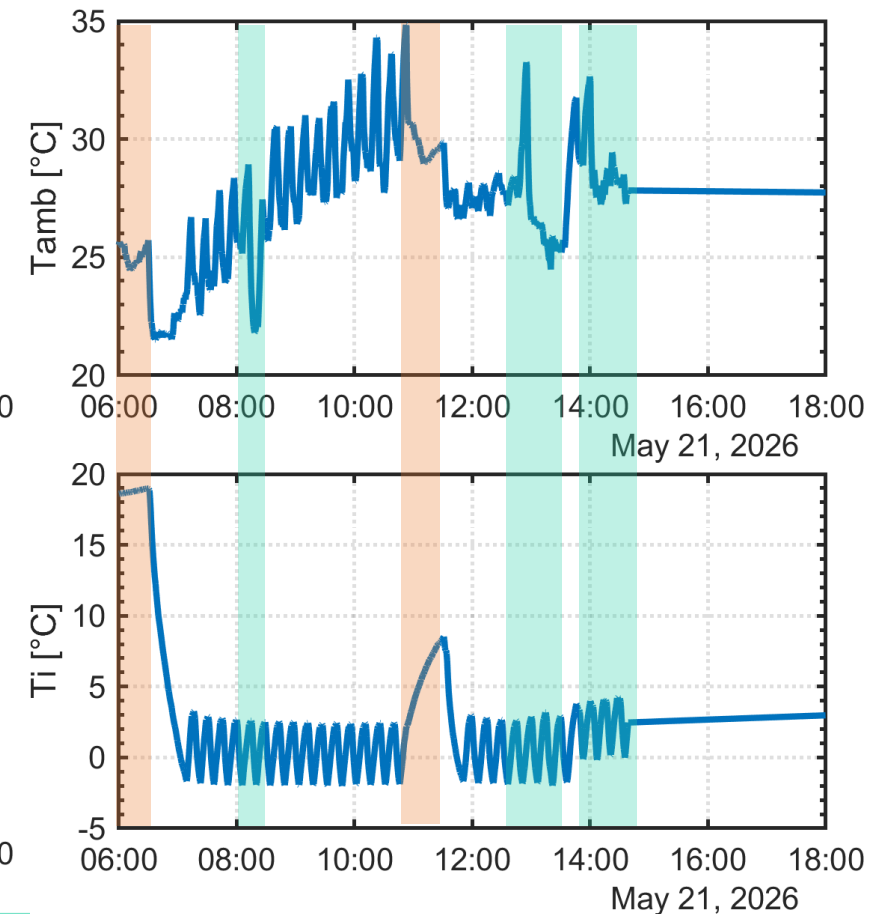
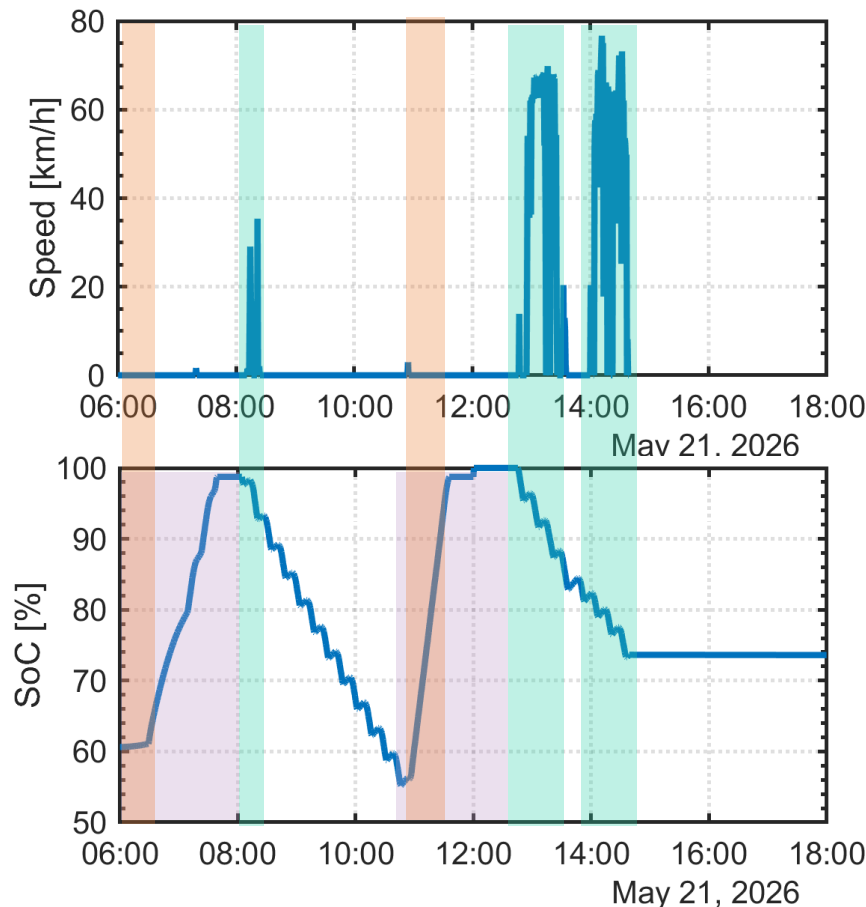
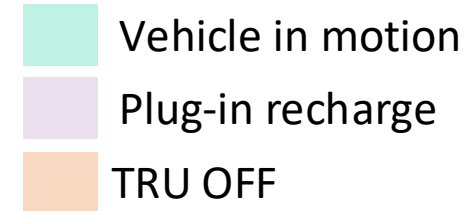
- **COP** values are reported based on the **total power** drawn from the battery pack, thus including
 - Fans
 - Inverter
 - Electronic & valves
- **Ejector** helps sustaining the COP and cooling power for $T_{amb} > 25^{\circ}\text{C}$



- The demonstrator proved that the system can operate at **ambient temperatures** up to **40°C**

Field Test example

- **Field tests** will be carried out to collect data in a **relevant environment**
- Following the field-testing campaign, the unit will be employed by a **supermarket as part of its fleet**
- **Autonomy**, **PV panel** energy contribution will then critically be discussed



Conclusion

- A **CO₂ Refrigeration Unit R744** capable of switching between a base cycle and an ejector cycle (under high ambient-temperature) has been conceptualized, designed and tested
- Tests demonstrate the **capability** of the unit to operate **up to 40°C ambient temperature**
- The ejector implementation allows to **improve the COP** (9%) and the **cooling power** (16%) of the unit at ambient temperature of **30°C**
- The collected data suggest possible improvements of the first design:
 - **Fan and auxiliary power** consumption have a significant impact on the overall COP (>10%) that can be reduced
 - Heat transfer in the gas cooler (GC) can be improved by optimizing the **airflow pattern**
 - The high-pressure controller and the **interaction with the ejector** can be improved

#FGasFreeLIFE

- **Project duration:**

- June 2026 – June 2029

- **Partners:**

- **PBX GmbH**, pbx cooling (Austria)
 - **CNR** - Consiglio Nazionale delle Ricerche
 - **Innovhub** - Stazioni Sperimentali per l'Industria (Italy)
 - **CLM** - Cluster Lombardo della Mobilità (Italy)

- **Objective:**

- Demonstrate light weight TRU R290 units for LCV across Europe
 - ***Technical Highlight:***
 - Charge reduction (< 250g)
 - Highly versatile (LT, MT and HP)

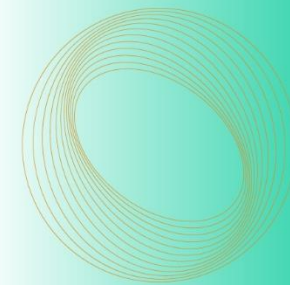


Co-funded by
the European Union





The Business Case Natural Refrigerants



Thank you
for listening
Any questions?



ATMO.org



ENOUGH
EUROPEAN FOOD CHAIN SUPPLY
TO REDUCE GHG EMISSIONS BY 2050

ENOUGH has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101036588.