LAST DEVELOPMENTS ON THE FREESCOO CONCEPT

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SOLARINVENT SRL

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SOLARINVENT

- Solarinvent is a startup company created at the beginning of 2014
- Our business idea is focused on the developing of efficient and low price air conditioning solutions fed by renewable energy sources
- Solarinvent goal is the development and diffusion on the market of freescoo system, of which owns IP license
- 5 members and 3 employees
- Many scientific collaborations with national and international research institutes such as Polytechnic of Milan, ENEA – Italian National Agency for New Technologies Energy and Sustainable Economic Development, EURAC Bolzano, University of Palermo, CNR, Fraunhofer ISE Freiburg Germany, AIT Vienna Austria, CSIRO Australia
- Involvement in the TASK 53 IEA "New generation solar cooling & heating systems (PV or solar thermally driven systems)"
- Winner of Italian funding program SMART & START (2014)
- Winner of SME INSTRUMENT PHASE 1 title 'Low temperature heat / solar driven air conditioning system for heating, cooling, dehumidification and ventilation of buildings — freescoo' (concluded Dec 2016)
- Start up phase based own financial resources

WHAT IS FREESCOO?

Freescoo is an innovative solar DEC air conditioning concept designed for **ventilation**, **cooling**, **dehumidification** and **heating** of buildings in residential and tertiary sectors.
Main features of the concept are:

- Use of water as refrigerant and heat as main energy input
- Use of the Cooled Packed Bed (CPB) technology and high efficiency evaporative cooling concepts
- Low grade solar heat (50-60°C) is used to drive the cooling process (Solar PVT air collector or traditional FP collector)
- High electric efficiency (Typical EER >13)
- Simple plug & play
- Several system configurations possible

Freescoo is a patented solution by the startup company SOLARINVENT

MAIN PROJECTS CARRIED OUT

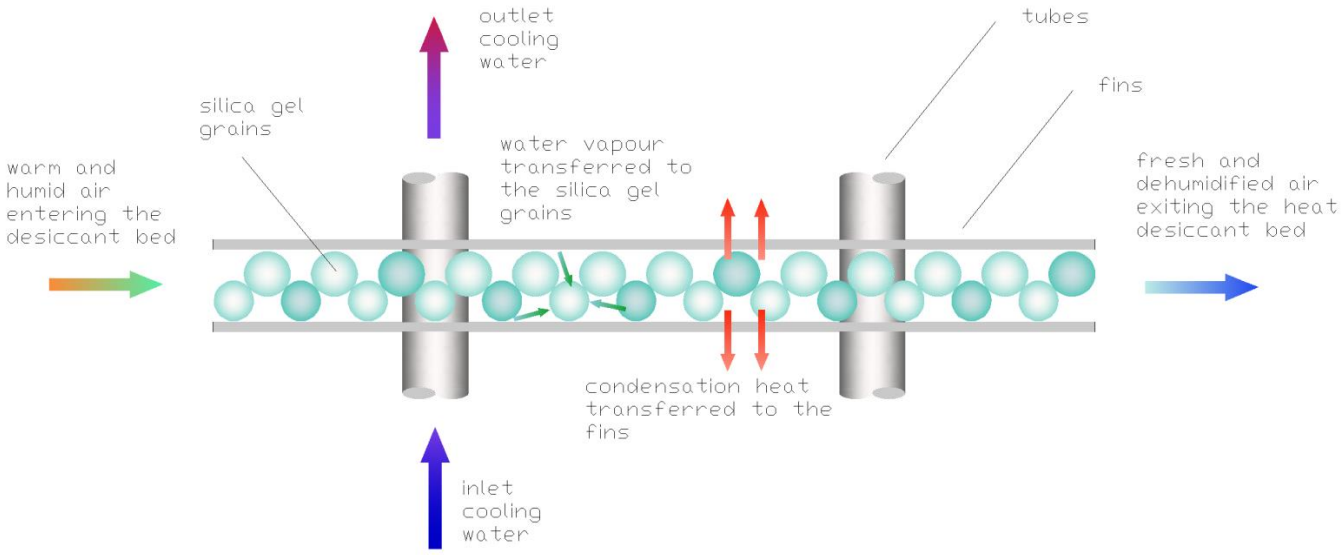
- **Research project ENEA** – University of Palermo funded by MSE – Ricerca di Sistema Elettrico dal titolo "Test funzionali ed ottimizzazione delle performance di due prototipi di condizionatore d'aria compatti Solar DEC"

- **Project ZERO-PLUS** "Achieving near Zero and Positive Energy Settlements in Europe using Advanced Energy Technology" Innovation action – H2020-EE-2015-1-PPP started on October 2015

- **Project freescoo for AMEE** – Agence Marocaine pour l'Efficacité Energétique. In the framework of an international cooperation between AMEE and the Italian Ministry for Environment, Land and Sea (IMELS), a freescoo Air Handling Unit has been installed at the library of AMEE in Marrakech in October 2016. The project is managed by the Italian University Politecnico di Milano and has been carried out with the collaboration of the company Pleion which delivered the solar evacuated tube collectors.

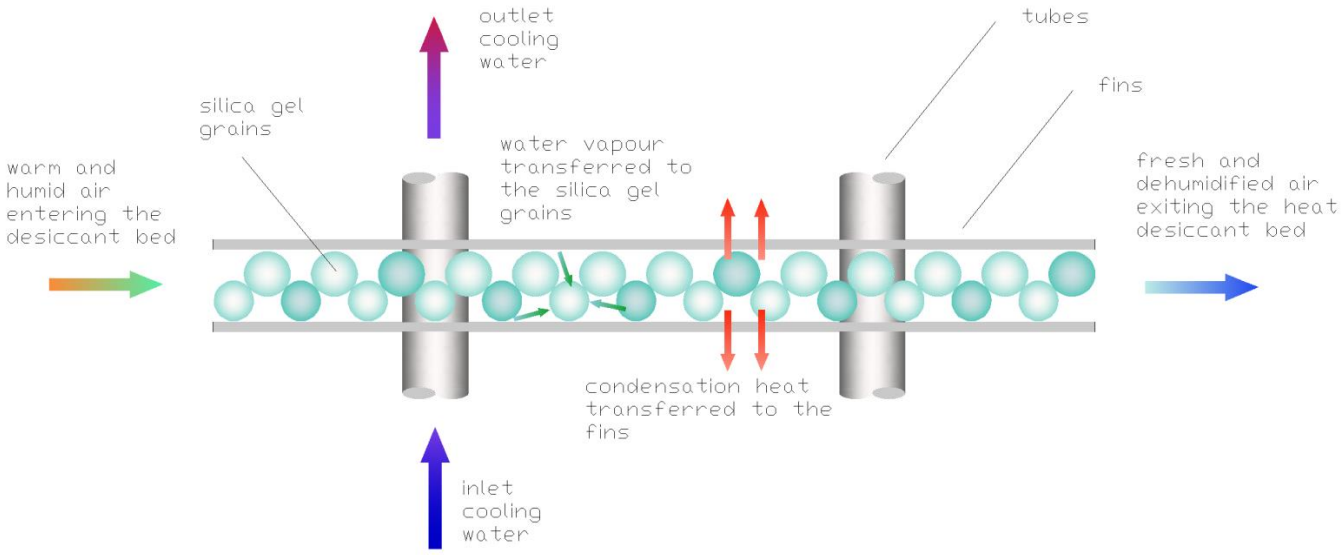
INNOVATIVE FIXED AND COOLED ADSORPTION BED

- 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;

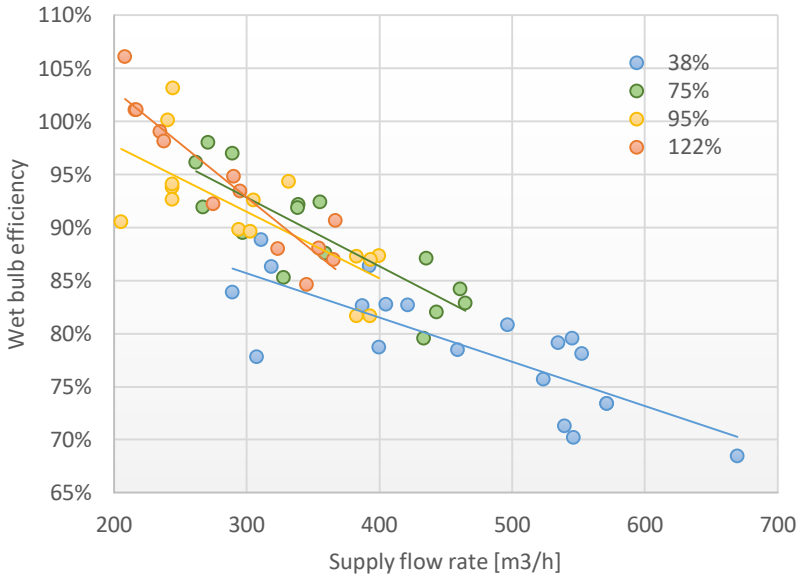


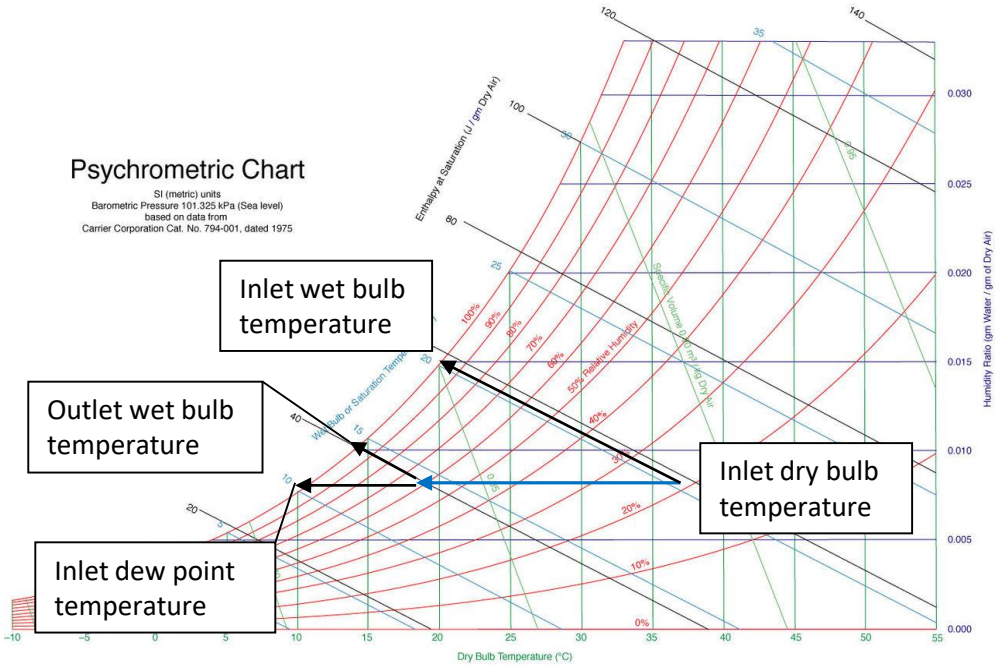
INNOVATIVE EVAPORATIVE HEAT EXCHANGER

- New counterflow and regenerative concept
- Wet bulb efficiency > 100% possible
- Size 85 x 45 x 19 cm

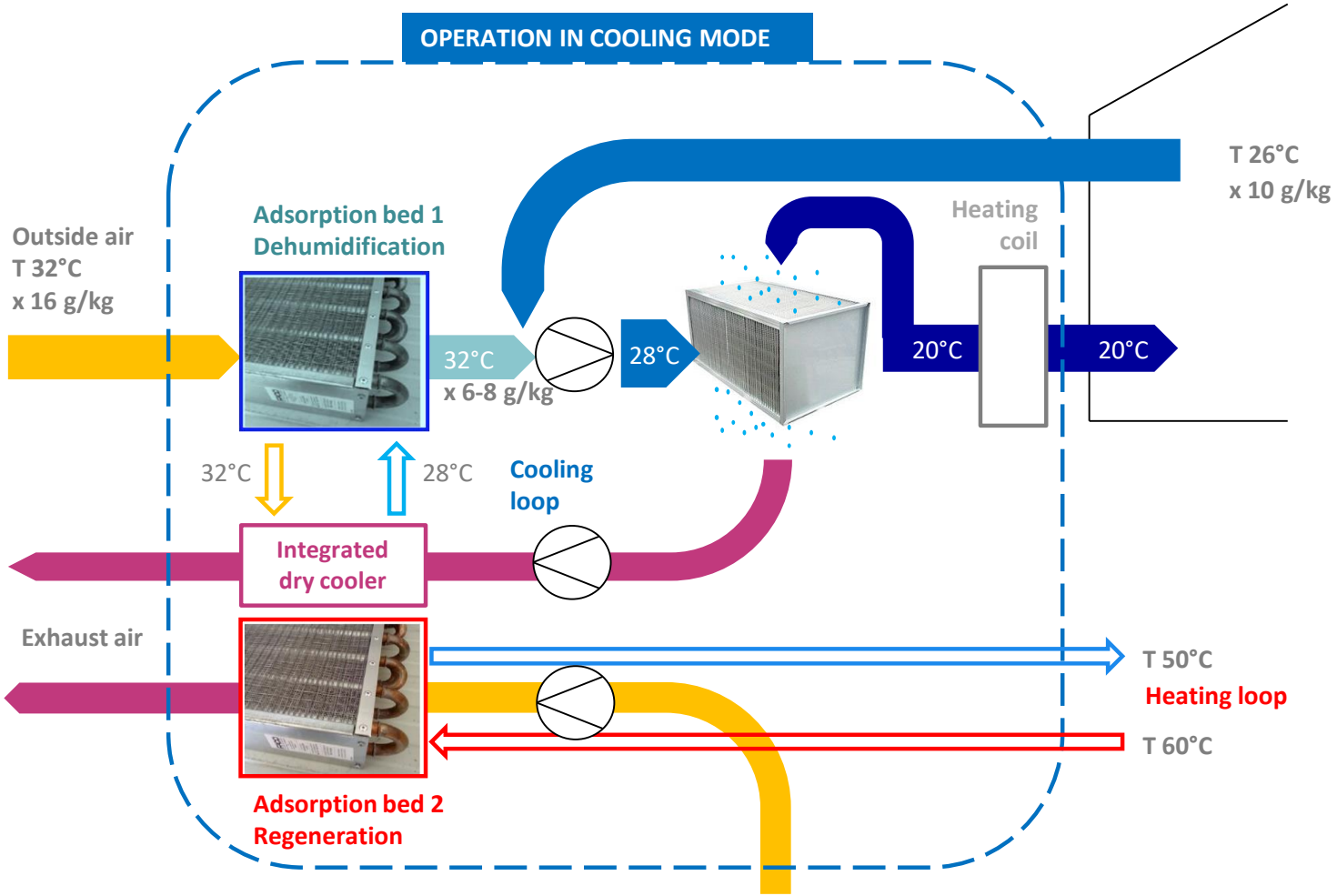
$$Ratio = \frac{Secondary\ air\ flow\ rate}{Supply\ air\ flow\ rate}$$

$$\varepsilon_{wet\ bulb} = \frac{(T_{in} - T_{out})}{(T_{in} - T_{wet\ bulb})}$$

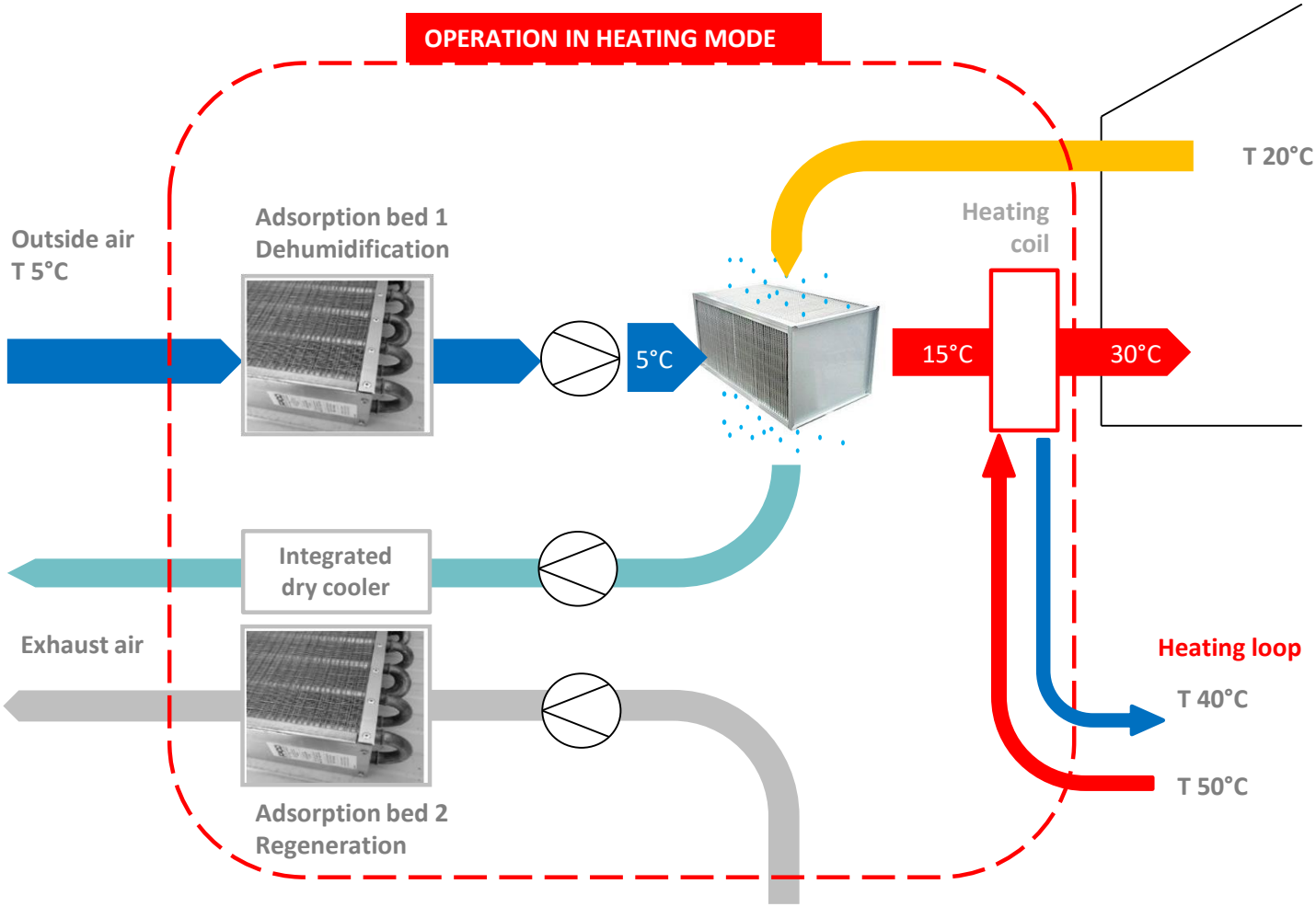




FREESCOO - COOLING CYCLE



FREESCOO - COOLING CYCLE

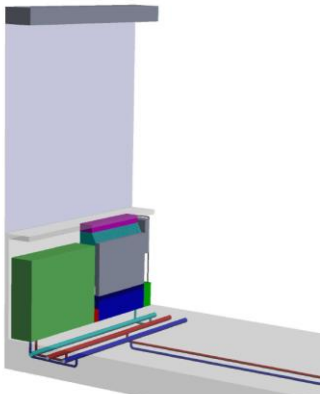


SYSTEM CONFIGURATIONS DEVELOPED

Compact stand alone rooftop unit

This unit offers the possibility to provide cooled, dehumidified or preheated air to the building with the necessary air change. It is suitable for residential users or service sectors that require solutions with low flow of air treatment. It's possible the integration with a photovoltaic system for a stand-alone functioning.

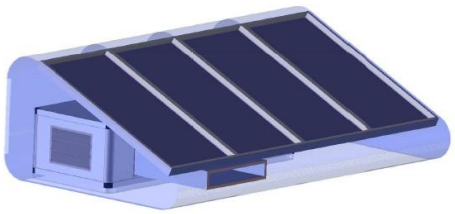
Installable on the roof of the building.



Compact facade system

This system offers the possibility to provide cooled, dehumidified or preheated air to the building with the necessary air change. It is suitable for residential users or service sectors that require low flow of air treatment. The system can be powered by liquid solar thermal or from any other heat source also operating at low temperature (50-60 ° C). Can be installed on the external walls of the building.

In case of new buildings or in case of more serious renovations, the unit can also be installed directly into the structure of the wall.



Air handling units

The system provides a complete air treatment and cover the needs of ventilation and air change. It is suitable for users requiring a treatment of an air flow > 1000 m3/h

The unit can be powered by solar thermal or by any other heat source also operating at low temperature (50-60 ° C).

The air handling unit can be installed in a remote position from the solar collectors.

FREESCOO STAND ALONE AT PALERMO AND ROME

Freescoo at UNIPA in Palermo

- Solar air collector area: 2,4 m^2
- Nominal flow rate: 500 m^3/h
- Max power absorbed: 150W
- Max cooling power: 2,5 kW (at $T_{outside}$ = 35°C, $RH_{outside}$ = 50%, T_{bui} = 27°C, RH_{bui} = 50%)
- Volume of conditioned space = 190 m^3
- Occupation pattern = small office

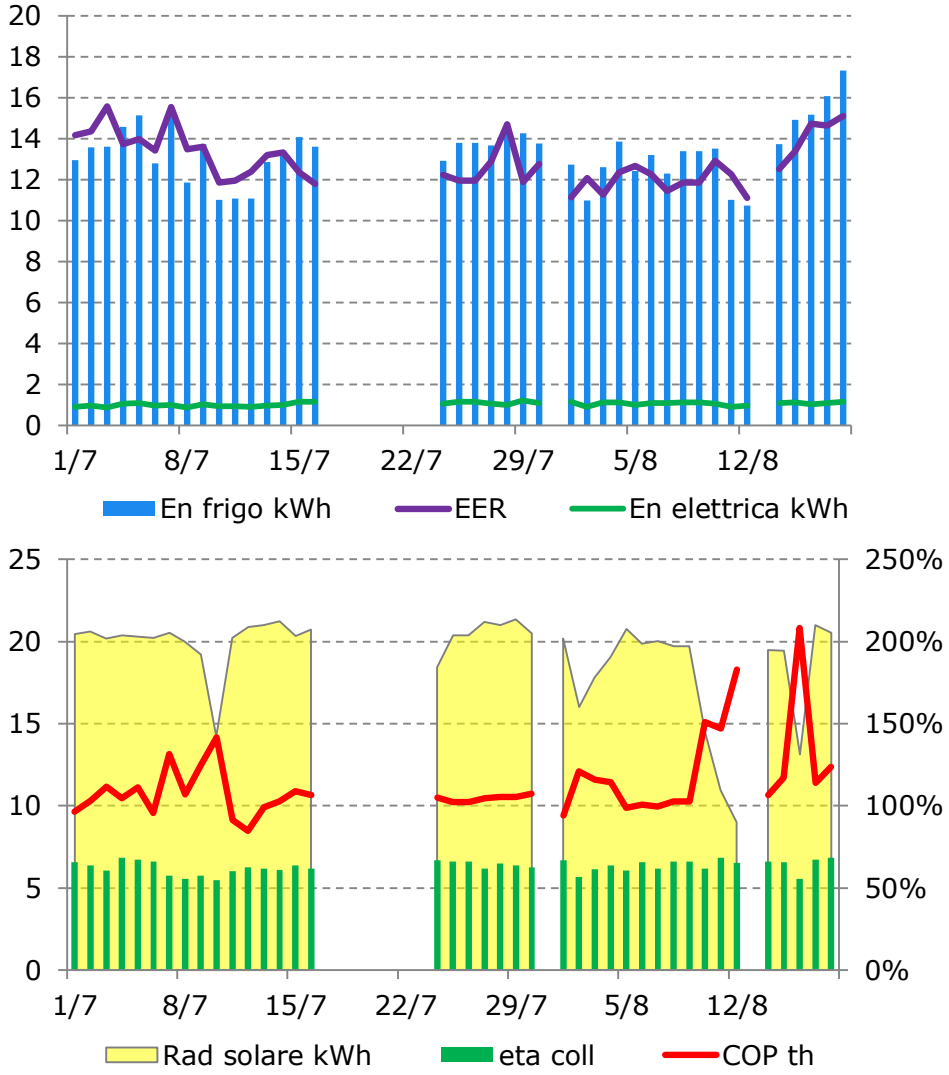
- Solar air collector area: 4,8 m^2
- Nominal flow rate: 1000 m^3/h
- Max power absorbed: 250W
- Max cooling power: 5 kW (at $T_{outside}$ = 35°C, $RH_{outside}$ = 50%, T_{bui} = 27°C, RH_{bui} = 50%)
- Occupation pattern = seminar room

Freescoo at ENEA in Rome

SOLARINVENT
Pietro Finocchiaro

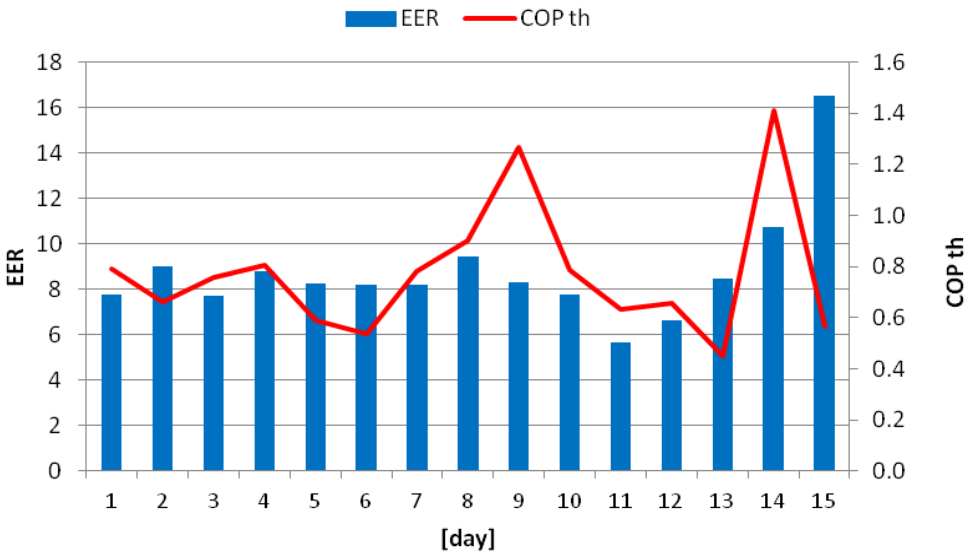
freescoo

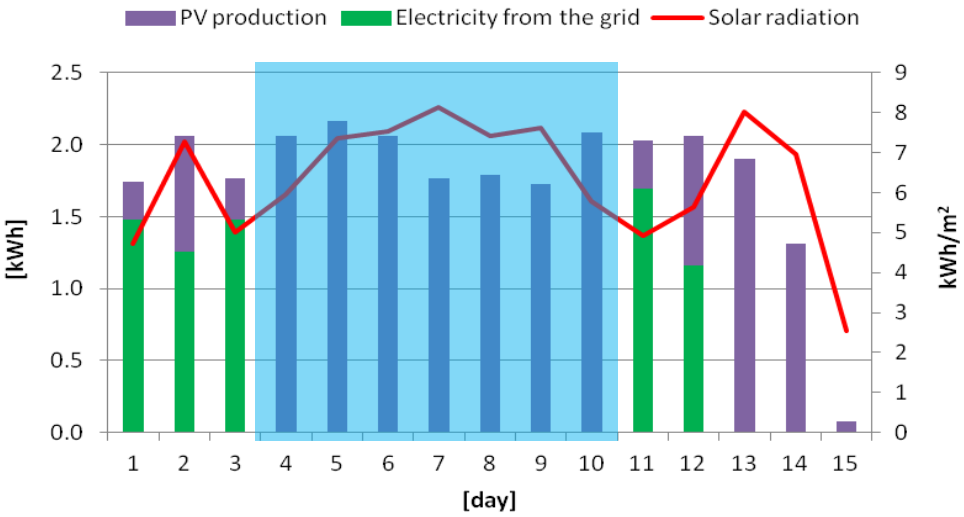
MID-TERM ENERGY PERFORMANCES: FREESCOO AT UNIPA



- 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

FREESCOO AT ENEA MID-TERM ENERGY PERFORMANCES





- Average EER = **8,2 NOT** taking into account the PV production
- Average EER_{grid} = **30.7** taking into account only the electricity taken from the grid
- Average thermal COP = **0,72**

- Seven days of continuous **stand-alone operation**
- 27% of electricity taken from the grid over the whole summer season
- 73% of electricity produced by PV

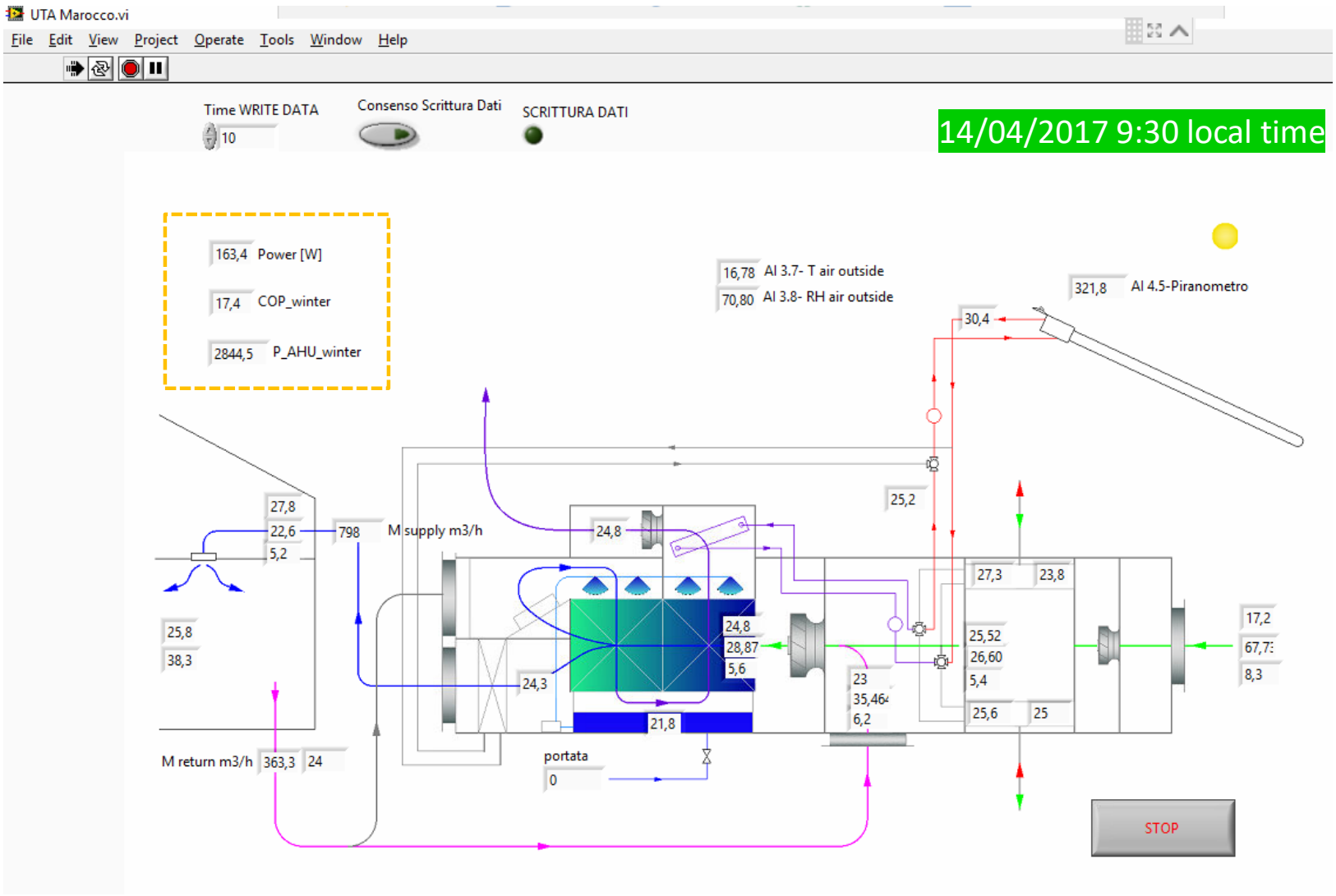
FREESCOO STAND ALONE PRESSO LA SEDE ENEA A LAMPEDUSA

FREESCOO AT AMEE IN MARRAKECH

FREESCOO AT AMEE IN MARRAKECH

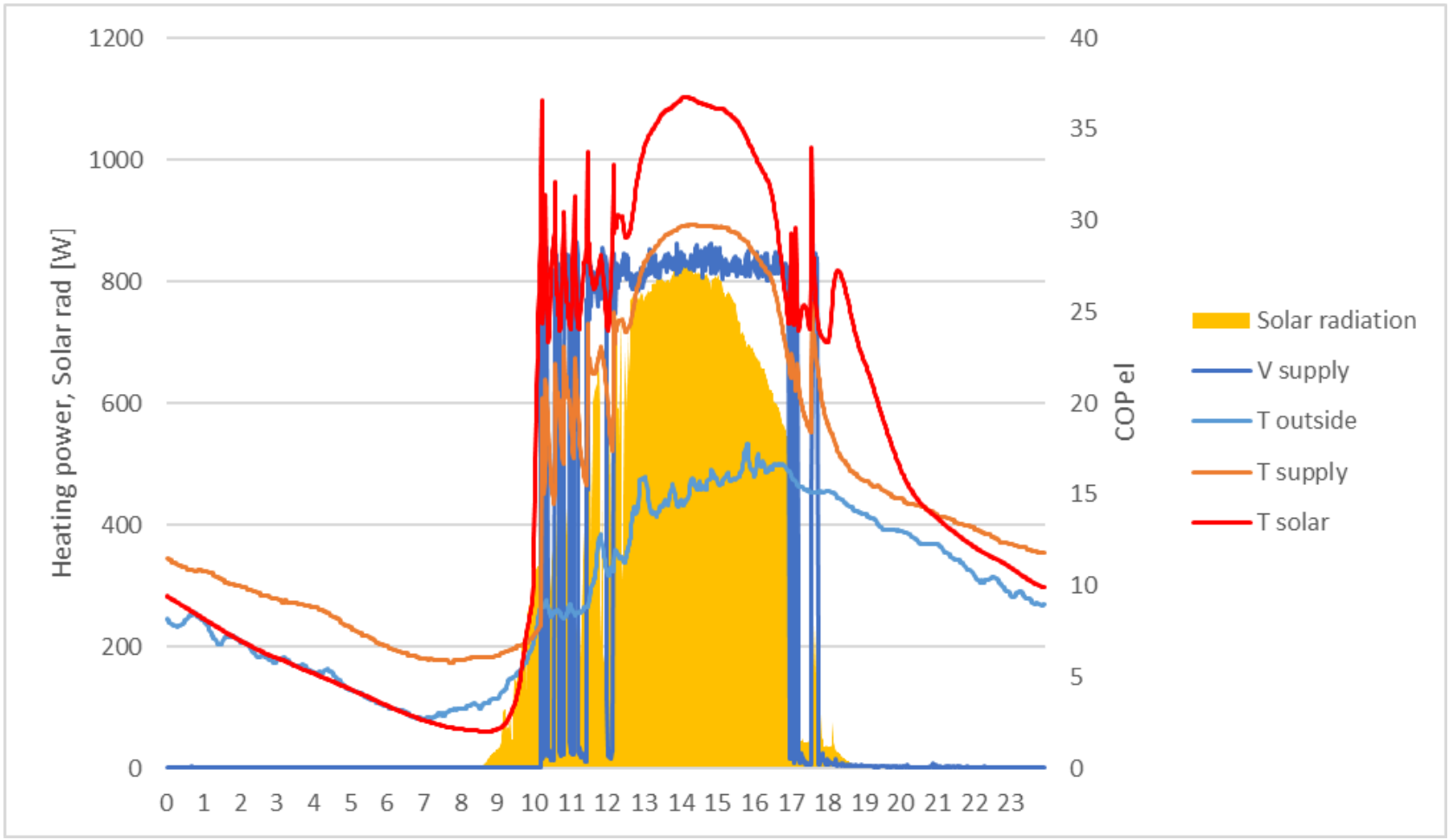
Monitoring results on cooling operation will be available after summer 2017

FREESCOO AT AMEE IN MARRAKECH



FREESCOO AT AMEE IN MARRAKECH

18/01/2017



FREESCOO AT AMEE IN MARRAKECH

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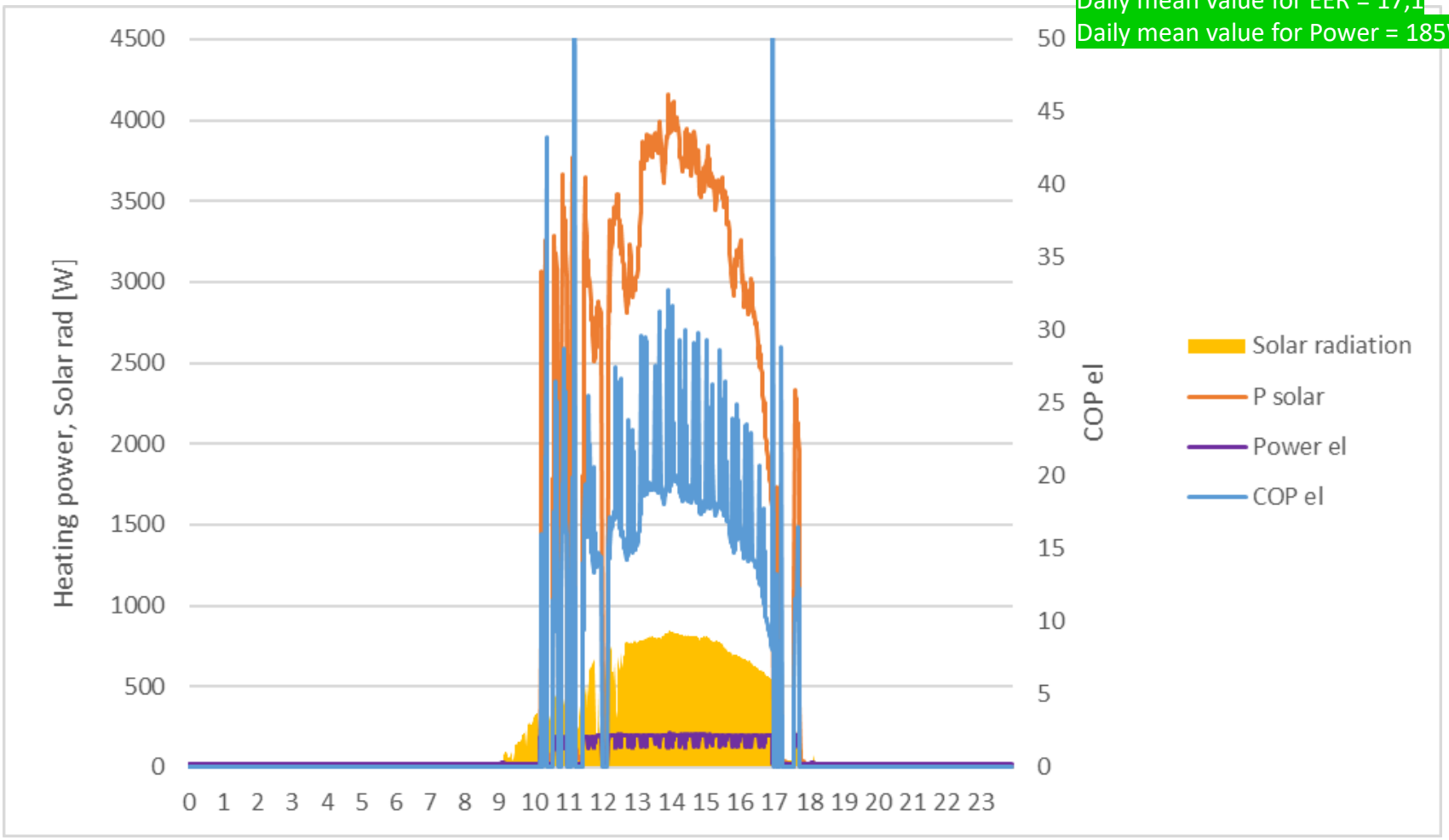
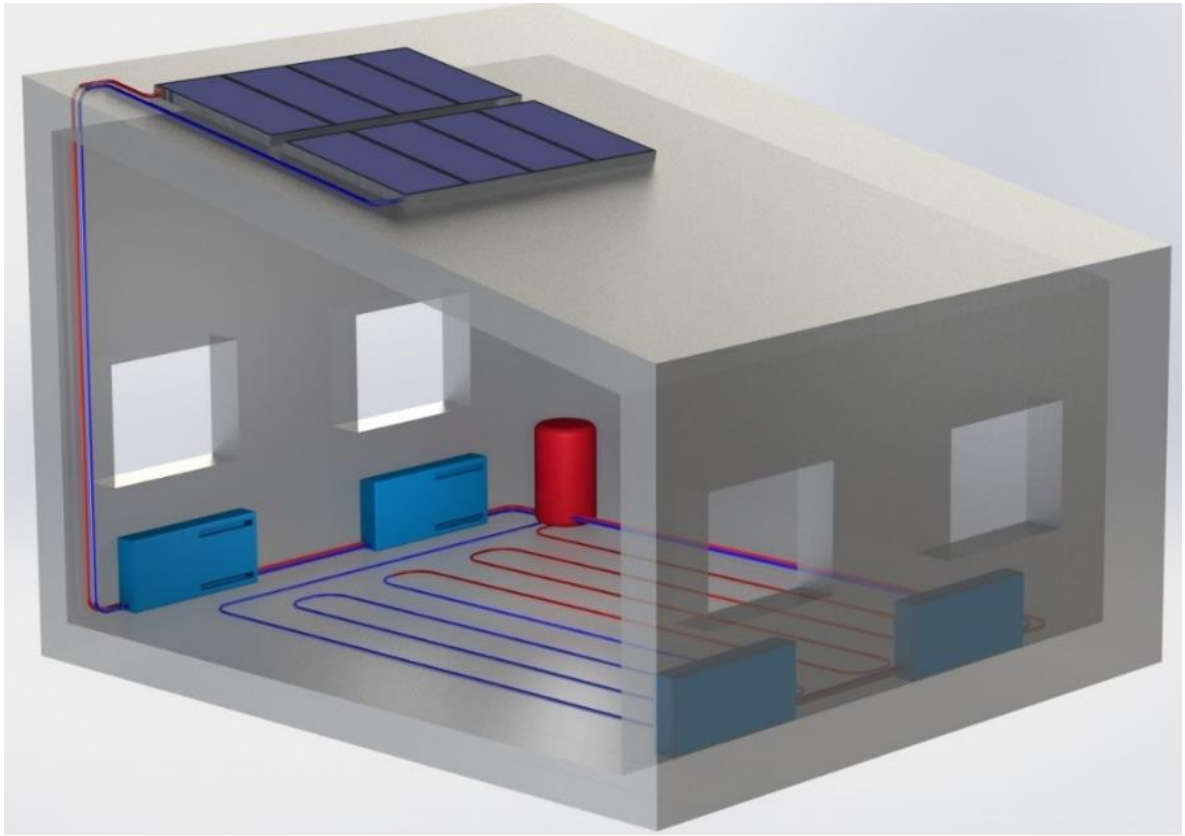
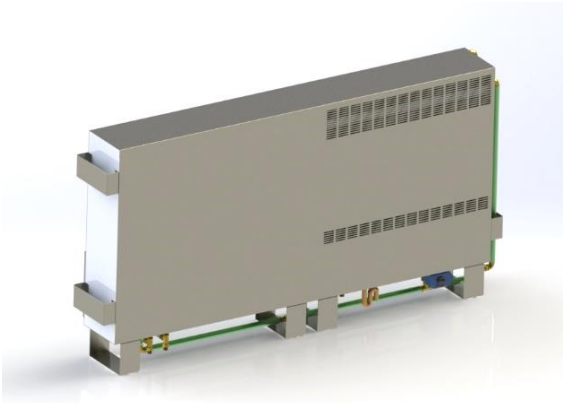
Daily mean value for EER = 17,1
Daily mean value for Power = 185W



FREESCOO COMPATTO PER INTEGRAZIONE IN FACCIATA



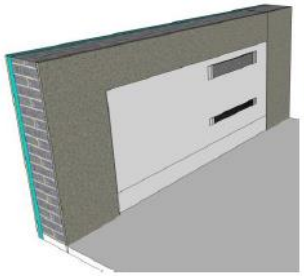


INTEGRATION INTO THE BUILDING ENVELOPE

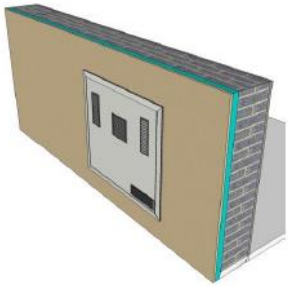
Connection proposals

1 

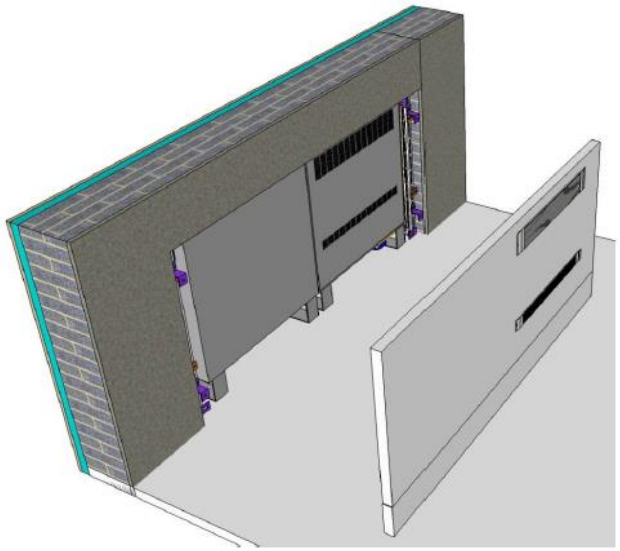
Completely embedded into the wall

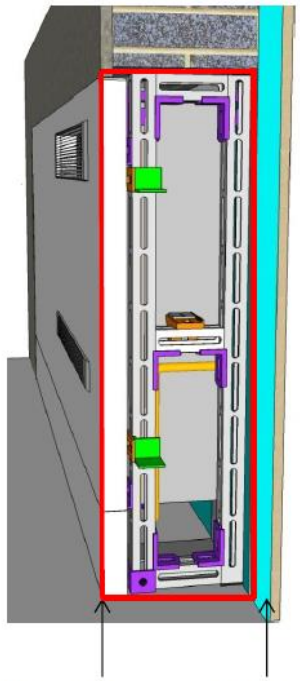


Interior View



External View



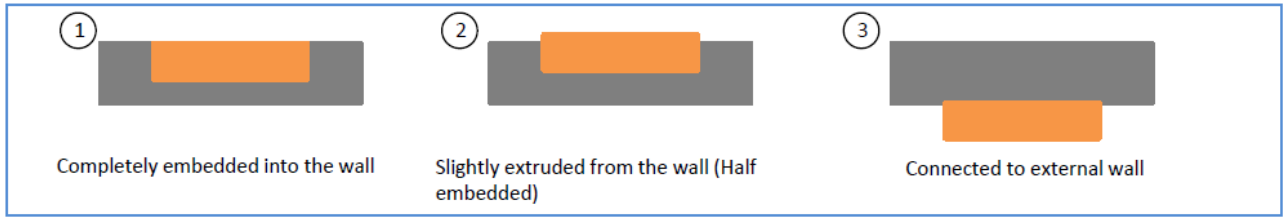


The frame system and Freescoo system

Fibran wall insulation product

INTEGRATION INTO THE BUILDING ENVELOPE

Connection proposals



1) Completely embedded into the wall
The frame system along with Freescoo HVAC system is inserted into the wall.
Advantage:
- The system to be levelled in-line with the internal wall.

Disadvantages:
- It is difficult to assemble on-site due to narrow gaps.
- Might affect U-value of the building due to the void on the wall element.

2) Slightly extruded from the wall (Half embedded)
The frame system along with Freescoo HVAC system is half embedded into the wall.
Advantage:
- It is easier to install on/site
- Minimized the impact on the building structure and the U-value of the building .

Disadvantages:
- There will be a "bay" like shape from the interior part of the room that formed by the design. (The interior wall might not levelled up in-line)

3) Connected to external wall
Advantage:
- Easy to install on-site
- Will not have any impact on the structure of the building.

Disadvantage:
- Only aesthetics of the design might be affected.
- Completely exposed into the external environment.

TECHNICAL DATA

Cooling performances	Compact stand alone rooftop unit	Compact facade system	Air handling units
Total cooling power	2,5 kW	2,5 kW	>5,5 kW
Thermal power to be supplied	–	2,0 kW	>4,0 kW
Air flow rate	500 m^3/h	500 m^3/h	>1000 m^3/h
Electrical power consumption	0,150 kW	0,200 kW	0,320 kW
Percentage of fresh air	33%	33%	33 – 100%
Water consumption at maximum power	4,5 l/h	4,5 l/h	9,9 l/h
EER	16,7	12,5	17,2

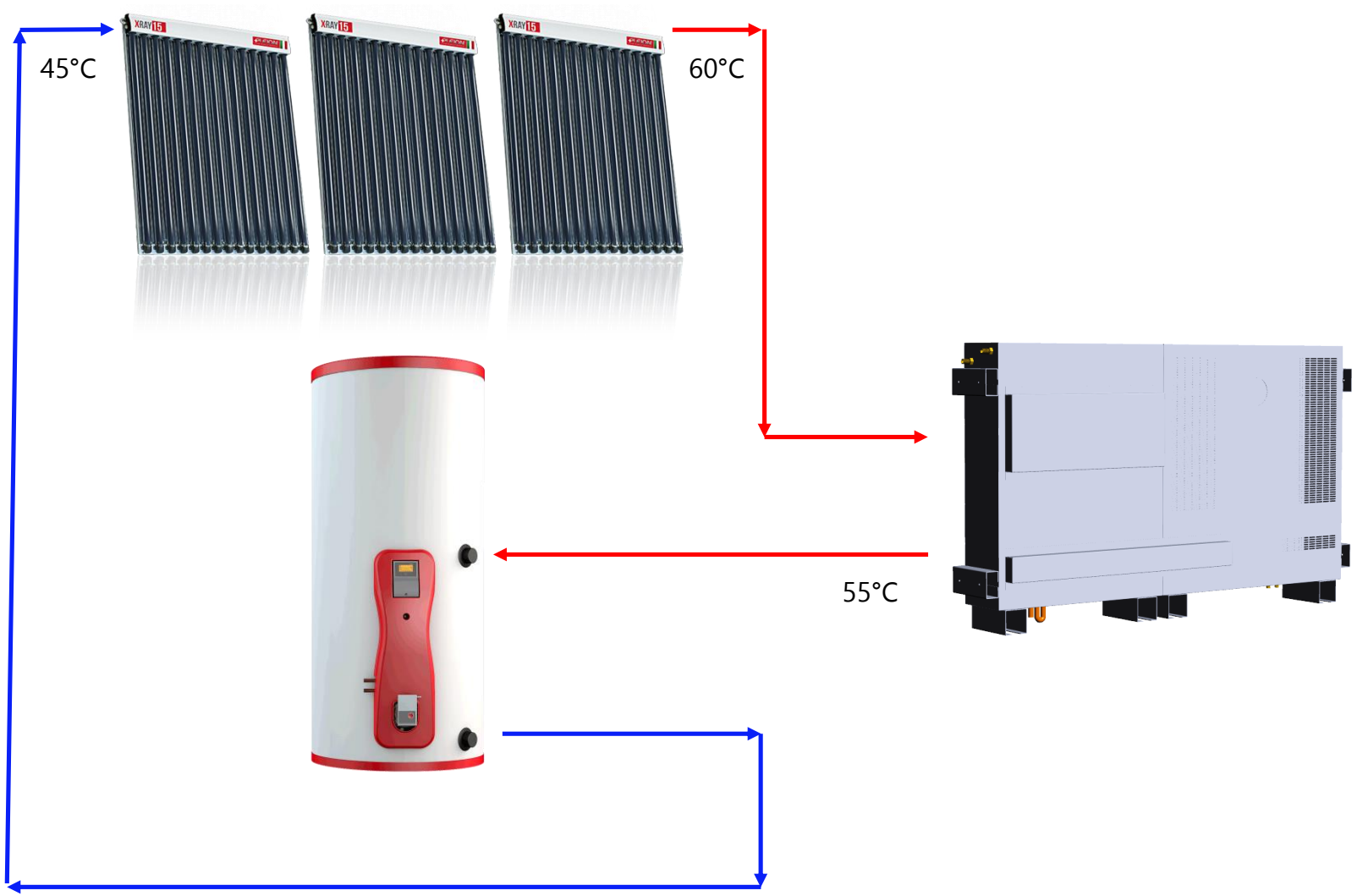
The data in cooling mode functioning are referred to an external air temperature of 35 ° C and a relative humidity of 45%, an internal temperature of 27 ° C and a relative humidity of 50% with the fan operating at maximum capacity. In no case the EER coefficient includes the production from photovoltaic.

TECHNICAL DATA

Heating performances	Compact stand alone rooftop unit	Compact facade system	Air handling units
Total heating capacity	1,5	4,7	>7,5
Thermal power to be supplied externally	–	3,0	>4,8
Electrical power consumption	0,05 kW	0,08 kW	0,18 kW
Air flow rate	500 m^3/h	500 m^3/h	>800 m^3/h
Percentage of fresh air	100%	100%	100%

The data in heating mode functioning are referred to an outdoor air temperature of 7 ° C and an internal temperature of 20 ° C with the fan operating at maximum capacity.

SOLAR THERMAL FOR DOMESTIC HOT WATER + FREESCOO



MAIN KEY PROPOSITIONS OF FREESCOO

- **Freescoo is the only compact open cycle (DEC) system** fed by low grade thermal energy and designed for cooling heating, dehumidification and ventilation of buildings
- **High EER** (measured 13, target > 15)
- **Energy savings** in a typical operating summer condition of: **50%** if compared to best-in class ductless mini split heat pumps; **70%** if compared to best-in class heat recovery ventilation systems and traditional split systems AC.
- **Thermal Efficiency >> 1** - Traditional DEC solutions based on adsorbent rotors have a thermal efficiency < 0.8 (absorption and adsorption chillers < 0,7)
- **Use of low grade thermal energy:** minimum temperature required for the operation of the system and in particular for the regeneration of the sorption material is **55°C**.
- **It can be integrated with existing residential heating distribution systems**
- **High sorption storage capacity:** the adsorption capacity of the desiccant material and, at the same time, the high mass of adsorbent hosted in the adsorption beds, allow to store solar thermal energy. If during the day the solar collectors have regenerated the adsorbent beds, in the evening the system can **keep working for 3-5 hours without heat supply**.
- **Simple construction, no use of harmful fluids, plug and play**
- Freescoo can also work as completely **stand-alone** system without grid connection using a small PV
- **Cost effective (target price 2000€/kW without solar) and competitive** in comparison to other HVAC and heat recovery ventilation systems on the market

TRNSYS SIMULATIONS: FREESCOO VS CONVENTIONAL HVAC

Main hypothesis on the analysis:

- Energy performances analyzed using a Freescoo unit simulation model developed in **TRNSYS**.
- Building type: **surface 25 m²**, occupation pattern office/residential, medium construction quality, south exposition
- An area of **3 m² of evacuated tube solar collectors** was considered in all the cases
- Direct connection between the solar collectors and the Freescoo HVAC unit (no tank for heat storage included)
- In the wintertime an **auxiliary heat pump (COP=3)** was considered to provide heat when solar heat is not sufficient
- Electricity bill for the benchmark system calculated on the basis of the same cooling/heating energy delivered by the Freescoo HVAC unit and the EER/COP given by the manufacturer
- A price of **0,25 €/kWh** was assumed in the calculation of the money savings
- 6 different locations considered (**Milan, Rome, Palermo, Marrakech, Barcelona, Berlin**) in order to assess Freescoo energy performances in both hot and intermediate climates
- The summer cycle is from June to September, whereas the winter cycle is from October to May
- system operated only from 8:00 to 18:00 (**10h – 7/days a week**), for a total of **3650** operating hours
- In summertime set points for temperature and relative humidity are respectively **26°C and 50%**
- In wintertime set points for temperature is **20°C**, no humidity control was performed; if the room temperature exceeds 23°C the use solar heat is stopped.

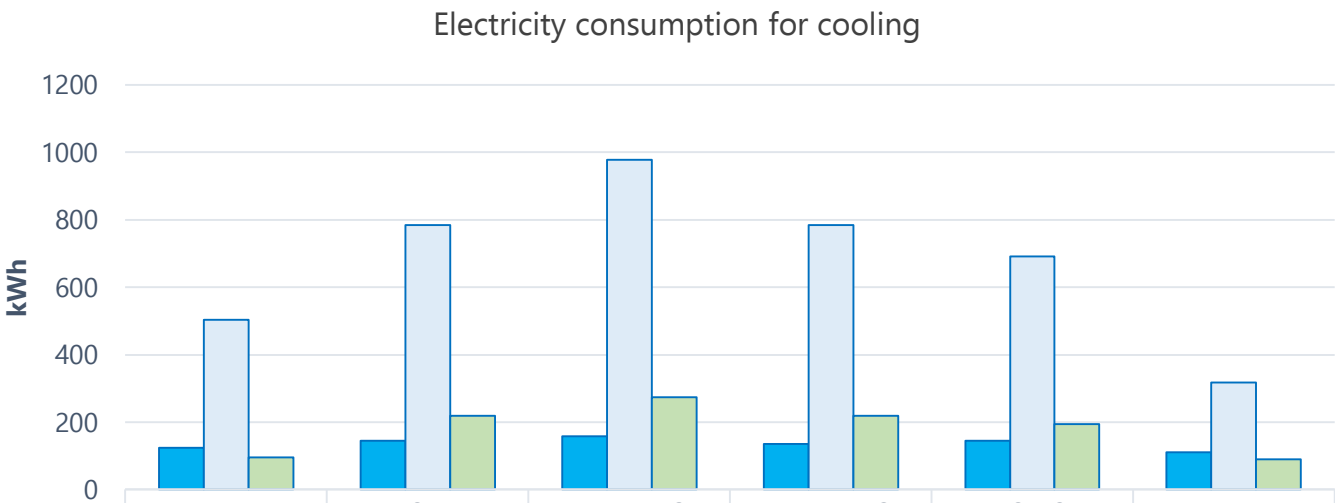
COST COMPARISON FREESCOO VS CONVENTIONAL HVAC

Results of simulation carried out in TRNSYS

Office 80 m^3 – air change 3 vol/h

Solar collector area 3 m^2

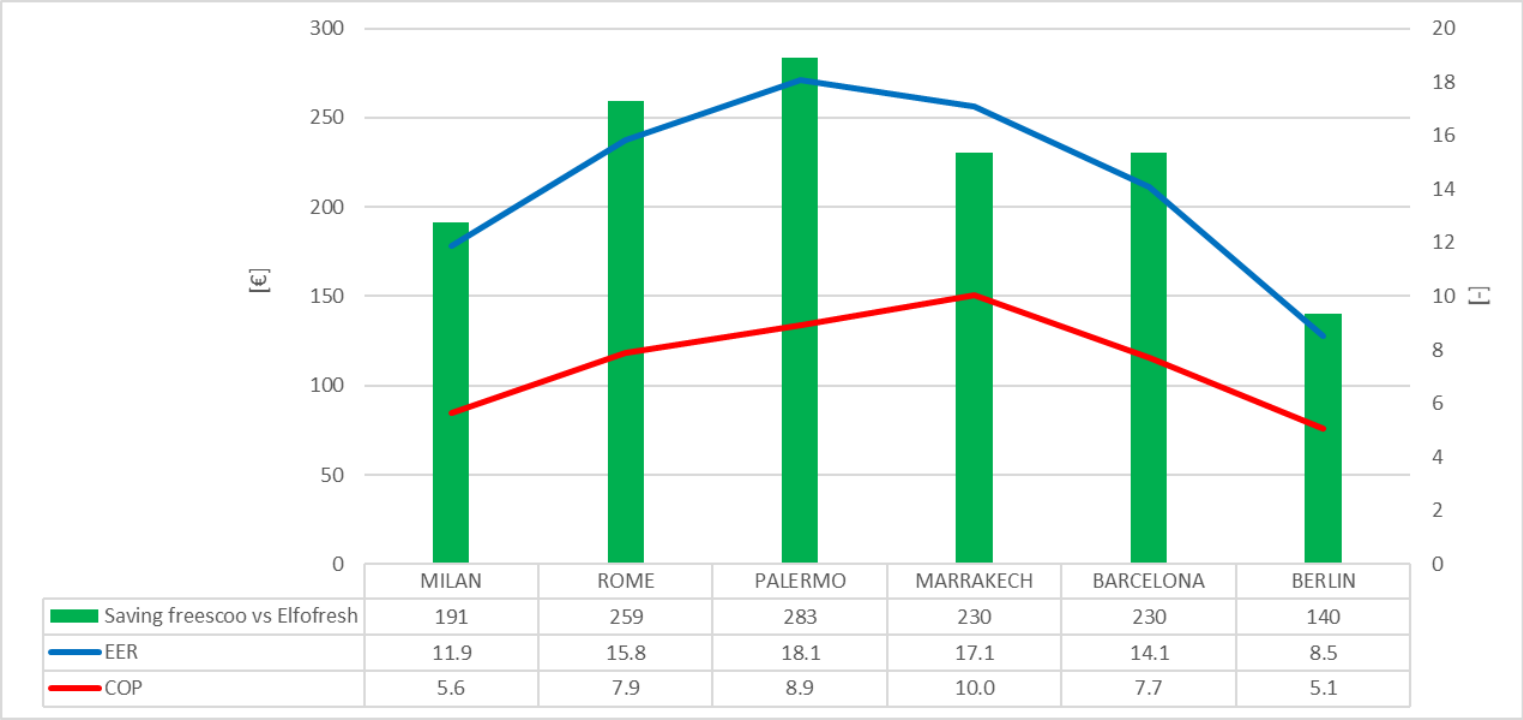
10 h operation per day



	MILAN	ROME	PALERMO	MARRAKECH	BARCELONA	BERLIN
freescoo	124	146	159	135	145	110
Elfofresh 300	503	785	978	785	692	318
Heatcharge VZ	96	220	274	220	194	89

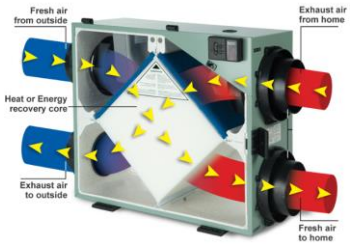
COST COMPARISON FREESCOO VS CONVENTIONAL HVAC

Results of simulation carried out in TRNSYS



	MILAN	ROME	PALERMO	MARRAKECH	BARCELONA	BERLIN
Saving freescoo vs Elfofresh	191	259	283	230	230	140
EER	11.9	15.8	18.1	17.1	14.1	8.5
COP	5.6	7.9	8.9	10.0	7.7	5.1

COST COMPARISON FREESCOO VS CONVENTIONAL HVAC



Model (Company)	ELFOFresh 300 (Clivet)	FREESCOO (SolarInvent)
Technology	Heat recovery ventilation system	**DEC + advanced evaporative cooling**
Functions	Cooling, Dehumidification, Ventilation, Heating	**Cooling, Dehumidification, Ventilation, Heating**
Driving Power	Electricity	**Heat (T>55°C)**
Installation type	Roof mounted	**Integrated in building facade**
List Price	€5500	**€5000**
Refrigerant / GWP	R410A / 2088	**Water / 0**
Cooling capacity	2,1KW	**2,5 KW**
Cooling power input	0,714KW	**0,2 KW** (electricity needed to operate the fans)
Seasonal EER	2,94 (average)	**10h per day - From 8,5 (Berlin) to 18,1 (Palermo)** **24h per day - From 7,2 (Berlin) to 19,8 (Palermo)**
Heating capacity	2,31KW	**3 KW**
Heating power input	0,624 KW	**0,08 KW** (electricity needed to operate the fans)
Seasonal COP*	3,70 (average)	**10h per day - From 5,1 (Berlin) to 10 (Marrakech)** **24h per day - From 5,4 (Berlin) to 8,9 (Marrakech)**

CONTRIBUTIONS TO TASK 53

- Subtask A - Provide data input for the LCA
- Subtask B - Provide data and simulation results (Trnsys)
- Subtask C - Monitoring data coming from the demo projects

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