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Climate-resilient ventilative cooling. Experimental performance of a renewable hybrid air-cooling technology under heatwave conditions

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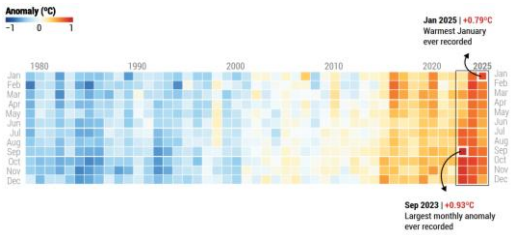
Agenda

- Introduction
- Methodology
- Results
- Conclusions

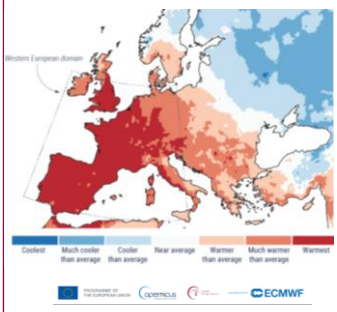
Driving forces: facts of climate scenario

Climate Change
Monthly global surface air temperature anomalies



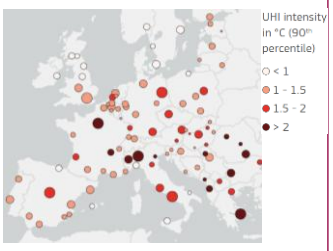
ERA5. ERA5. Credit: C3S/ECMWF, 2025

Heat waves
Frequency and intensity



ERA5. Credit: Copernicus Climate Change /ECMWF, 2025

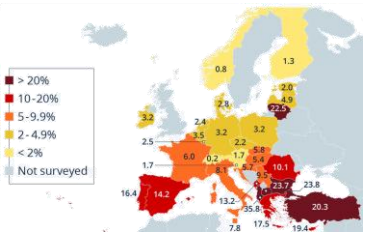
Urban heat island intensity
Cities with a medium-high UHI intensity



EU cities and heat extremes, 2024

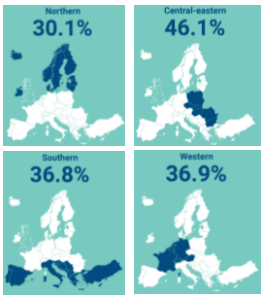
Impact assessment: where conventional cooling fails

Energy Poverty
Share of households unable to adequately heat their homes in 2021



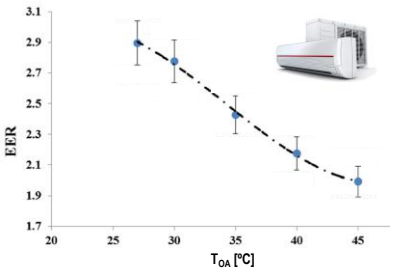
N. Della Valle, C. Maduta, D. D'Agostino, G. Koukoufikis, Unpacking energy vulnerability in the European Union: Linking thermal discomfort with adaptive capacity, Energy Research & Social Science, (129) 2025. https://doi.org/10.1016/j.erss.2025.104376

Cooling Difficulty
Percentage of households unable to keep their homes adequately cool



Overheated and underprepared: Europeans' experiences of living with climate change European Environment Agency, 2026

Reduced energy efficiency
Variation of EER with ambient temperature

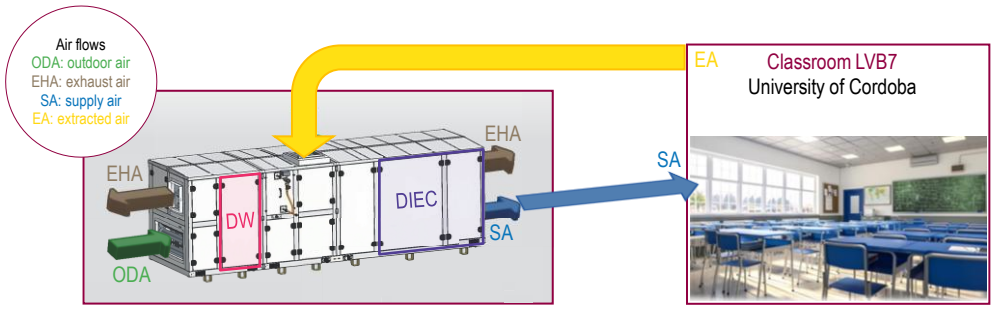


Deymi-Dashtebayaz, M., Farahnak, M., Moraffa, M. et al. Experimental evaluation of refrigerant mass charge and ambient air temperature effects on performance of air-conditioning systems. Heat Mass Transfer 54, 803–812 (2018). https://doi.org/10.1007/s00231-017-2173-6

Objectives. Climate-resilient ventilative cooling systems

Renewable hybrid air-cooling technology		
Energy Performance Technical Validation	**Sustainable IAQ** Environmental Integrity	**Heatwave Resilience** Climate Adaptation
To assess the thermal and electrical **energy performance** of the system compared to conventional AC degradation.	To evaluate **cooling to water ratio and air to water ratio** using 100% outdoor air with independent T/RH control.	To prove **system resilience** under extreme heatwave scenarios (>40°C).

Renewable hybrid air-cooling technology

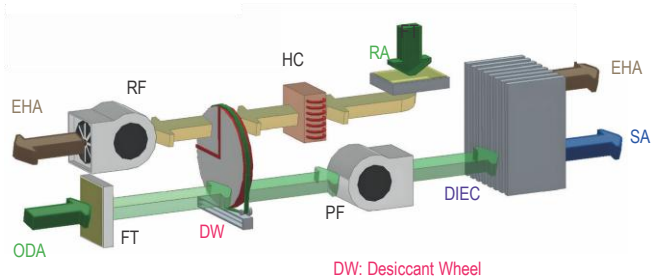


- ✓ DW: desiccant wheel
- ✓ DIEC: dew-point indirect evaporative cooler

- ✓ Cooling without refrigerants
- ✓ Ventilation 100% outdoor air
- ✓ Independent control: T, HR, CO_2

Renewable hybrid air-cooling technology

General layout
Main components



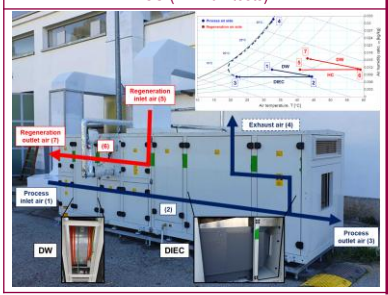
DW: Desiccant Wheel
DIEC: Dew-point Indirect Evaporative Cooler
FT: air filters
PF: process fan
RF: regeneration fan
HC: heating coil

Characteristics
Advantages

- Low environmental impact
- Low carbon footprint
- No refrigerants
- Very high energy efficiency
- Use renewable energy sources
- 100% outdoor air
- Independent control of T, RH and CO_2

From lab to real-world: testing roadmap

Stage I. Lab Tests
DIEC (N1-N27 tests)
RACU (N1-N64 tests)



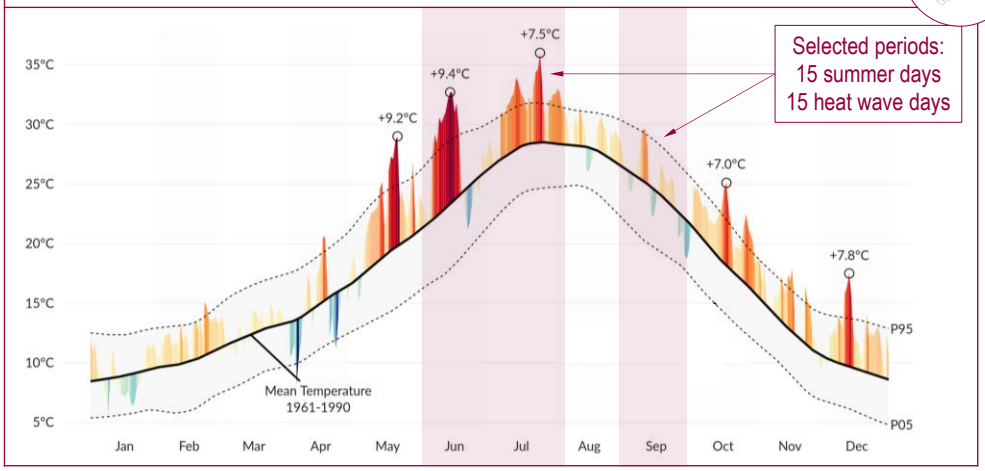
Stage II. Real condition tests
System performance
Cordoba outdoor heat wave and super heat wave

Stage III. Real conditions tests
System and building assessment
Classroom B7, Da Vinci Building

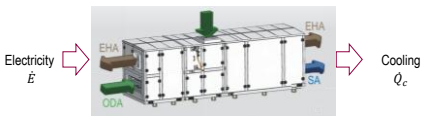
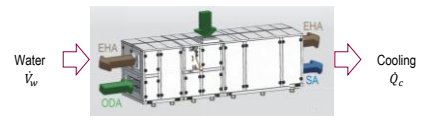
Outdoor summer and heat wave conditions

Mean outdoor temperatures in Cordoba, Spain, 2022

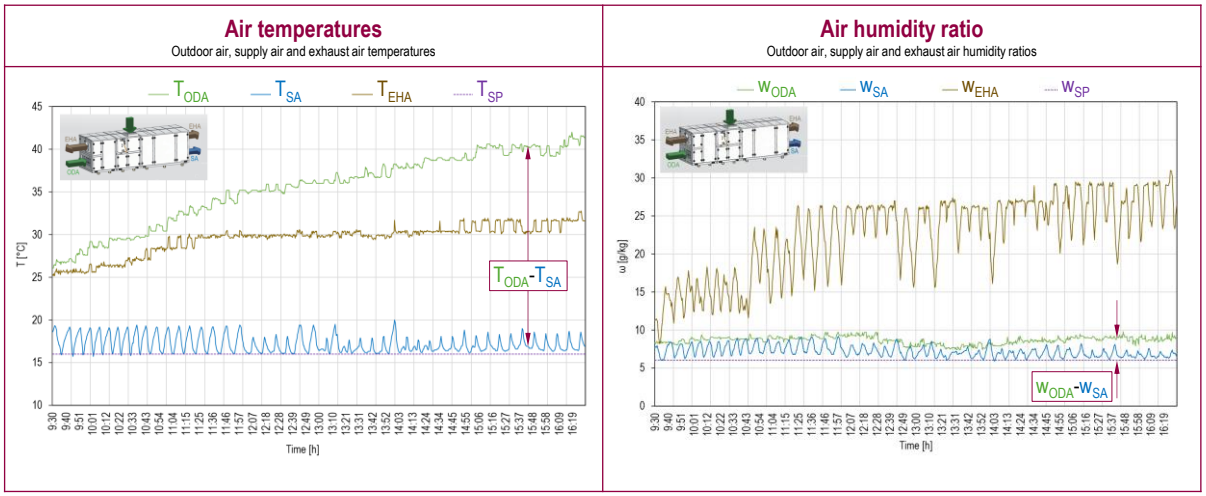
Compared to historical daily mean temperatures (1961-1990)



Experimental methodology. Daily energy/water performance

Energy Efficiency in Refrigeration Daily EER	Water consumption efficiency Daily cooling to water efficiency (CWE_d) and daily air to water efficiency (AWE_d)
$$EER_d = \frac{\int_{t_1}^{t_2} \dot{Q}_c \cdot dt}{\int_{t_1}^{t_2} \dot{E} \cdot dt} \; [kWh_t/kWh_e]$$	$$CWE_d = \frac{\int_{t_1}^{t_2} \dot{Q}_c \cdot dt}{\int_{t_1}^{t_2} \dot{V}_w \cdot dt} \; [kWh_t/m_w^3] \quad AWE_d = \frac{\int_{t_1}^{t_2} \dot{V}_{SA} \cdot dt}{\int_{t_1}^{t_2} \dot{V}_w \cdot dt} \; [m_{sa}^3/l_w]$$
$$EER_d = \frac{daily\ energy\ cooling\ and\ ventilation}{daily\ energy\ consumption}$$	$$CWE_d = \frac{daily\ energy\ cooling\ and\ ventilation}{daily\ water\ consumption} \quad AWE_d = \frac{daily\ supply\ air\ for\ cooling\ and\ ventilation}{daily\ water\ consumption}$$
	

Experimental results. Daily operation 13th July 2022



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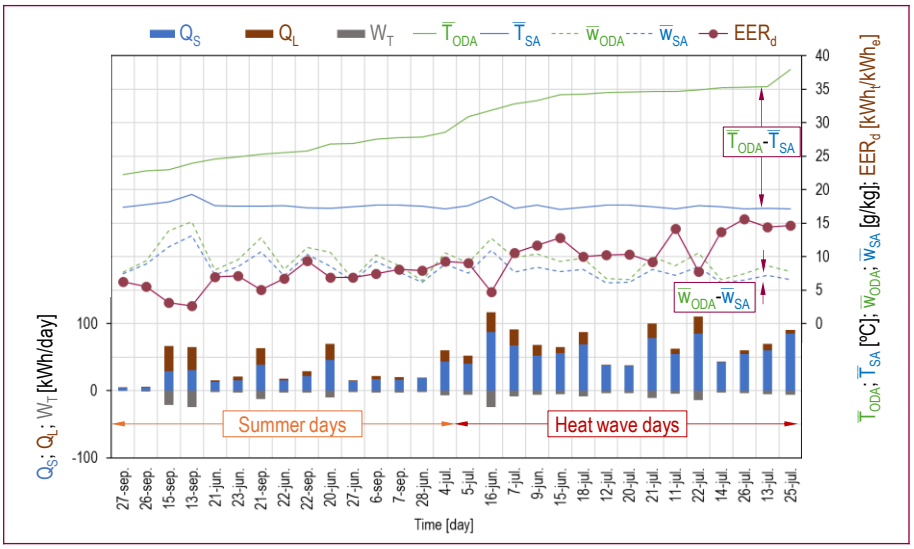
Experimental results. Daily energy performance



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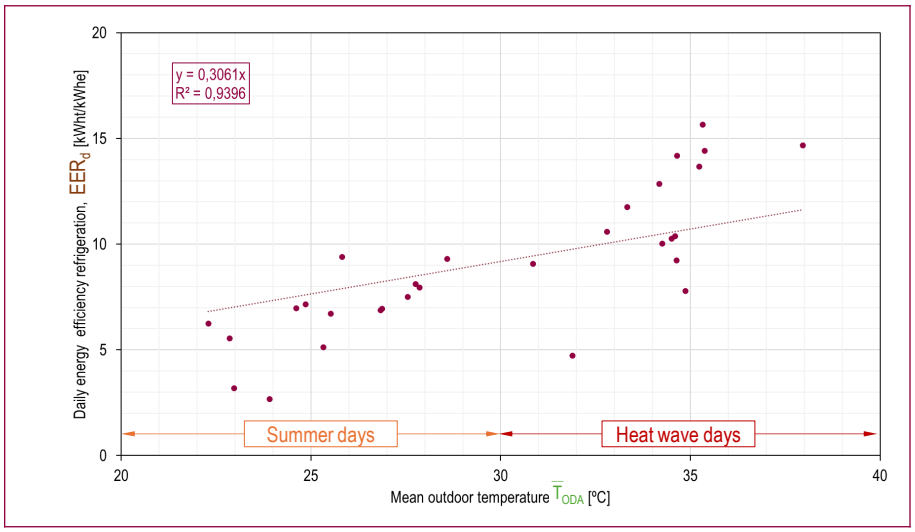
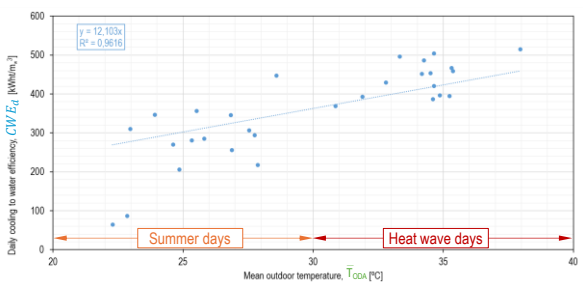
Experimental results. Daily energy performance



Experimental results. Daily water efficiency

Daily cooling to water efficiency

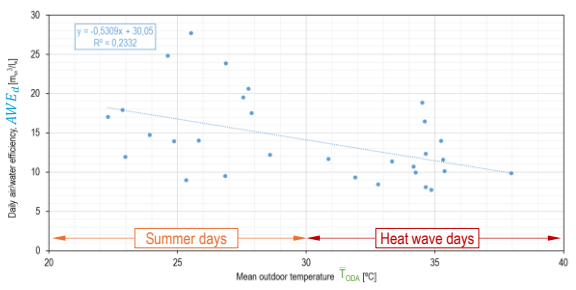
Cooling to water efficiency, CWE_d



$$CWE_d = \frac{daily\ energy\ cooling\ and\ ventilation}{daily\ water\ consumption}$$

Daily air to water efficiency

Air to water efficiency AWE_d



$$AWE_d = \frac{daily\ supply\ air\ for\ cooling\ and\ ventilation}{daily\ water\ consumption}$$

Conclusions

- The system maintained stable supply-air conditions under >40 °C outdoor air.
- Its energy performance improved under heatwave stress, unlike conventional DX cooling.
- It delivered cooling with 100% outdoor air, no refrigerants, and moderate water use.
- Hybrid desiccant–evaporative cooling is a strong candidate for climate-resilient ventilative cooling in Southern Europe.

Conclusions

Heatwaves are the stress test of future ventilation and cooling systems.
In this study, the hybrid desiccant–evaporative concept proved that the most severe conditions can also be the conditions of best performance

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Thanks for your attention!

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