IEA SHC TASK 53 NEW GENERATION SOLAR COOLING SYSTEMS

1ST MEETING – VIENNA

AIT - MARCH 18-19, 2014

FREESCOO: A NEW COMPACT SOLAR AIR CONDITIONER BASED ON FIXED AND COOLED ADSORPTION BEDS

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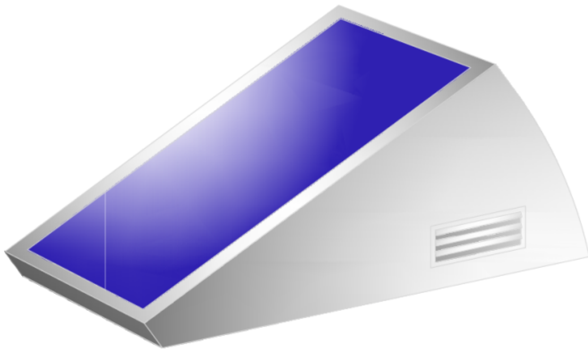
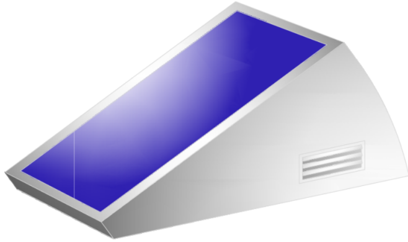
SOLARINVENT SRL



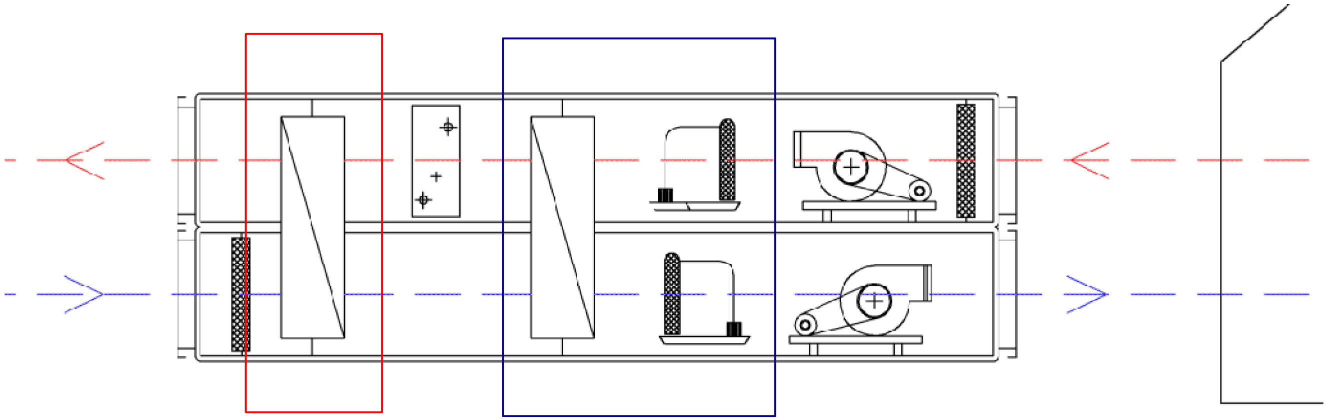
INTRODUCTION

- Freescoo (**FREES**olar**COO**ling) is a innovative solar DEC air conditioning system based on fixed and cooled adsorption beds
- Project lead by the startup company SOLARINVENT SRL
- First prototype developed and tested in summer 2013
- Second generation prototype soon
- Monitoring data for at least two demo systems will be available after summer 2014
- Several interaction aspects with the new TASK 53:
  - New solar thermally driven product entering the market
  - Integration with PV
  - Innovative, efficient thermally driven concept
  - Compact, simple design, low cost



INTRODUCTION

- In DEC systems desiccant rotors are commonly used
- The use of desiccant rotors implies that condensation heat is rejected into the processed air and has to be removed by means of the indirect evaporative cooling process
- System based on simultaneous adsorption and desorption processes
- The rotating sensible heat exchanger has to carry over two tasks:
  - Heat recovery
  - Cold production
- Enthalpy difference of the DEC AHU strongly dependent on the efficiency of sensible heat exchanger and return humidifier



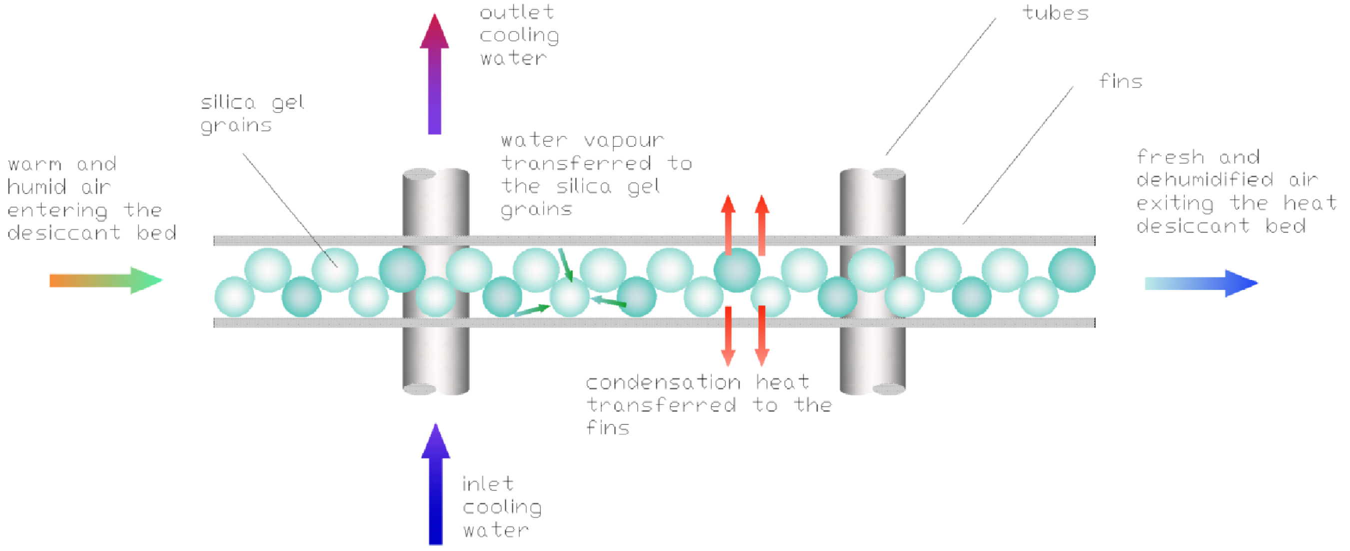
ADSORPTION PROCESS BASED ON DESICCANT ROTORS

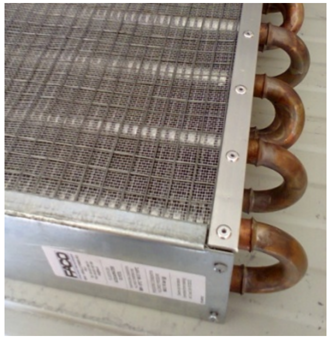
Furthermore:

- An increase of the desiccant material temperature is responsible also for higher regeneration temperatures required
- Desiccant rotors are built to host a relatively low mass of adsorbent.
- Energy storing is commonly based on the mass and the heat capacity of the fluid used for the regeneration of the desiccant
- The use of hot air as regeneration fluid is suitable only with systems without storage

INNOVATIVE FIXED AND COOLED ADSORPTION BED

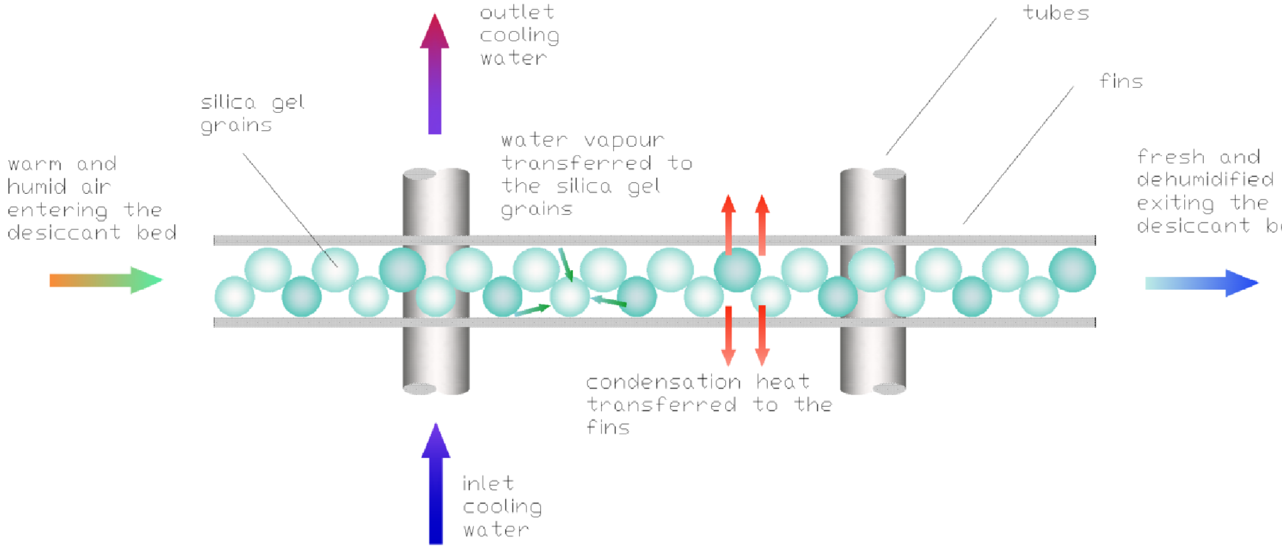
- The component is a fin and tube heat exchanger commonly used in the air conditioning sector, wherein the spaces between the fins are filled with silica gel grains
- The developed component allows a simultaneous **mass transfer** between the moist air and the adsorbent media and **heat exchange** between 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 and in general better overall energy performances of the system;

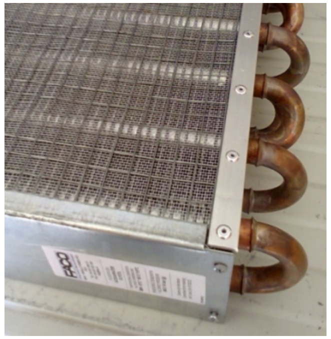




INNOVATIVE FIXED AND COOLED ADSORPTION BED

- 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 later when regeneration heat is not available, strongly reducing the necessity for thermal storage;

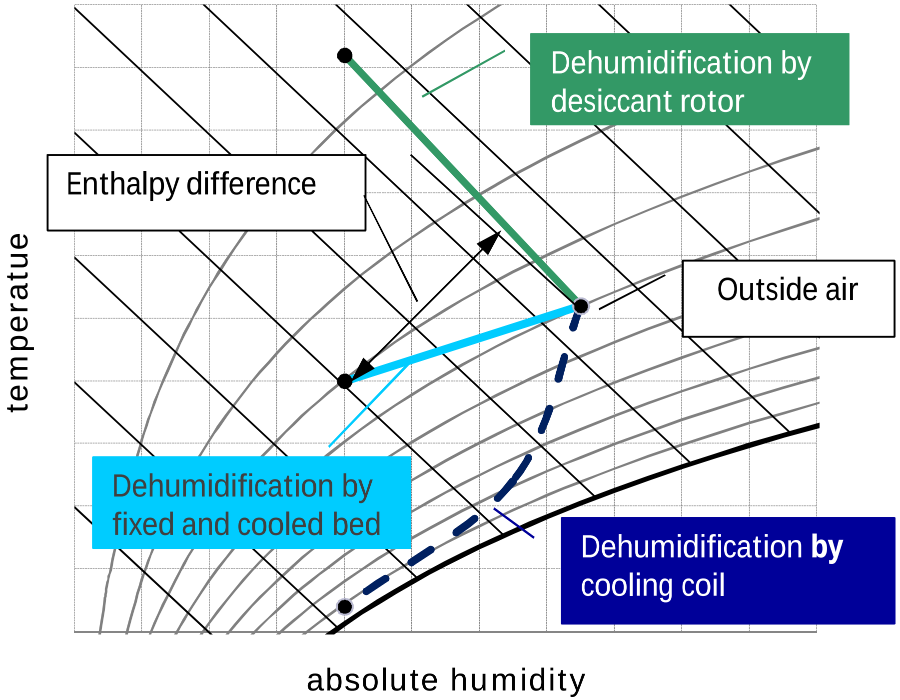




COMPARISON OF THE ADSORPTION PROCESSES

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



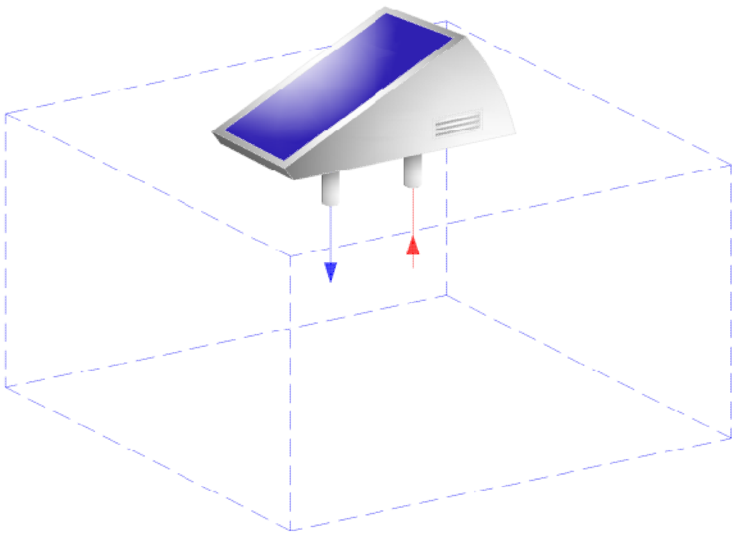
Dehumidification by fixed and cooled desiccant bed

- Condensation 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

DESIGN CONCEPT OF THE NEW DEC CYCLE

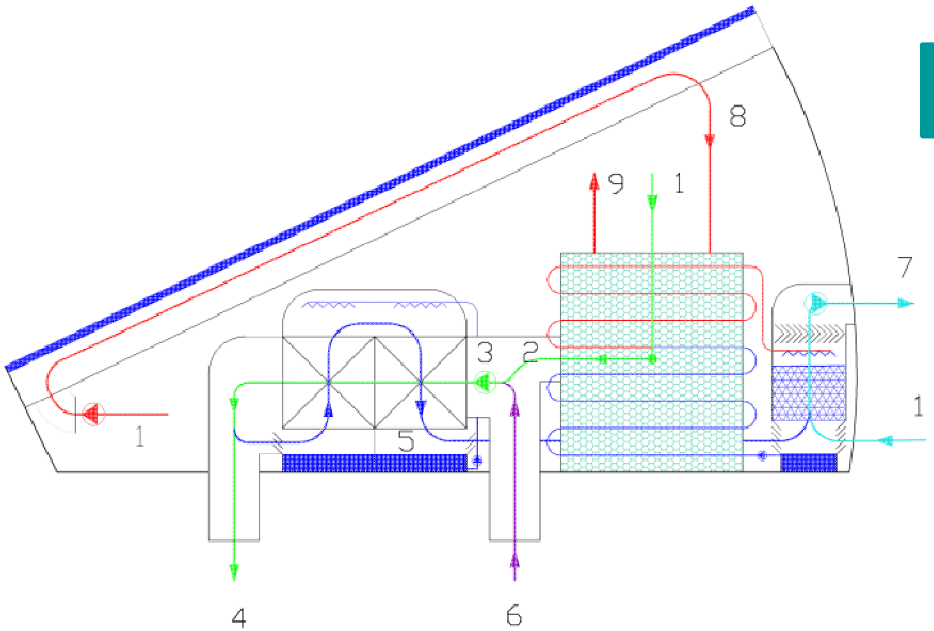
SYSTEM DESIGN SPECIFICATIONS

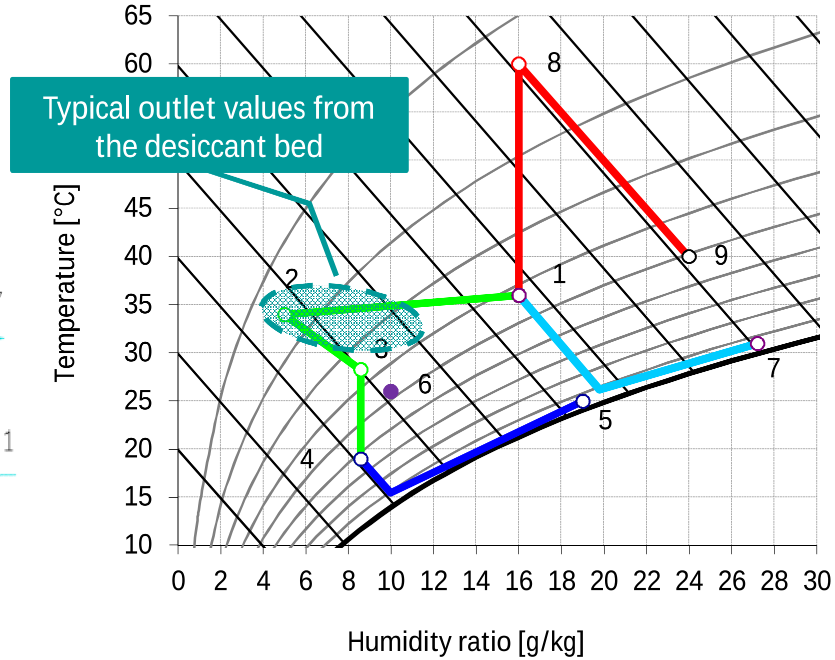
- Designed for small scale applications of air ventilation, dehumidification and cooling
- Based on fixed and cooled adsorption beds and high efficient evaporative cooling concepts
- Use of solar air collectors
- Minimization of parasitic energy consumption
- Solar autonomous, no use of auxiliary energy source for cold production
- System should be compact, all in one, reliable, and easy to install



DESCRIPTION OF THE NEW DEC SYSTEM

- The new compact system developed is based on the use of two fixed packed desiccant beds of silica gel operating in a batch process and cooled by cooling tower, and two wet wet heat exchangers connected in series
- Adsorption bed designed to be operated in “low flow” mode (air velocity =0.16 m/s)
- A portion of the primary air flow rate exiting the wet heat exchanger is drawn into the secondary side

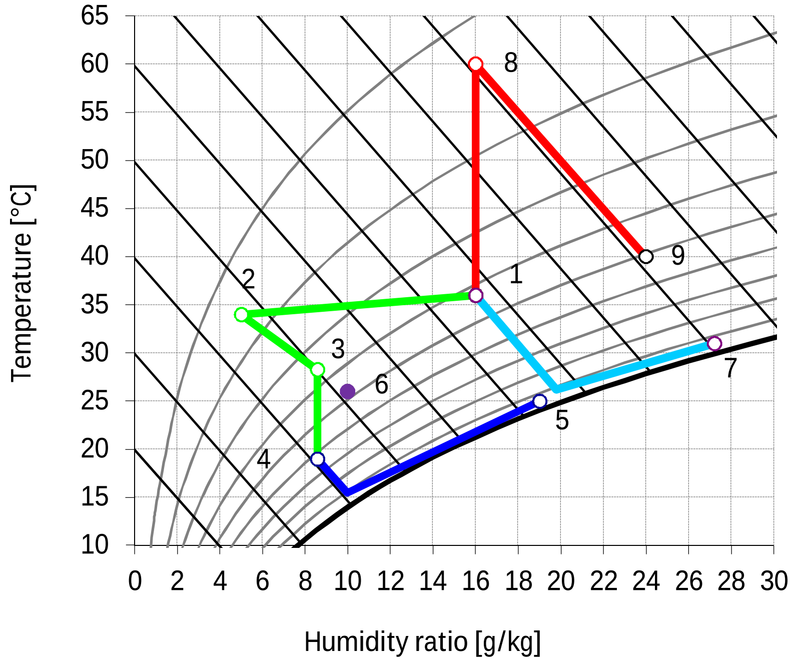




DESCRIPTION OF THE NEW DEC SYSTEM

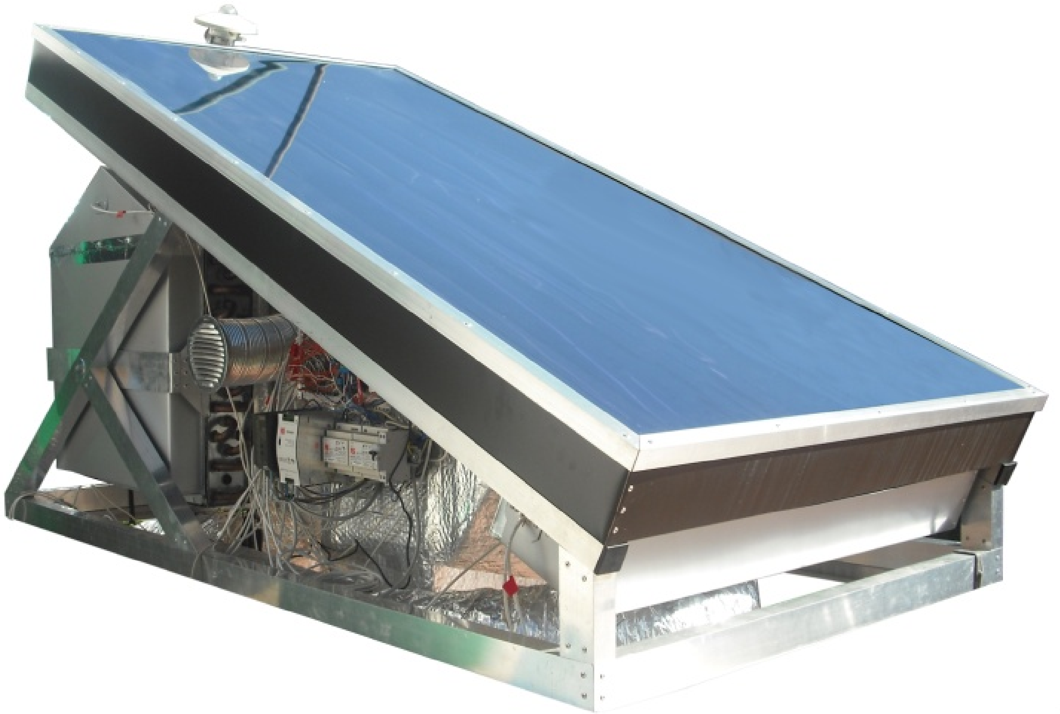
- Main electricity consumptions of the system are related to the use of three fans (solar, main, cooling tower) and two pumps (wet HX, cooling tower)
- A system of air valves provides the switch from one bed to the other in order to guarantee a continuous dehumidification process
- No auxiliary device included

		Description	**x**	**T**	**H**
		-	**g/kg**	**°C**	**kJ/kg**
Process air	1	Outside air	16.0	36.0	77.2
	2	Adsorption bed	6.0	34.0	49.5
	3	Mixing	9.6	28.3	52.8
	4	Wet HX1 + HX2	9.6	19.0	43.3
Building	6	Return air	11.0	26.0	54.1
Secondary air in wet heat exchangers	4	Wet HX1 + HX2	9.6	19.0	43.3
	5	Humidification	10.8	17.0	44.4
Cooling tower	1	Inlet cooling	19.8	28.0	78.7
	7	Cooling tower	25.5	30.0	95.3
Regeneration air	1	Outside air	16.0	36.0	77.2
	8	Solar collector	16.0	60.0	102.0
	9	Desorption	24	40	101.96



FIRST REALIZED PROTOTYPE

- Solar air collector area: (1x2) m^2
- Two ADS beds, with 15 kg of silica gel each
- One wet HX
- Total flow rate: 500 m^3/h
- Max electric power: 0,2 kW
- Max cooling power: 2,2 kW (at $T_{outside}$ = 35°C, $RH_{outside}$ = 50%, T_{bui} = 27°C, RH_{bui} = 50%)
- Total weight ≈ 150 kg



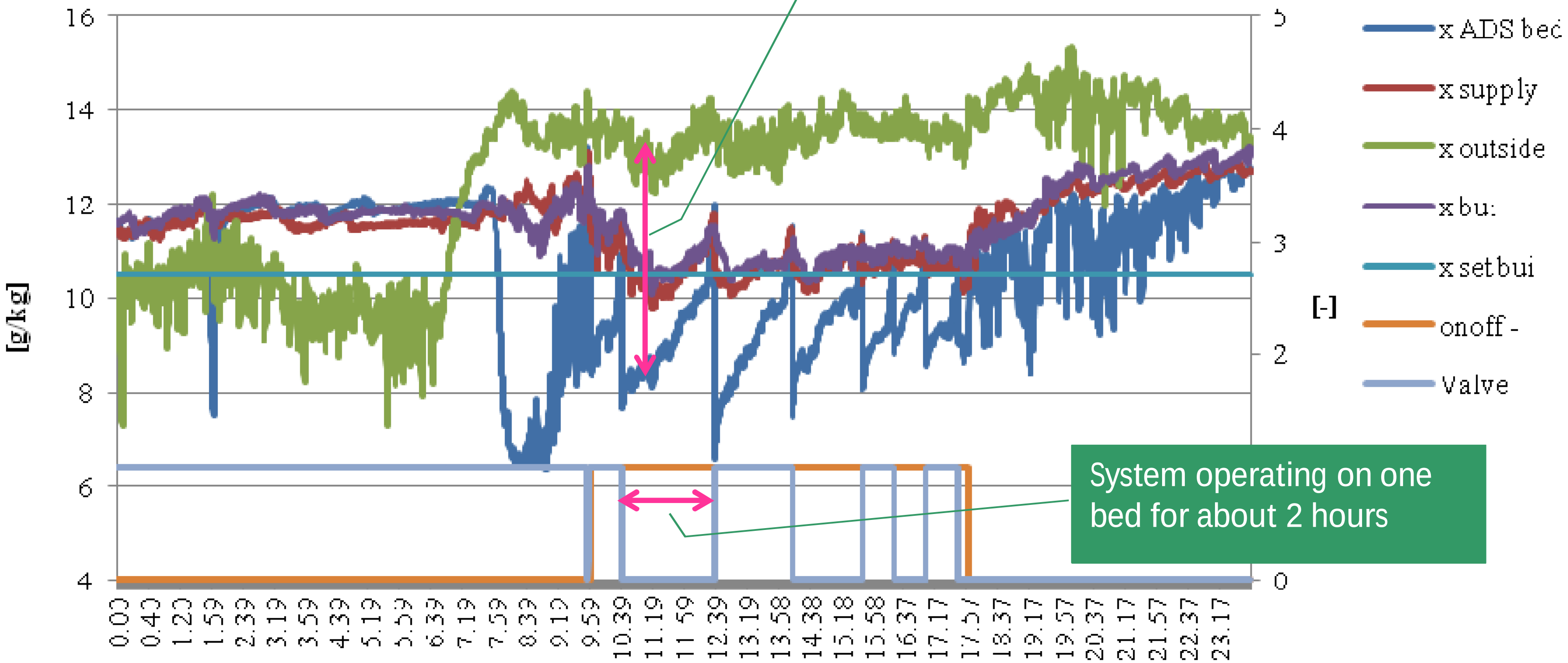
International PCT pending

HUMIDITY RATIO VALUES

5th day of the selected week

T ouside max °C	x ouside max g/kg	T ouside average °C	x ouside average g/kg
31.3	14.4	29.3	13.4

Humidity ratio difference about 5 g/kg

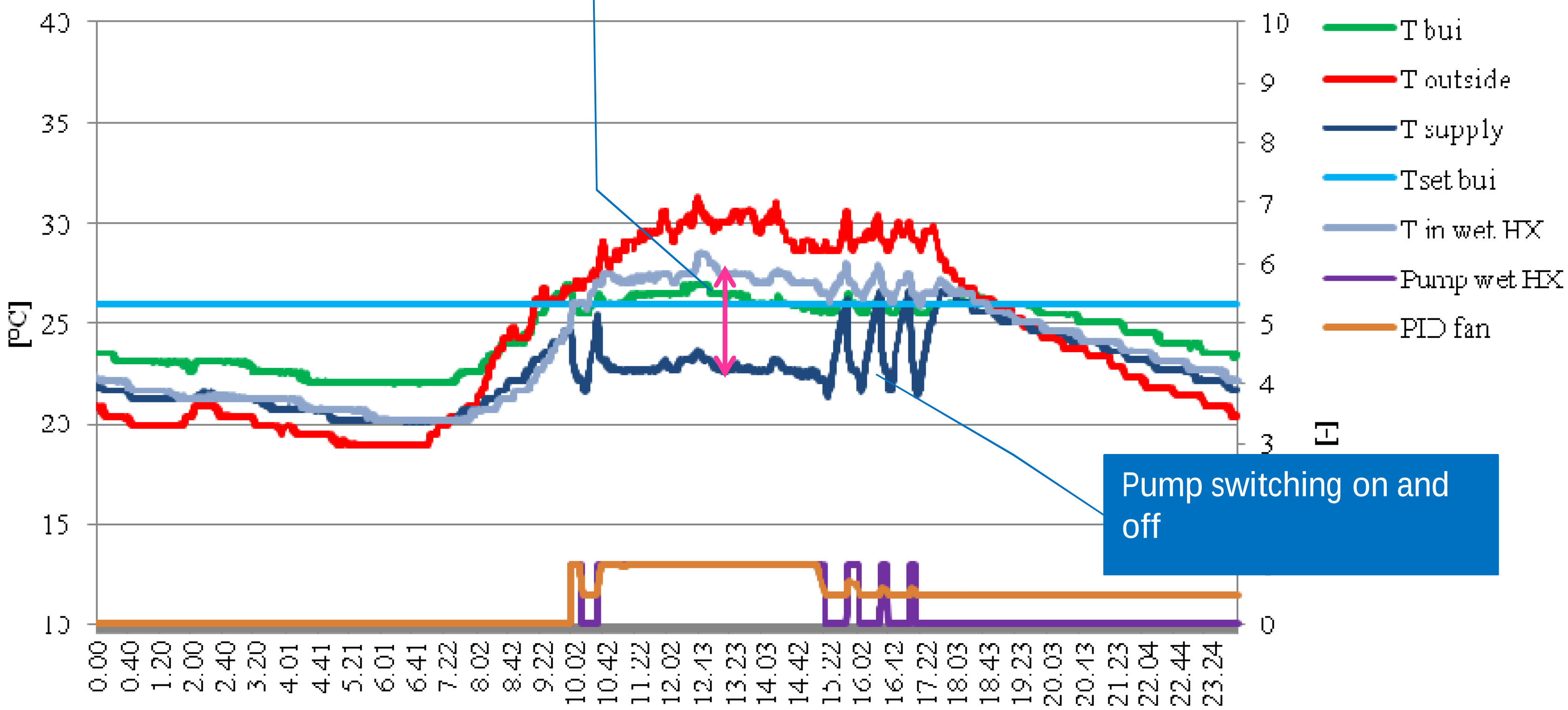


TEMPERATURE VALUES

5th day of the selected week

T ouside max °C	x ouside max g/kg	T ouside average °C	x ouside average g/kg
31.3	14.4	29.3	13.4

temperaure difference about 5 °C

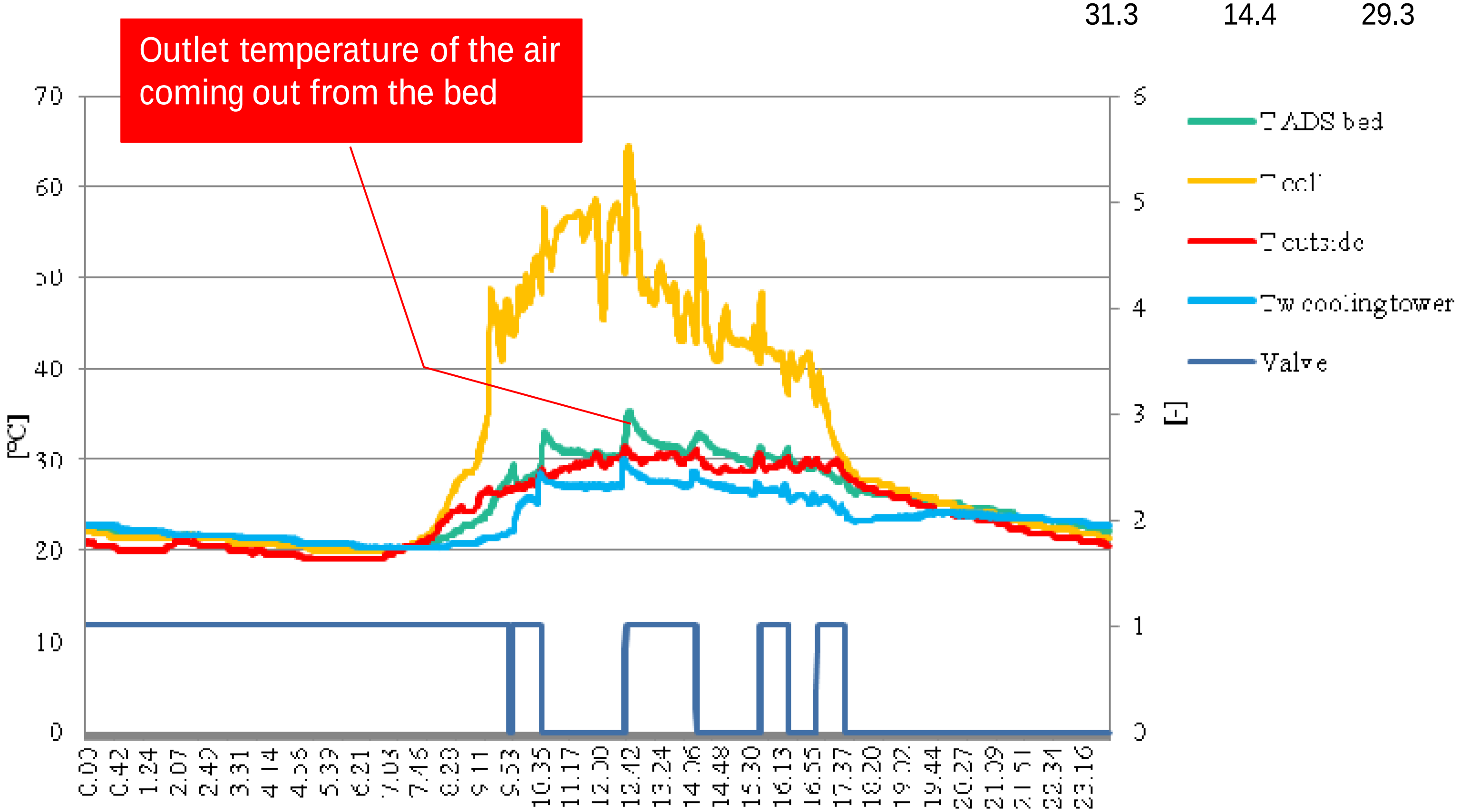


Pump switching on and off

SOLAR, ADS BED AND COOLING TOWER

5th day of the selected week

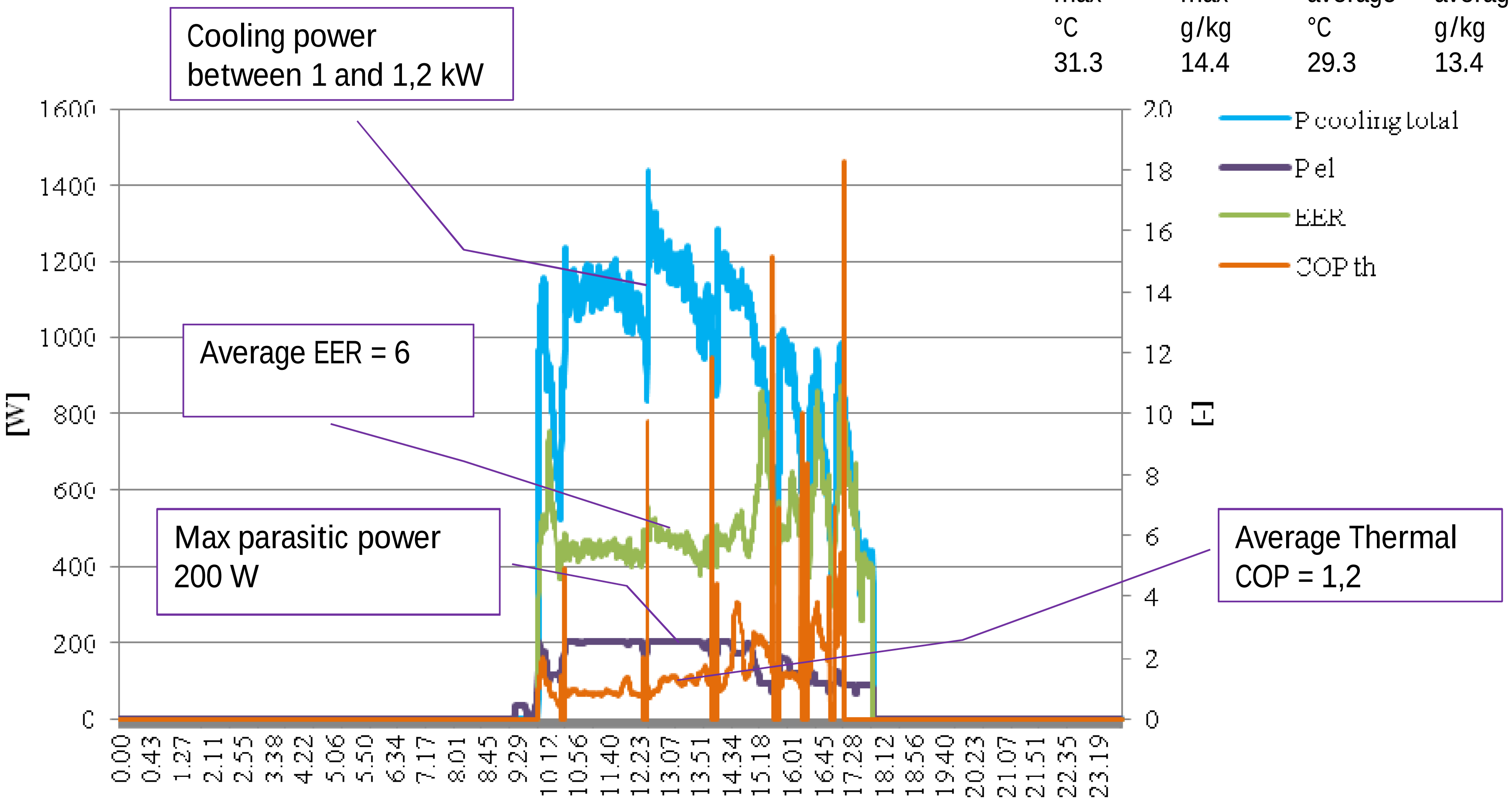
T ouside max °C	x ouside max g/kg	T ouside average °C	x ouside average g/kg
31.3	14.4	29.3	13.4



MAIN ENERGY PERFORMANCES

5th day of the selected week

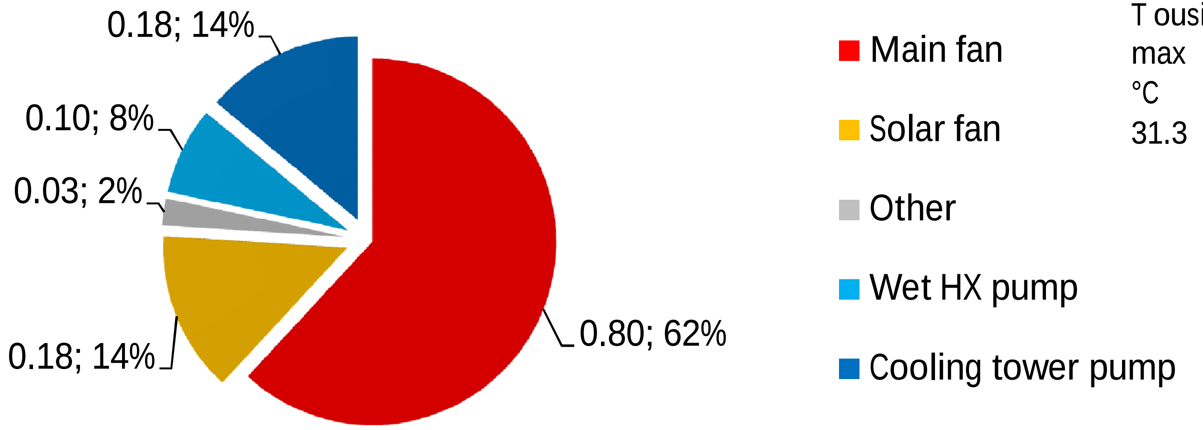
T ouside max °C	x ouside max g/kg	T ouside average °C	x ouside average g/kg
31.3	14.4	29.3	13.4

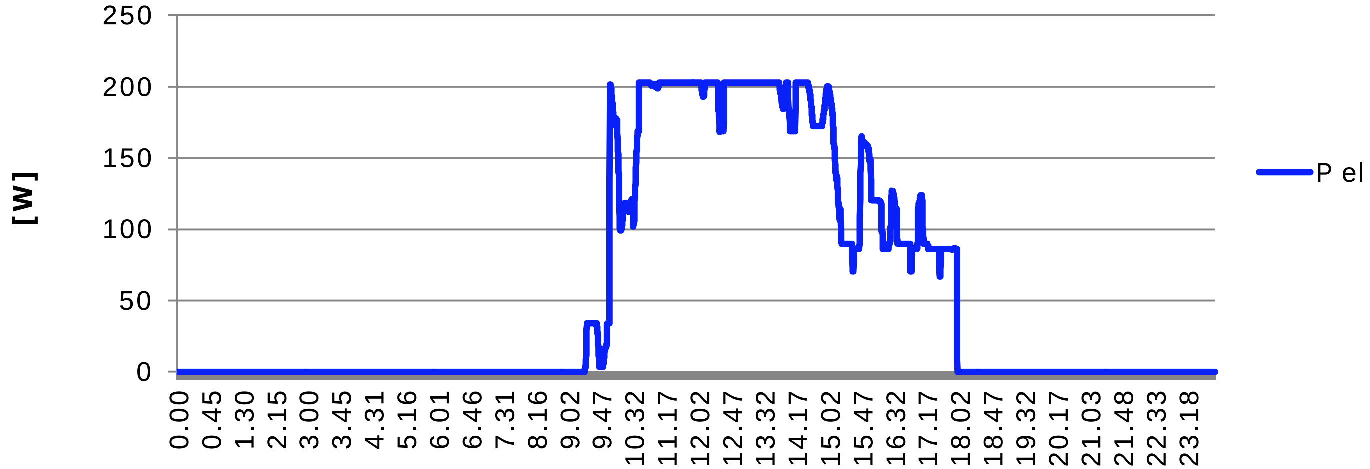


ELECTRICITY CONSUMPTIONS DISTRIBUTION

5th day of the selected week

T ouside max °C	x ouside max g/kg	T ouside average °C	x ouside average g/kg
31.3	14.4	29.3	13.4





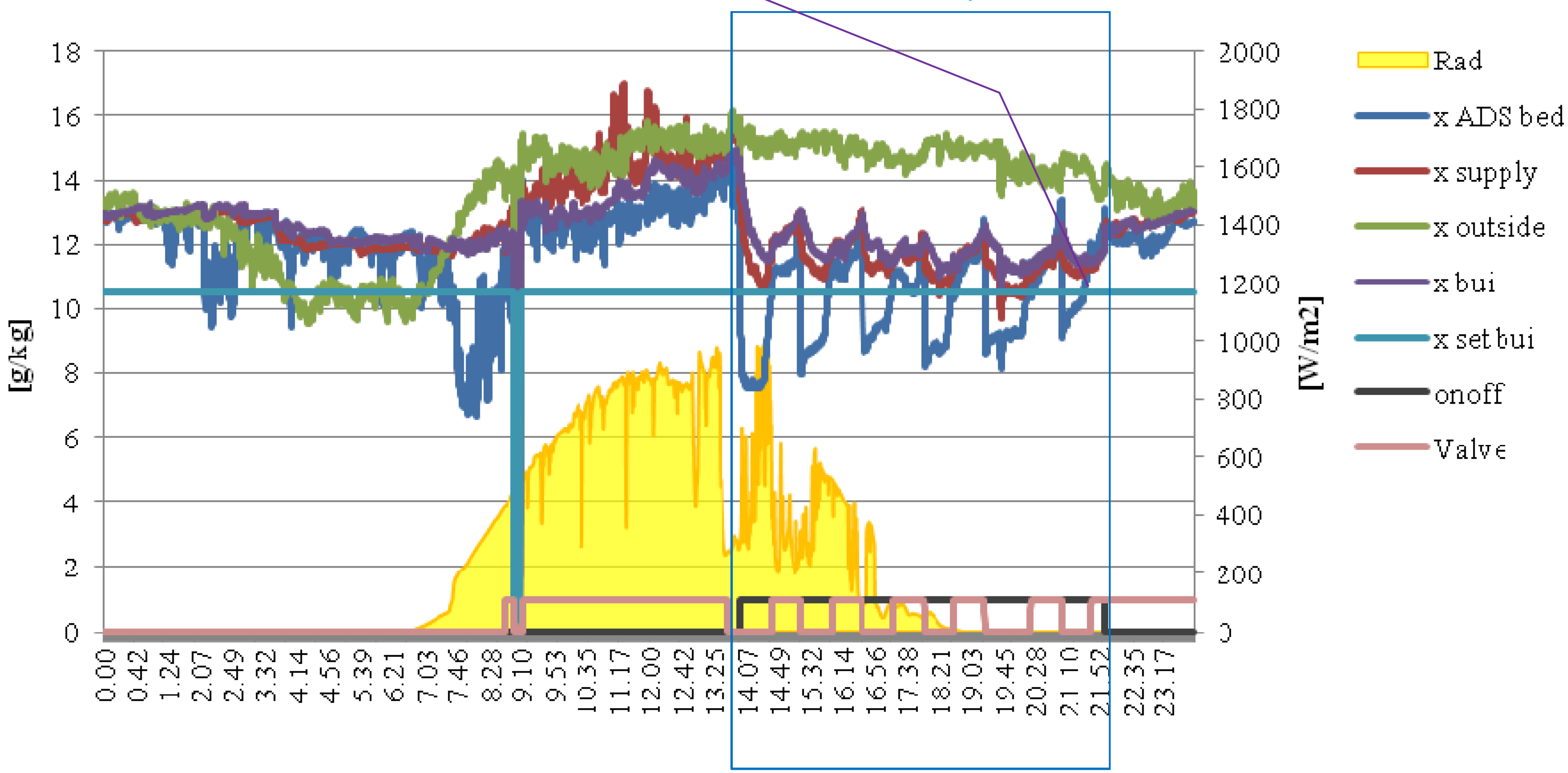
HUMIDITY RATIO VALUES

6th day of the selected week

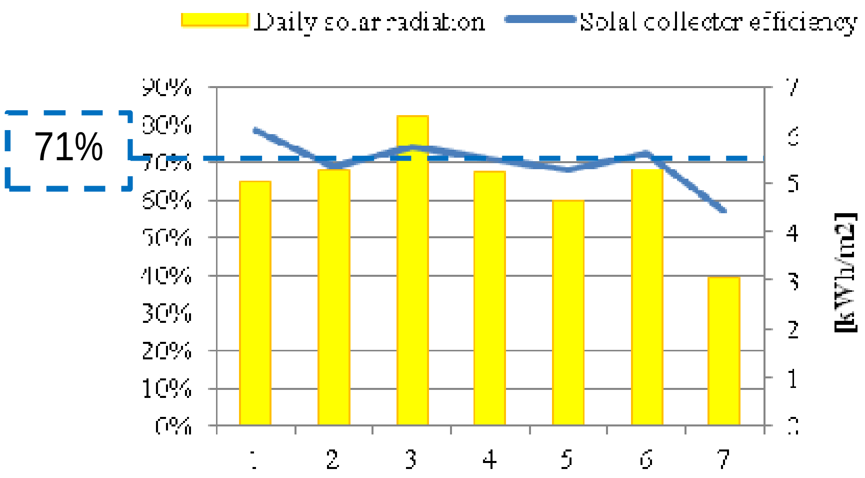
T ouside max °C	x ouside max g/kg	T ouside average °C	x ouside average g/kg
31.1	15,7	26,0	14,8

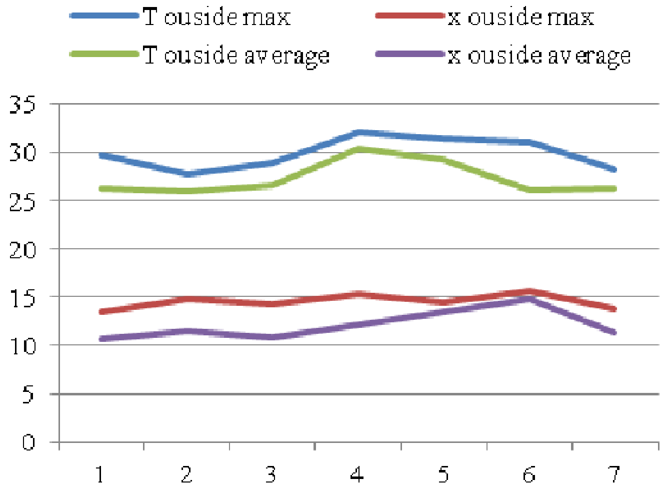
System could provide dehumidification for several hours after the sunset

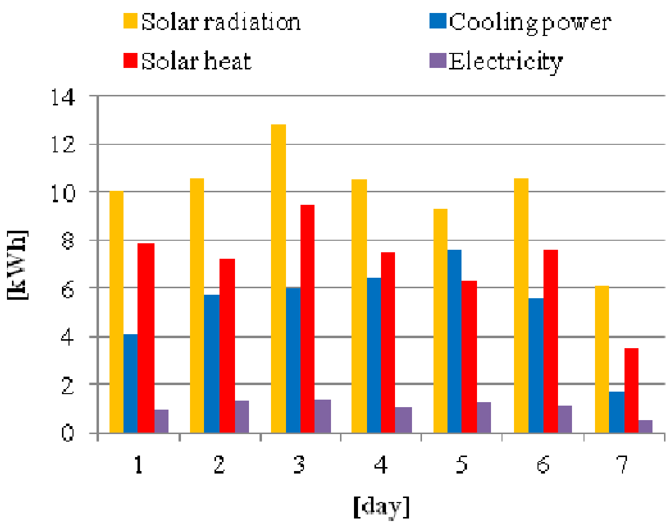
Operation time from 2:00 pm to 10:00 pm

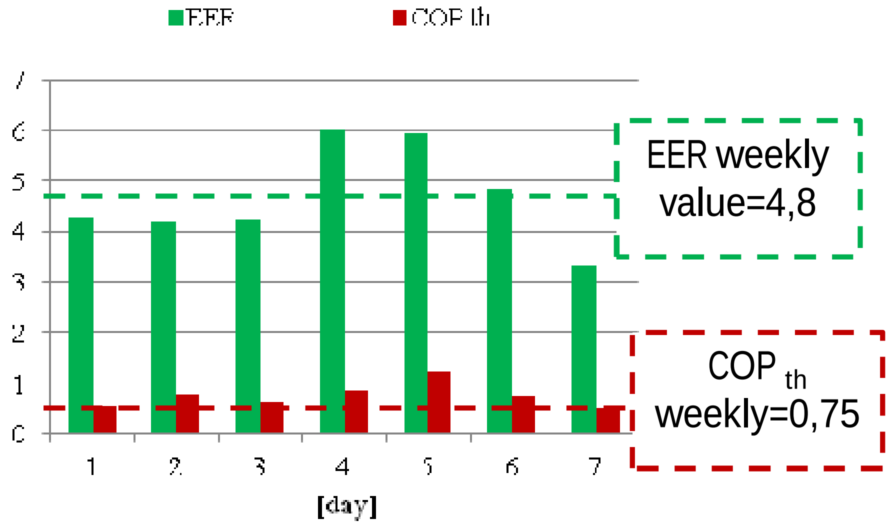


DAILY WEATHER CONDITIONS AND PERFORMANCE INDICATORS – ONE WEEK OF OPERATION







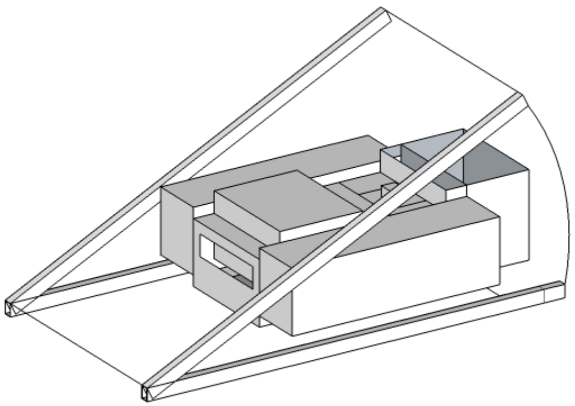


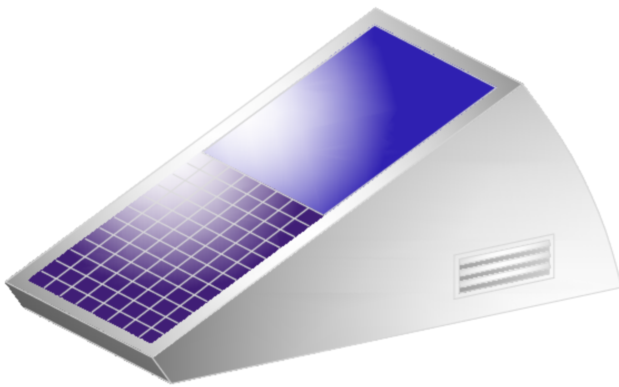
FIRST PROTOTYPE: SUMMARY OF MAIN RESULTS

- Low temperature required for the regeneration of the desiccant material (max 60°C), standard solar flat plate air collector can be used
- Good performances especially in terms of building humidity control
- Interesting EER and thermal COP values, several optimizations still possible
- The opportunity to use the desiccant bed as latent storage permits to supply cooling energy to the building also several hours after the sunset
- Control of the dehumidification process acting on the temperature of the bed is possible
- The fact that adsorption and desorption processes happen in different times can be considered an advantage for the control of the dehumidification process

SECOND GENERATION PROTOTYPE

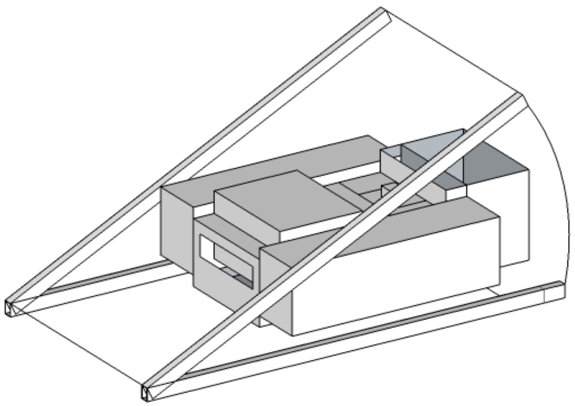
- Increased max cooling power: from 2.2kW to 3.4kW
- Decreased max electricity power required: from 200W to 150W
- Lower total electricity consumption due to optimized control strategy and redesign of components & air channels
- Components powered in DC 24V
- Hybrid operation: PV/thermally driven system

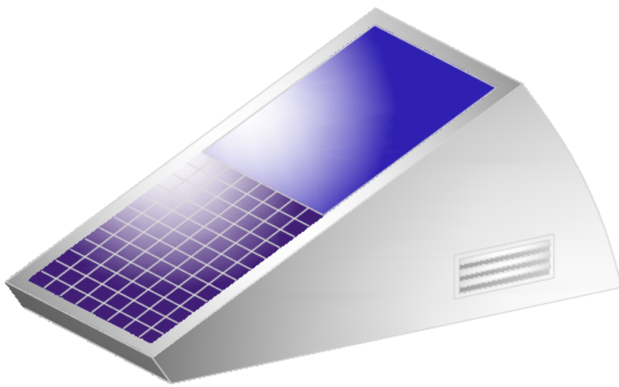




SECOND GENERATION PROTOTYPE

- Off-grid operation possible
- Heating integration possible in the wintertime and mid-seasons (direct solar heating, dehumidification)
- Possible integration of an heat pump for wintertime
- At least two prototypes installed and monitored in the next months





POSSIBLE CONTRIBUTIONS WITHIN TASK 53

Subtask A

- A2: New system configurations for cooling (AC, food conservation) and heating (DHW, ambient)
- A3: Storage (electrical and thermal) concepts and management

Subtask B

- B3: Models of components (identification/validation) and system simulation
- B4: Control strategy analysis and optimization for ST and PV

Subtask C

- C3: Monitoring data analysis on technical issues & on performances

CONTRIBUTIONS FROM UNIPA

UNIVERSITA' DEGLI STUDI DI PALERMO
DIPARTIMENTO DEIM

Contribution from UNIPA-DEIM (Marco Beccali, Maurizio Cellura)

- A5: LCA and techno-eco comparison between reference and new systems

  UNIPA confirms the availability to lead the activity

- C3: Monitoring data analysis on technical issues & on performances (and other related subtask C activities)

  UNIPA has been contracted by ENEA to test two prototypes of Freescoo

  UNIPA will co-operate in monitoring procedures definition, project selection and description, reporting of best practices

Thank you for your attention!