WORKSHOP

NEW GENERATION SOLAR COOLING & HEATING SYSTEMS (PV OR SOLAR THERMALLY DRIVEN SYSTEMS) / IEA SHC TASK 53

COMPACT SMALL SOLAR DESICCANT COOLING SYSTEM

freescoo

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A NEW CONCEPT FOR AIR CONDITIONING

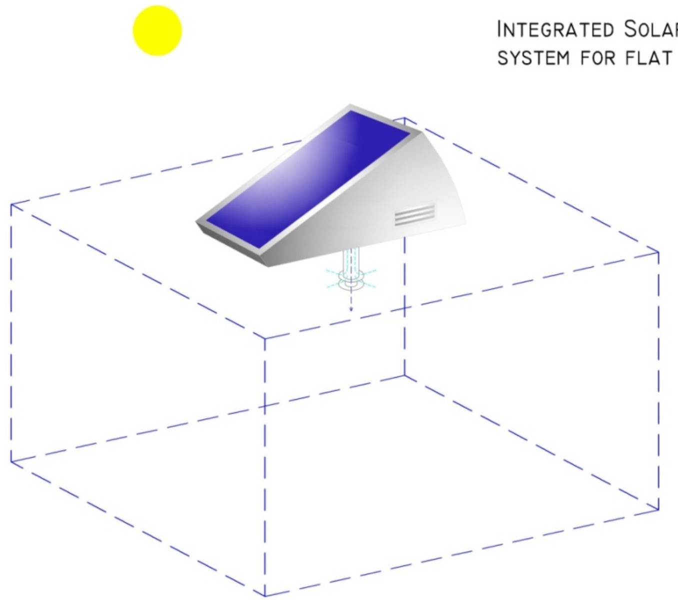
freescoo

- Freescoo (from **FREE S**olar **COO**ling) is an innovative solar DEC air conditioning system designed for ventilation, dehumidification and cooling in small scale applications
- It is a project lead by the startup company SOLARINVENT SRL
- In the framework of a Research Project funded by the Italian Ministry of Economic Development, two freescoo prototypes were installed and tested at the University of Palermo and at the Research Center ENEA Casaccia
- The cooling process is an open cycle based on fixed and cooled adsorption beds and efficient indirect evaporative cooling concepts

A NEW CONCEPT FOR AIR CONDITIONING

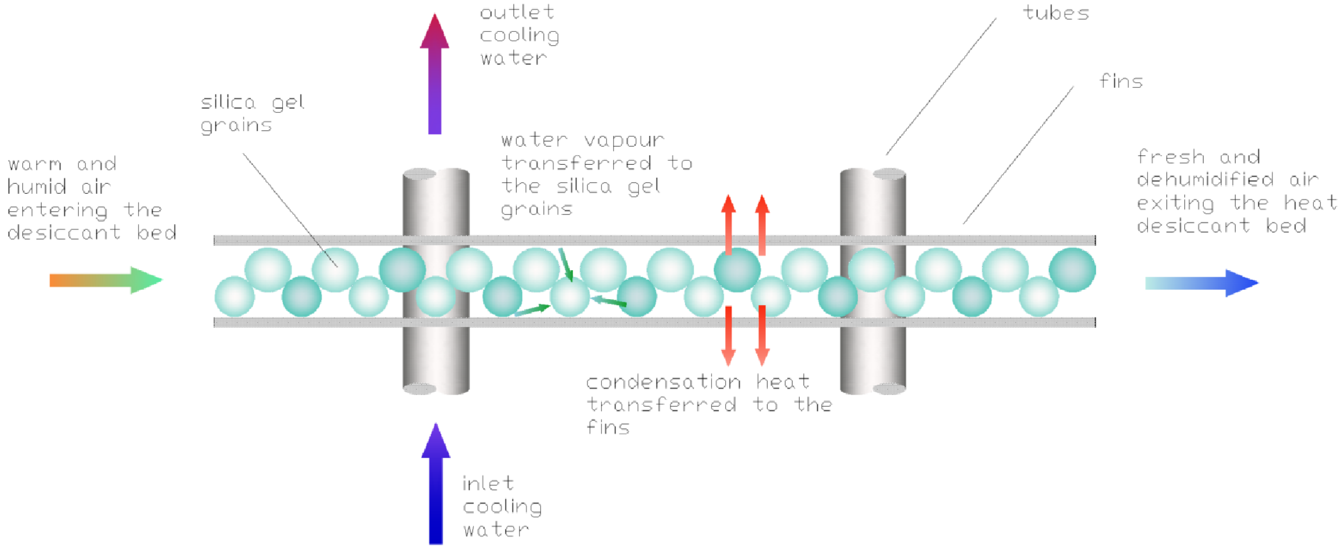
MAIN SYSTEM FEATURES

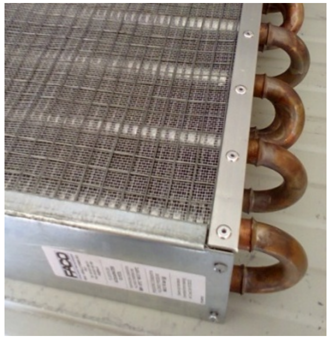
- Use of solar PVT air collector (in alternative, common solar flat plate collectors can be applied with small changes)
- Low parasitic energy consumption
- Connection to the water supply required
- Solar autonomous, no use of auxiliary energy source for cold production
- Compact, all in one and easy to install



DEHUMIDIFICATION BY PCB ADSORPTION BED

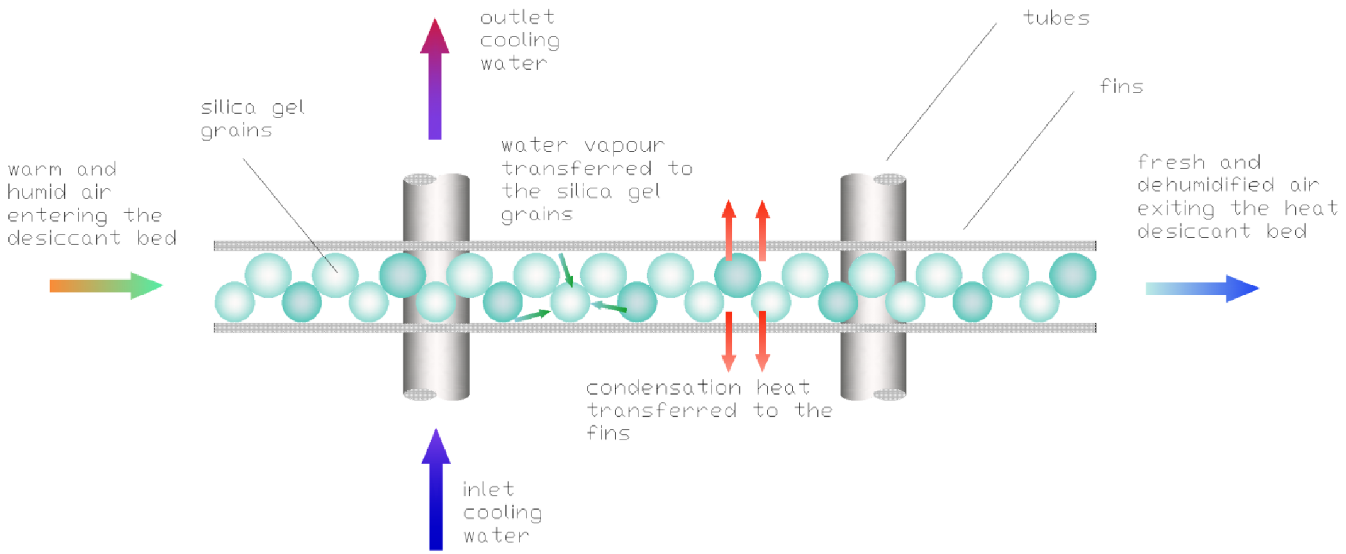
- The packed and cooled adsorption bed (**PCB)** is a fin and tube heat exchanger commonly used in the air conditioning sector, wherein the spaces between the fins are filled with silica gel grains
- The developed component allows a simultaneous **mass transfer** between the moist air and the adsorbent media and **heat exchange** between the air and the water flowing into the heat exchanger tubes;
- The cooling of the desiccant material during the adsorption process allows high dehumidification performances of the desiccant bed;

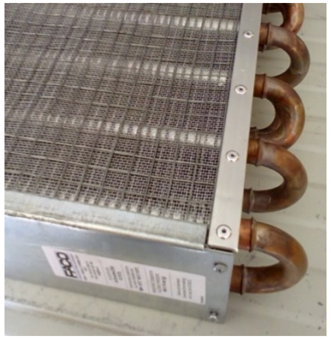




PACKED AND COOLED ADSORPTION BED

- Water temperatures required can be easily achieved with a cooling tower;
- High amount of silica gel can be used;
- Adsorption and desorption processes happen in different times;
- Solar energy can be efficiently stored in the desiccant in terms of adsorption capacity which can be used when regeneration heat is not more available, strongly reducing the necessity for thermal storage;





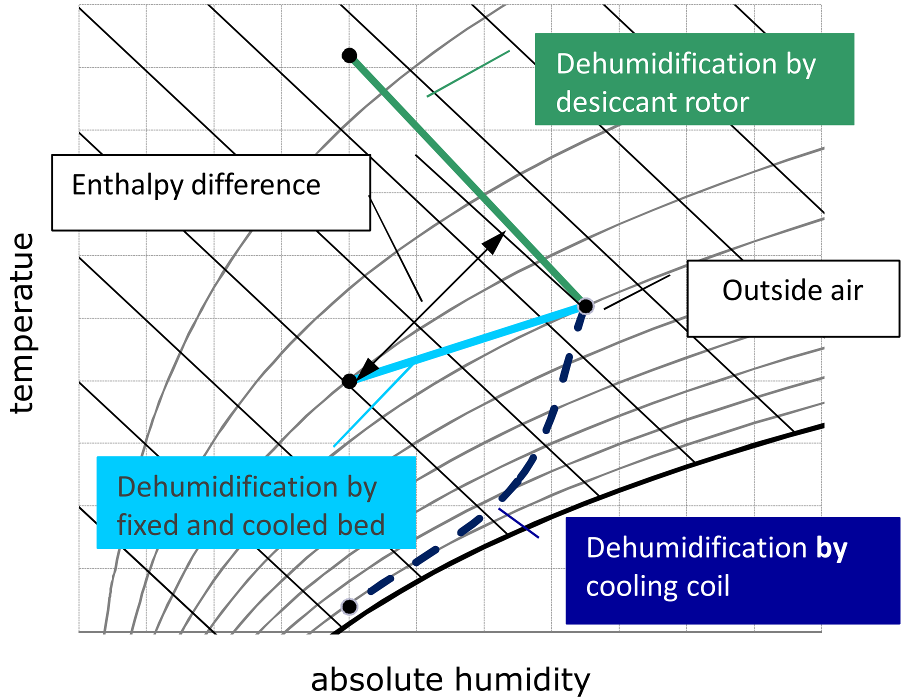
COMPARISON OF THE ADSORPTION PROCESSES

Dehumidification by desiccant rotor

- Adsorption process realized by means of desiccant rotors is a quasi – isoenthalpic transformation
- It presents the disadvantage of causing a temperature increase of the desiccant material
- No enthalpy difference between in and out

Dehumidification by fixed and cooled desiccant bed

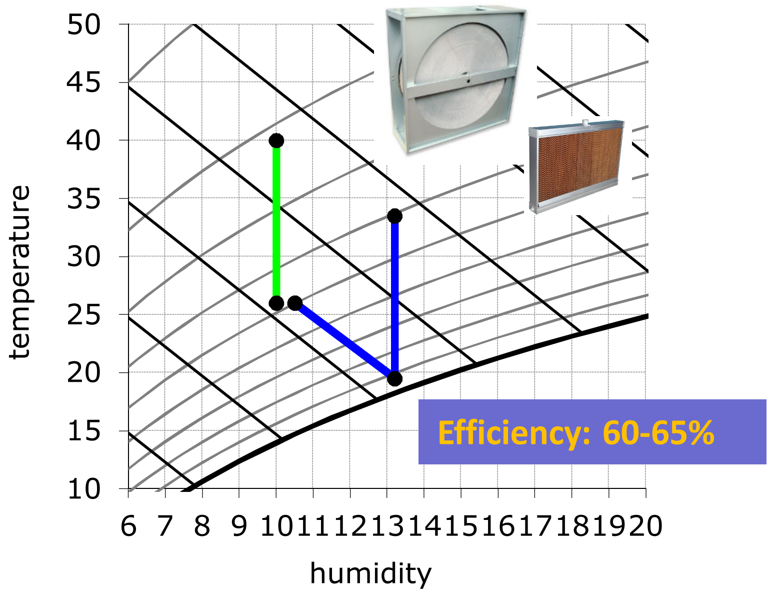
- Adsorption heat can be rejected
- The thermodynamic process causes an enthalpy difference between inlet and outlet air conditions
- In general, the temperature of air exiting the adsorption bed can be lower than the one of incoming air
- Downstream indirect evaporative cooling process can be operated at lower temperature

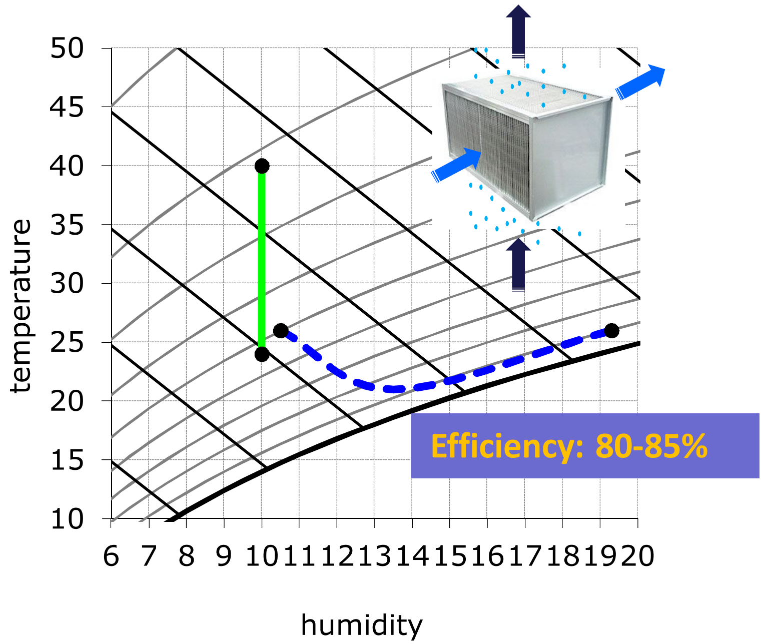


INDIRECT EVAPORATIVE COOLING: COMPARISON OF THE SOLUTIONS

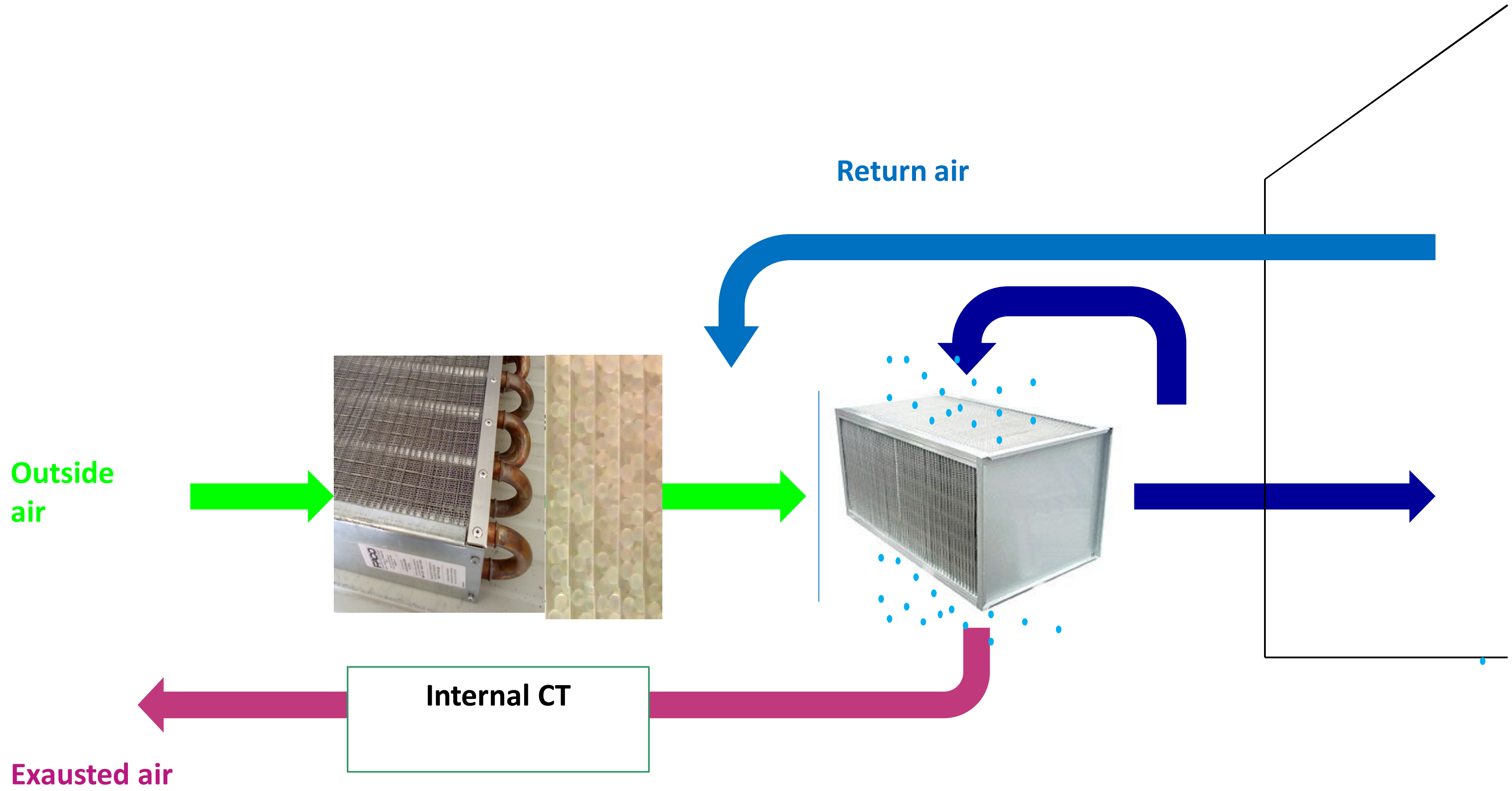
- Saturation inside the heat exchanger not possible
- Secondary air flow passing through the channels rapidly increases its temperature

- Saturation inside the heat exchanger possible
- the temperature of the secondary air is close to the local wet-bulb temperature of the air stream which increases gradually during the humidifying process

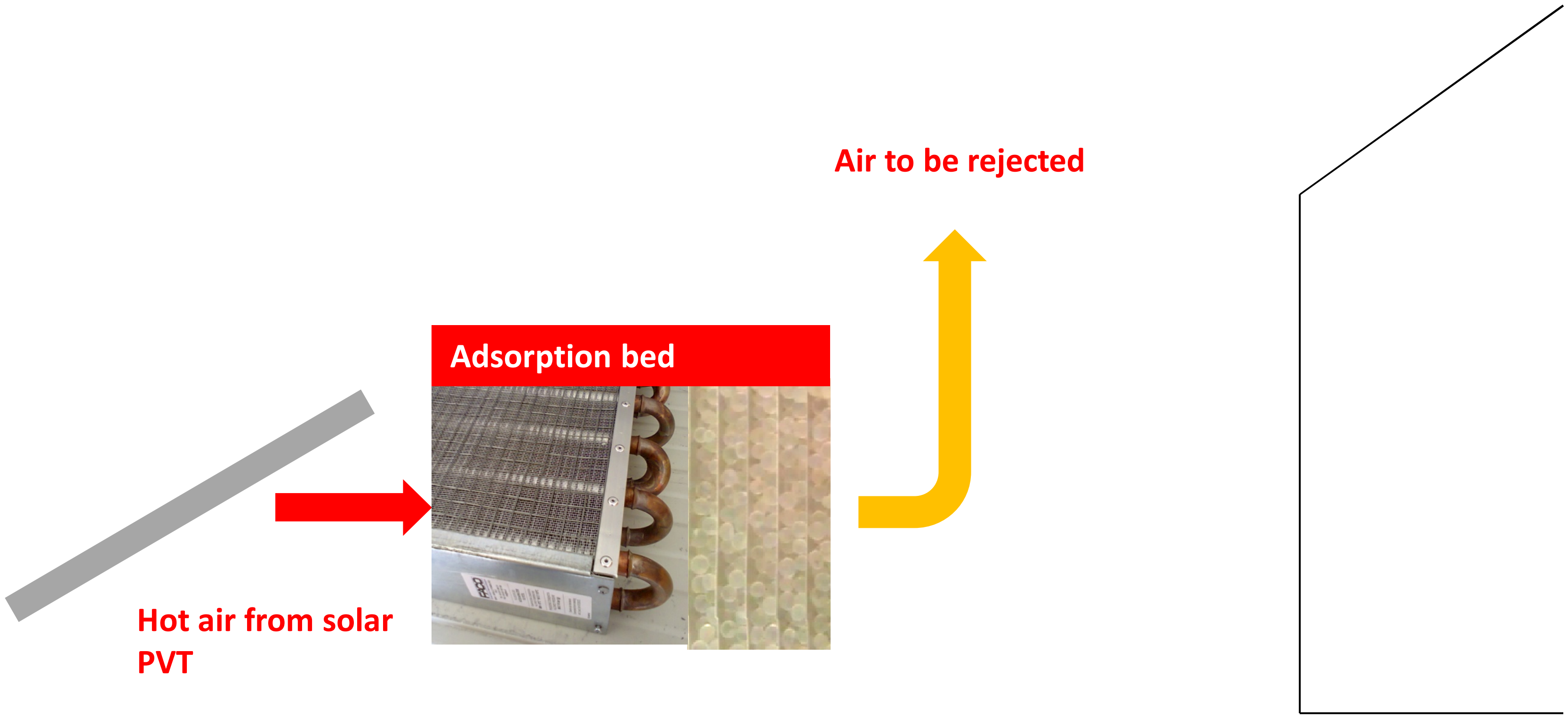




CONCEPT OF THE NEW DEC CYCLE: ADS + COOLING

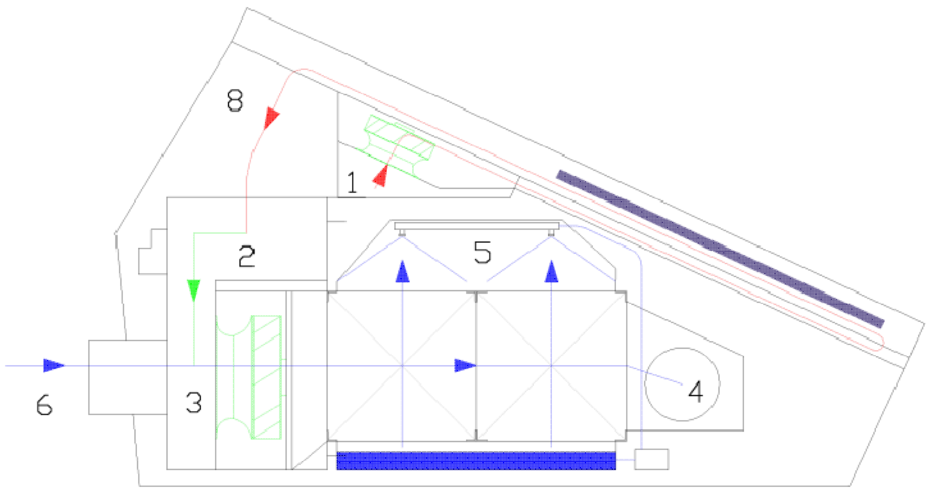


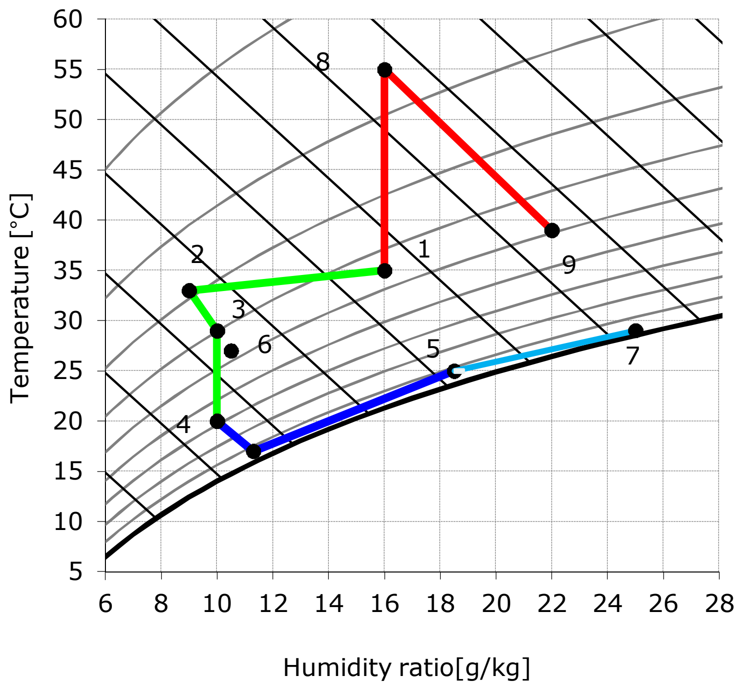
CONCEPT OF THE NEW DEC CYCLE: DESORPTION



DESCRIPTION OF THE NEW DEC CONCEPT

- The two fixed packed desiccant beds are operated in a batch mode and cooled by cooling tower
- A wet heat exchanger which applies the indirect evaporative cooling effect
- A portion of the primary air flow rate exiting the wet heat exchanger is drown into the secondary side





International PCT pending

FREESCOO AT UNIVERSITY OF PALERMO (ITALY)

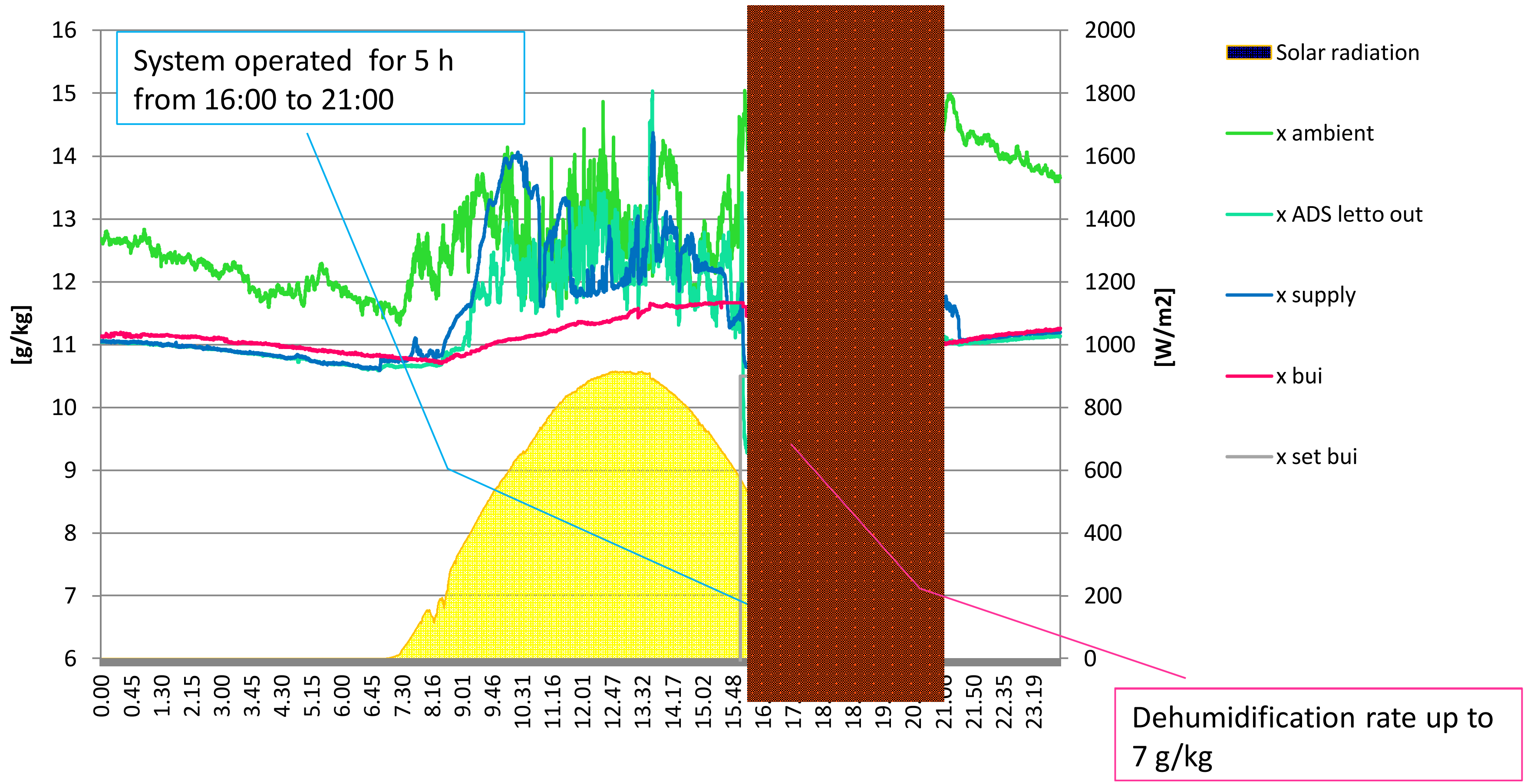
- Solar air collector area: 2,4 m^2
- Two desiccant beds
- Nominal flow rate: 500 m^3/h
- Max power absorbed: 150W
- Max cooling power: 2,7 kW (at $T_{outside}$ = 35°C, $RH_{outside}$ = 50%, T_{bui} = 27°C, RH_{bui} = 50%)
- Total weight ≈ 230 kg
- Volume of conditioned space = 190 m^3
- Occupation pattern = small office
- Auxiliary device installed: Split system

Freescoo at UNIPA in Palermo

INSTANTANEOUS ENERGY PERFORMANCES

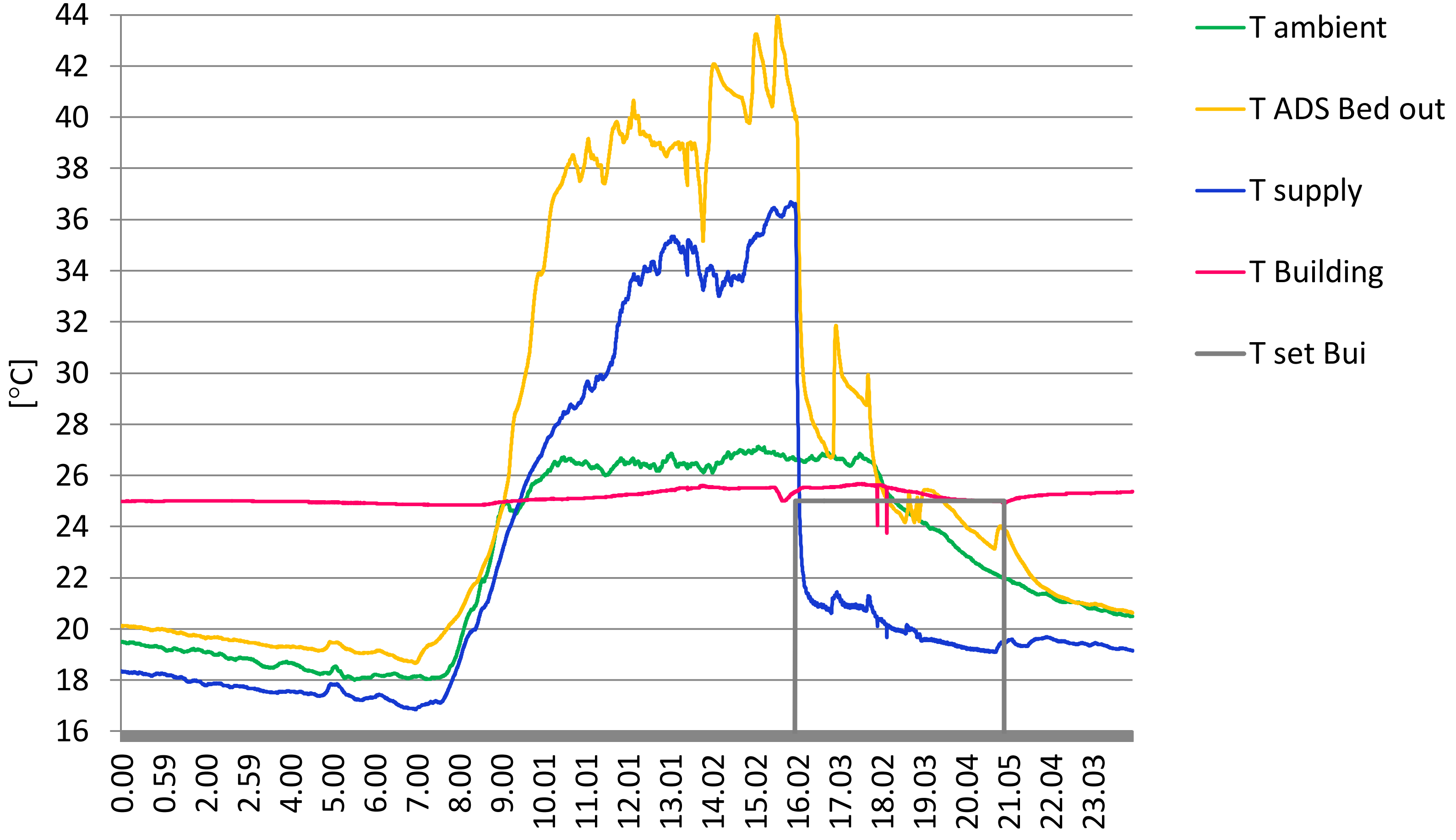
Results of freescoo prototype installed at UNIPA of Palermo

Dehumidification



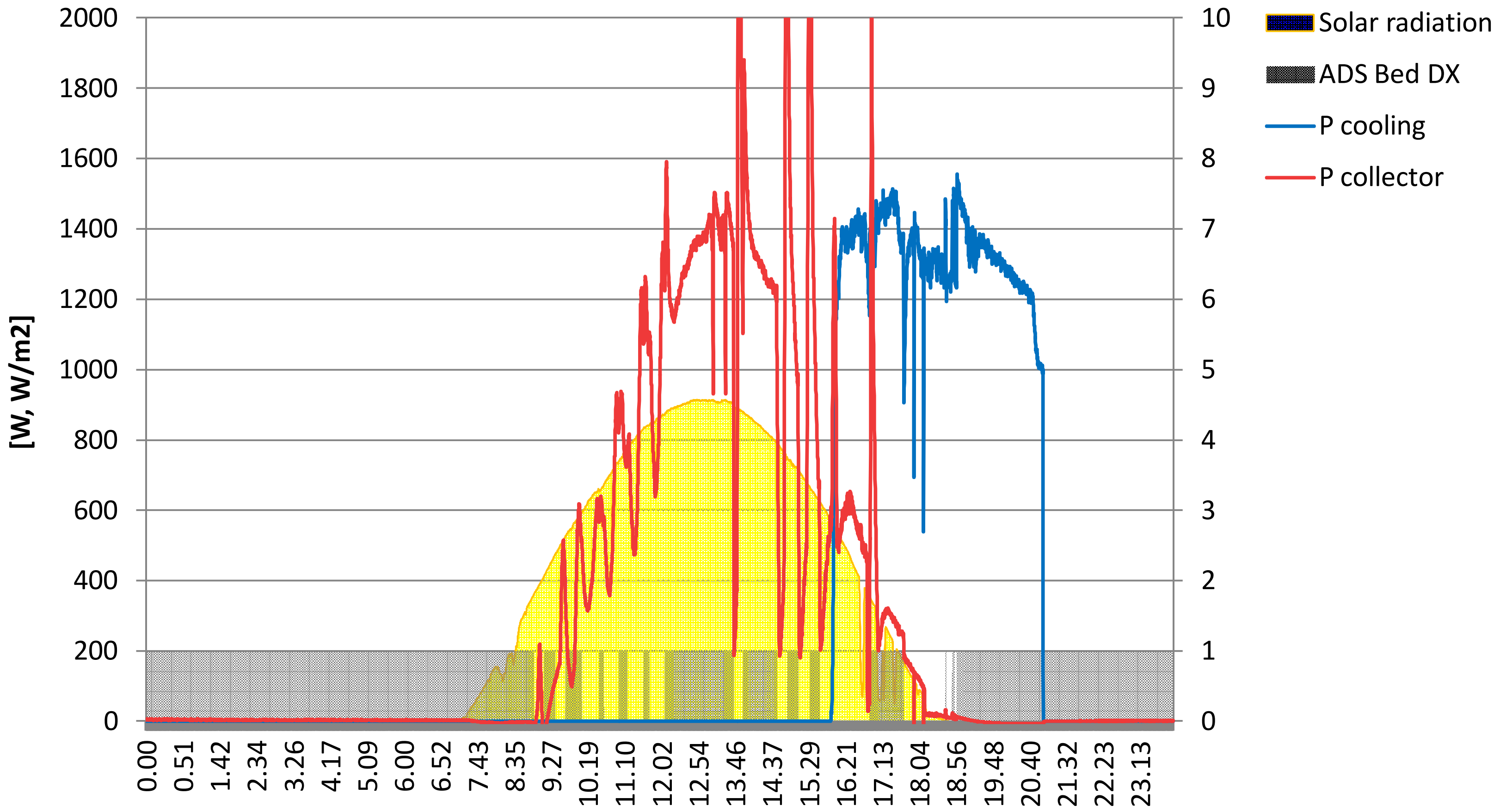
INSTANTANEOUS ENERGY PERFORMANCES

Temperature profiles in the machine



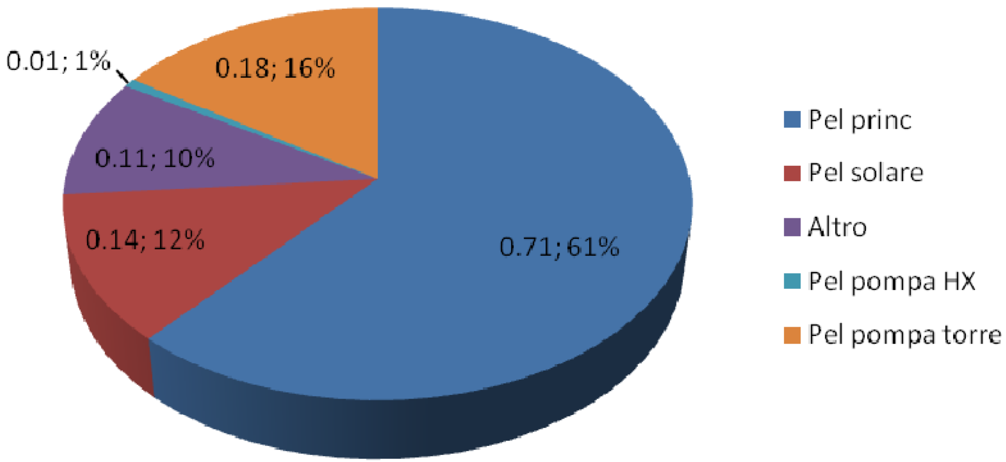
INSTANTANEOUS ENERGY PERFORMANCES

Cooling after the sunset



DAILY ENERGY PERFORMANCES

Electricity distribution among the components



- Daily EER = **14,2** **NOT** taking into account the PV production
- Daily EER_{grid} = **70** taking into account only the electricity taken from the grid (0,2 on 1,0 kWh)
- 20% of electricity taken from the grid
- 80% of electricity produced by PV
- Daily thermal COP_{th}= **1,2**
- Eff_{coll}= 57%

FREESCOO AT ENEA RESEARCH CENTER IN ROME

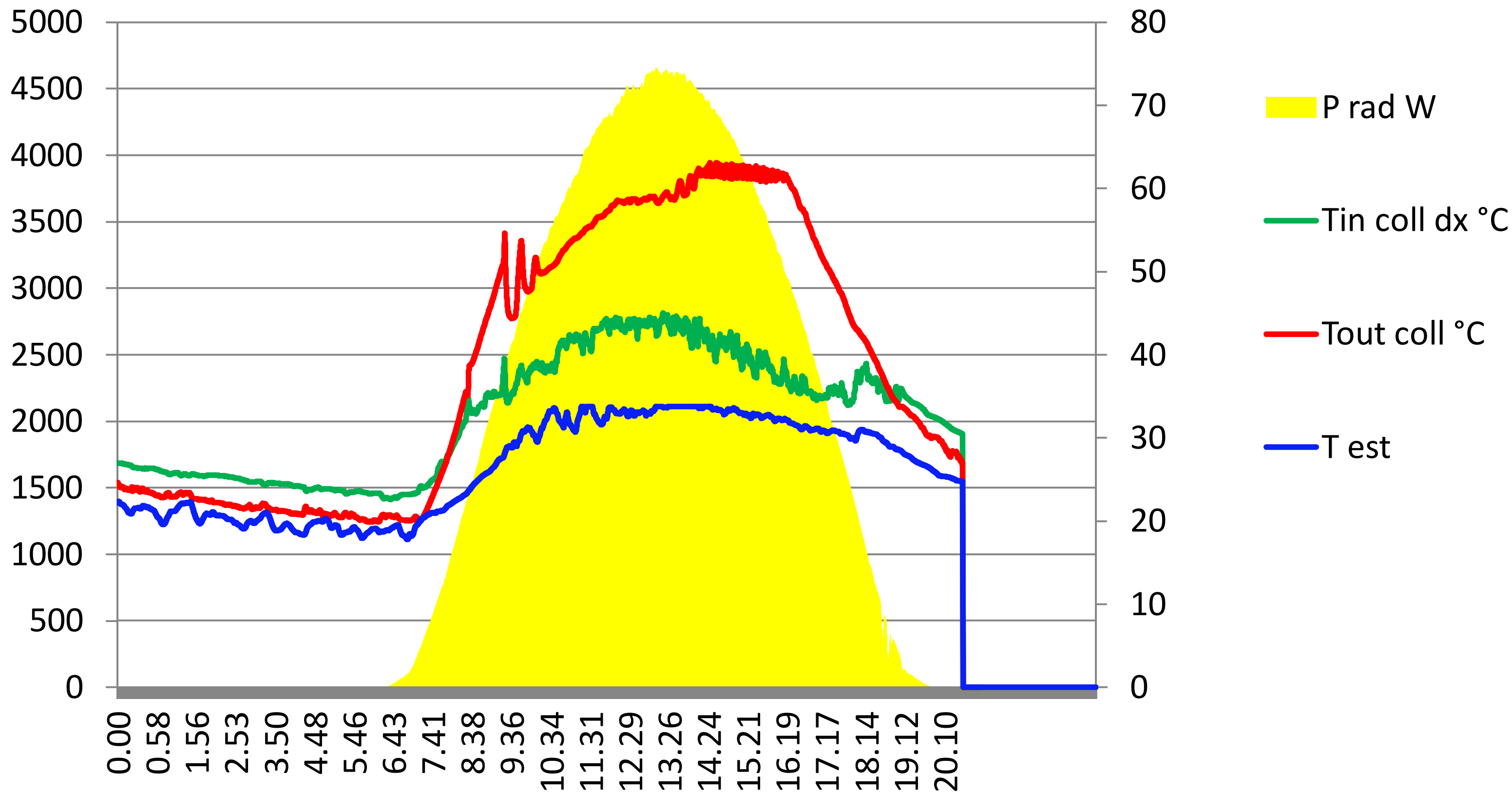
- Solar air collector area: 4.8 m^2
- Two desiccant beds
- Nominal flow rate: 1000 m^3/h
- Max power absorbed: 250W
- Max cooling power: 5,5 kW (at $T_{outside}$ = 35°C, $RH_{outside}$ = 50%, T_{bui} = 27°C, RH_{bui} = 50%)
- Total weight ≈ 400 kg
- Volume of conditioned space = 125 m^3
- Occupation pattern = seminar room
- Auxiliary device installed: 5 x 2,5 kW fan coil

Freescoo at ENEA in Rome

INSTANTANEOUS ENERGY PERFORMANCES

Results of freescoo prototype installed at ENEA in Rome

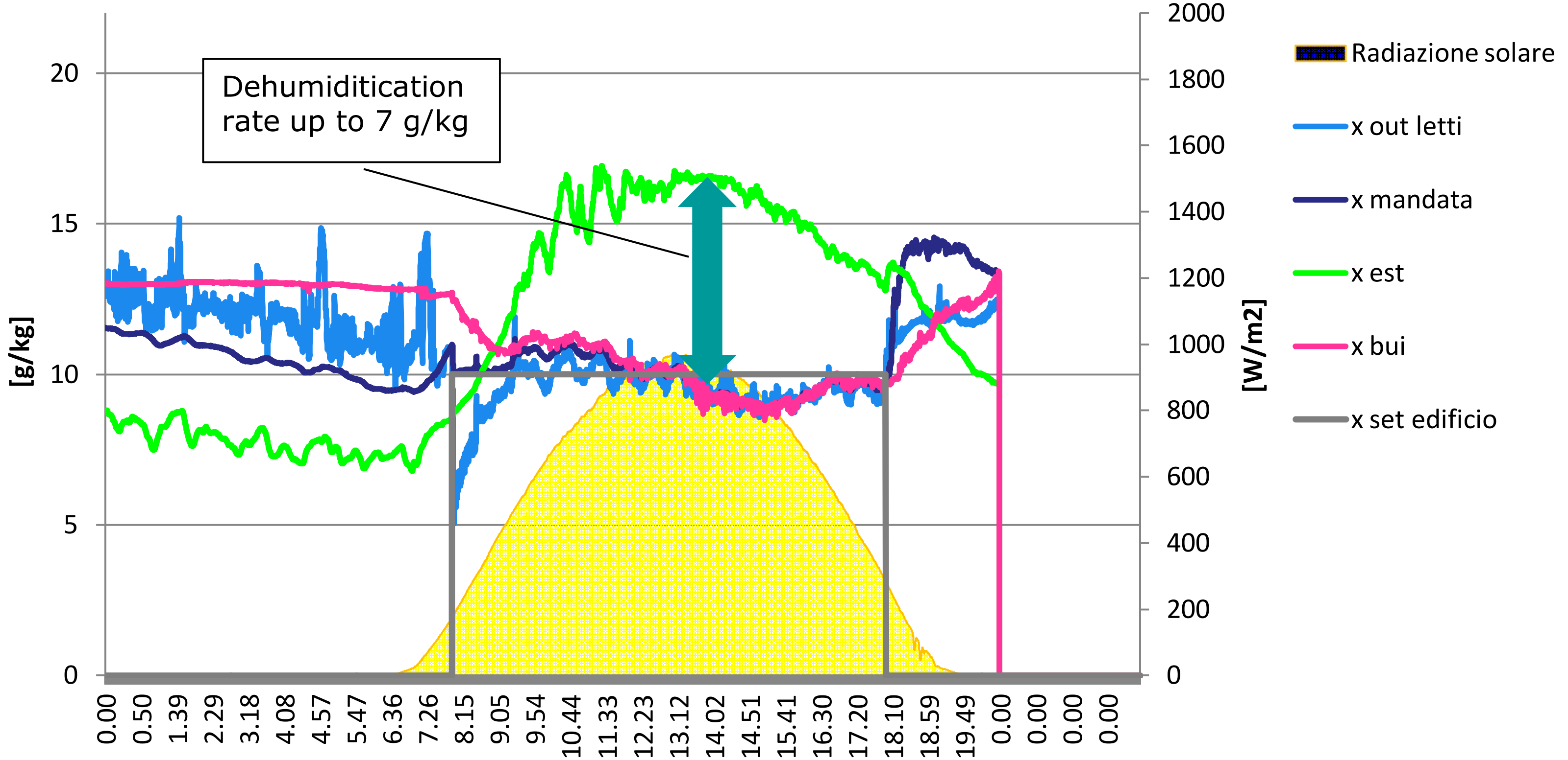
Temperature profile – solar collector



INSTANTANEOUS ENERGY PERFORMANCES

Results of freescoo prototype installed at ENEA in Rome

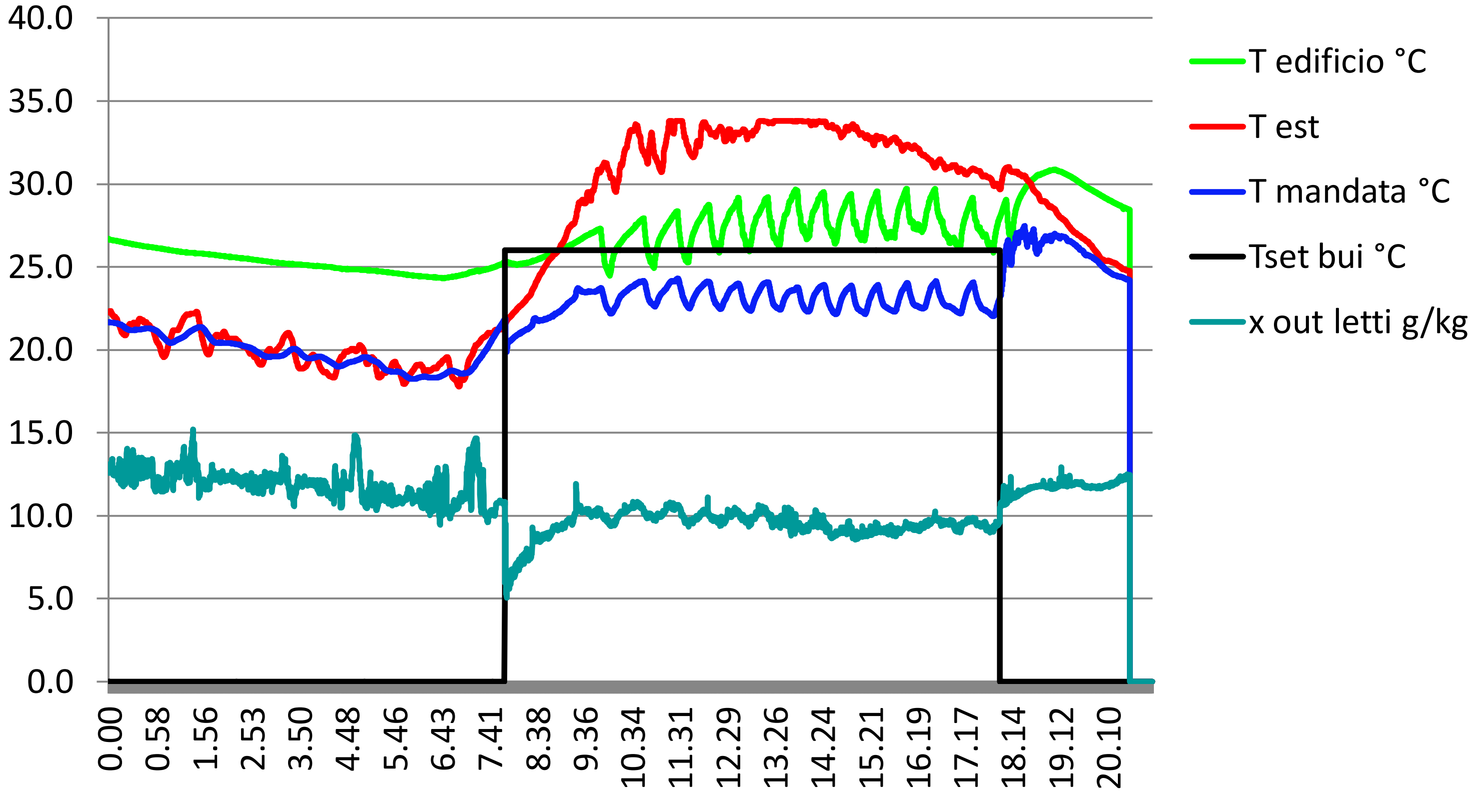
Humidity rate profile



INSTANTANEOUS ENERGY PERFORMANCES

Results of freescoo prototype installed at ENEA in Rome

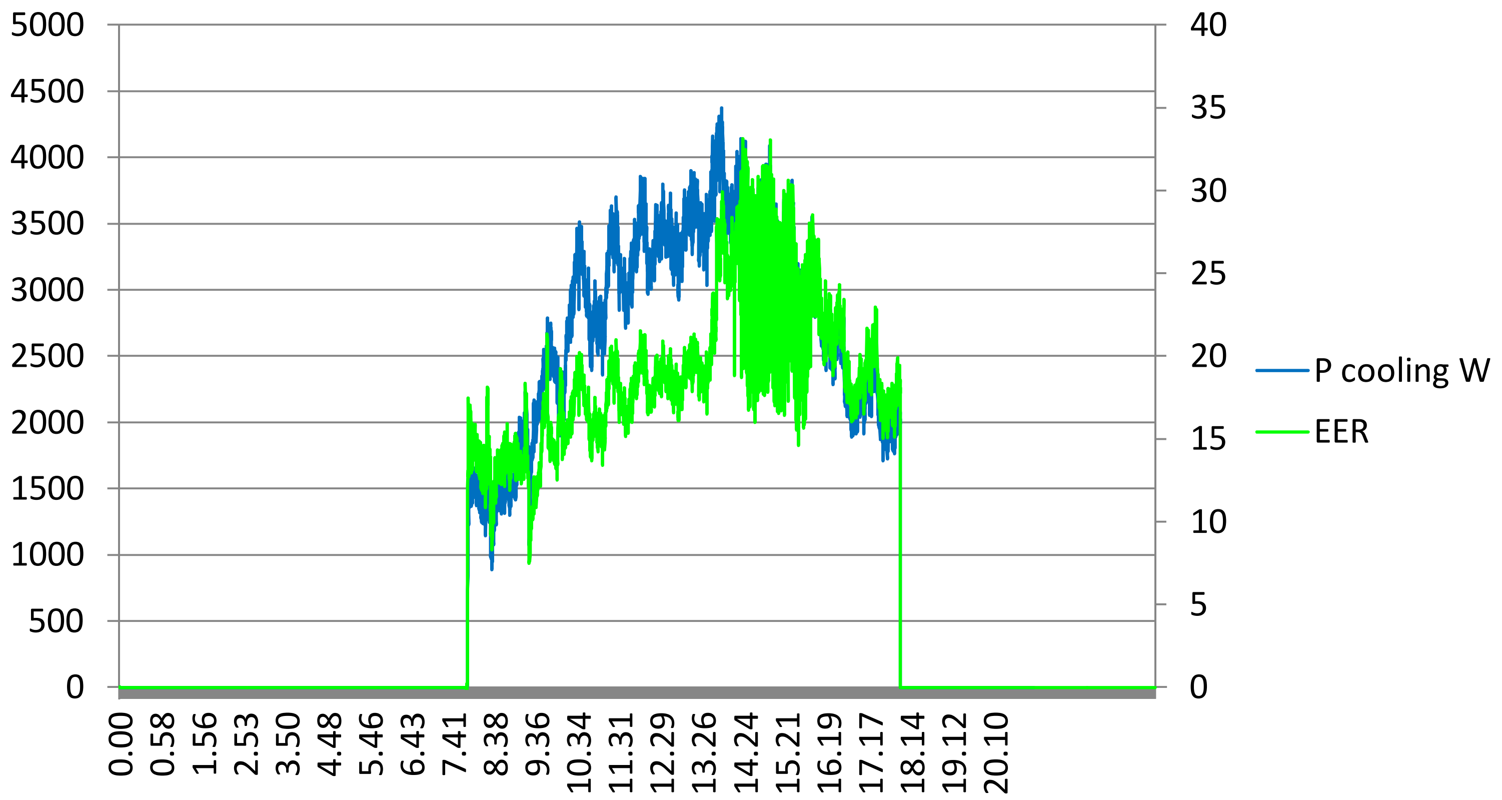
Temperature profile - cooling



INSTANTANEOUS ENERGY PERFORMANCES

Results of freescoo prototype installed at ENEA in Rome

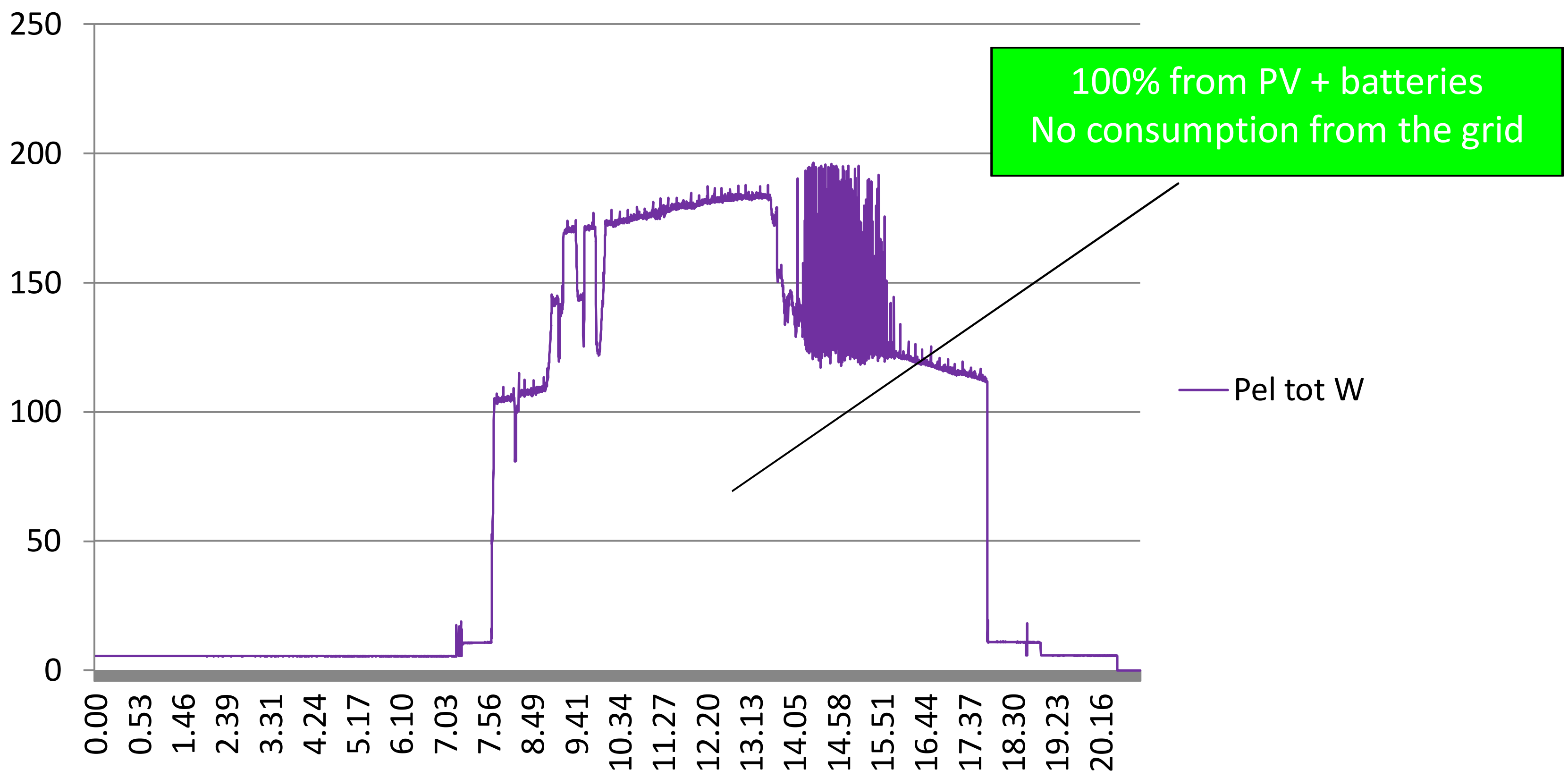
Cooling power profile



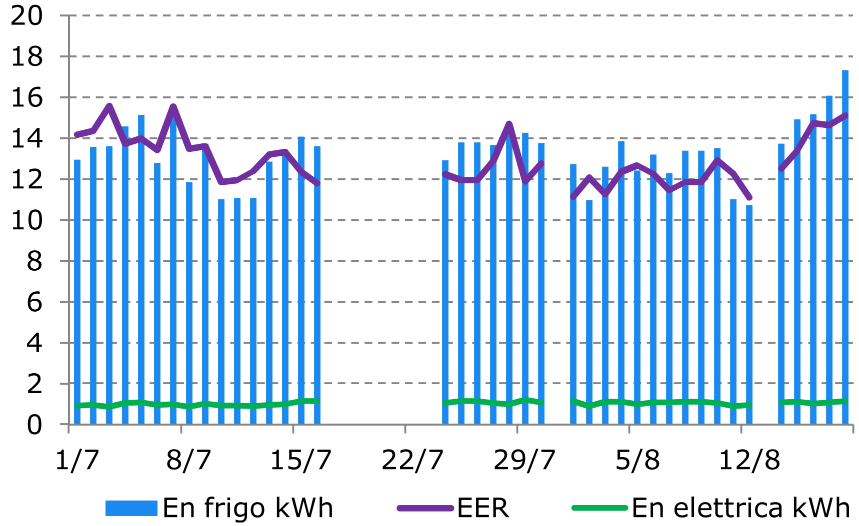
INSTANTANEOUS ENERGY PERFORMANCES

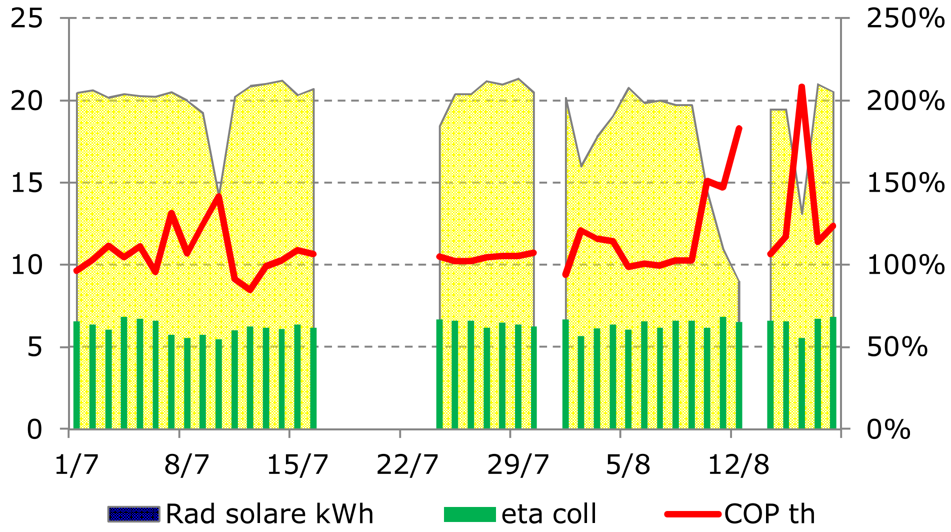
Results of freescoo prototype installed at ENEA in Rome

Power profile



MID-TERM ENERGY PERFORMANCES: FREESCOO AT UNIPA





- 40 days of operation
- Average EER = **12,8** **NOT** taking into account the PV production
- Average EER_{grid} = **50.7** taking into account only the electricity taken from the grid
- Average thermal COP = **1,1**
- 25% of electricity taken from the grid
- 75% of electricity produced by PV

LIFE CYCLE ASSESSMENT: FREESCOO AT UNIPA

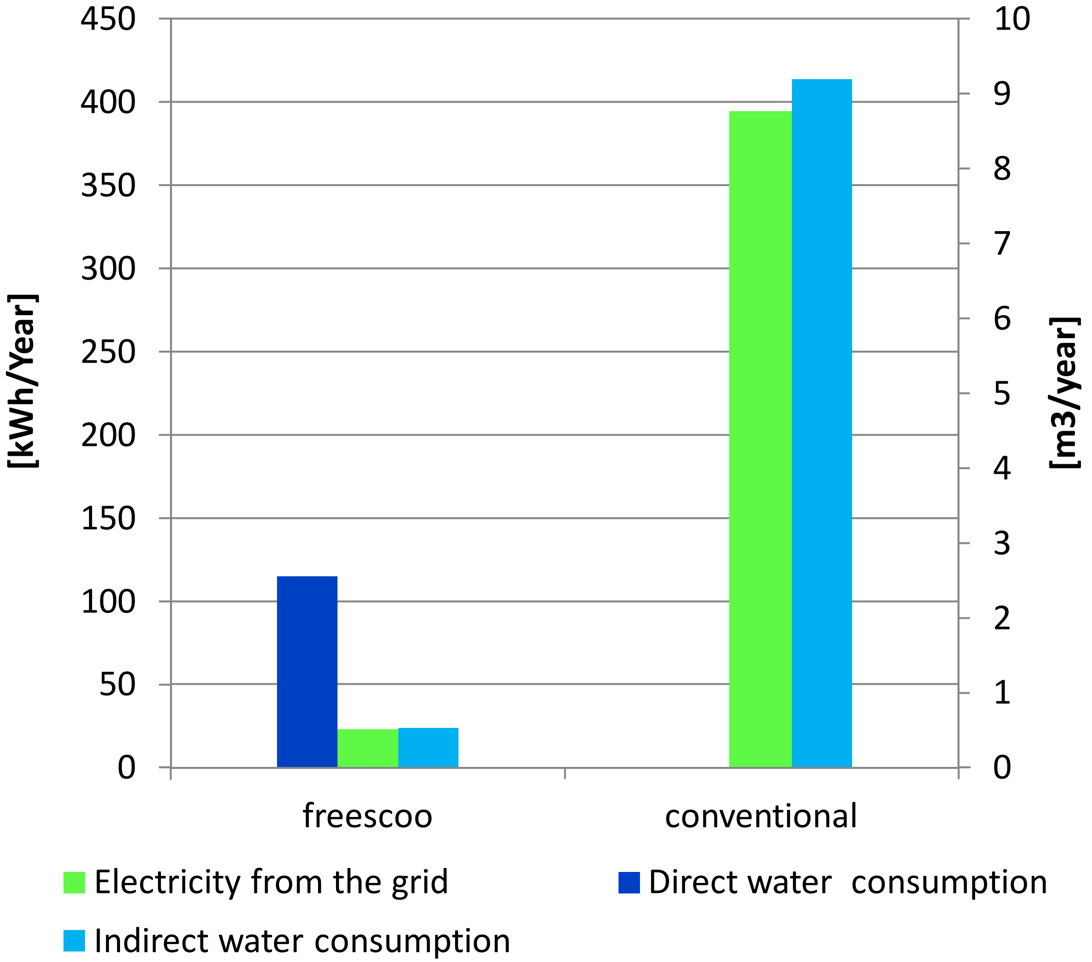
PRIMARY ENERGY CONSUMPTIONS

Impact category	Total	Costruction	Usage
	MJ	MJ	MJ
Non renewable, fossil	23333	20192	3141
Non-renewable, nuclear	4349	3879	470
Non-renewable, biomass	0	0	0
Renewable, biomass	287	258	28
Renewable, wind, solar, geothermal	54	43	11
Renewable, water	3149	2858	291
Total	31171	27230	3941

ENVIRONMENTAL IMPACTS

Impact indicator	Unit	Total	Costruction	Usage
Climate change	kg CO2 eq	1828	1595	233
Ozone depletion	kg CFC-11 eq	0	0	0
Photochemical ozone formation	kg NMVOC eq	6	5	1
Acidification	molc H+ eq	13	11	1
Terrestrial eutrophication	molc N eq	19	17	2

LIFE CYCLE ASSESSMENT: FREESCOO AT UNIPA



- Operation performance data extrapolated from 40 days of monitoring
- Operation hours in cooling/year= 1200 h eq to 90 days
- EER of the convential unit assumed = 3
- Lyfe time of the systems = 15

SUMMARY

- Low temperature of the regeneration of the desiccant (45-65°C)
- Lower air velocities are needed in comparison to the values commonly used for AHU components (values < 0,4 m/s are preferable)
- An accurate design of the desiccant bed can limit pressure drops (large cross area, high porsity)
- Desiccant bed is used as sorption storage permitting to supply cooling energy several hours after the sunset
- Control of the dehumidification process acting on the temperature of the bed is possible
- Pre-heating of regeneration air flow rate due to the metal casing of the machine
- Good performances both in terms of EER and thermal COP values registered
- Nominal cooling power never reached during the monitoring period
- Low electricity power (150W and 250W, resp. for the small and the bigger machine)
- Off-grid operation possible thanks to the internal PV production