SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Latest developments of the freescoo project

Marco Beccali, Prof. Eng.
TASK 53 IEA
ABU DHABI, UAE, 29.10.2017

Task 53

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:

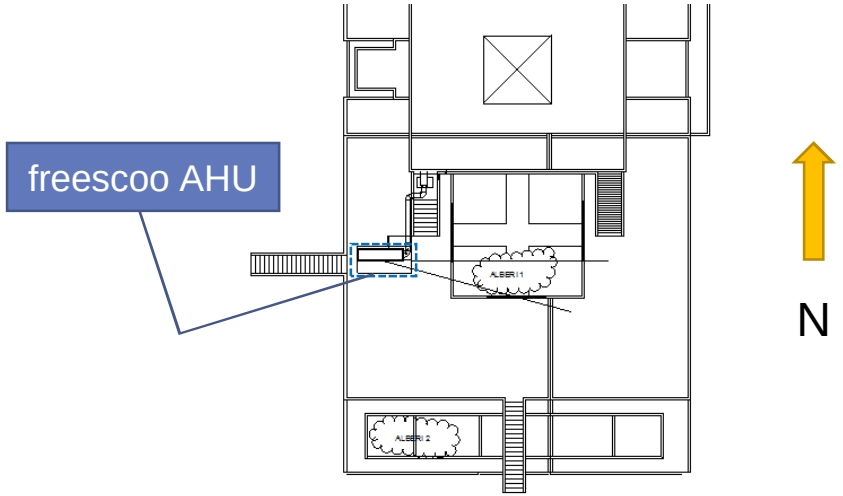
- Use of water as refrigerant and heat as main energy input
- Use of the Cooled Packed Bed (CPB) technology and high efficiency evaporative cooling concepts
- Low grade solar heat (50-60°C) to drive the cooling process
- High global electrical efficiency (Typical EER >10)
- Preassembled and ready to be installed
- Several system configurations possible

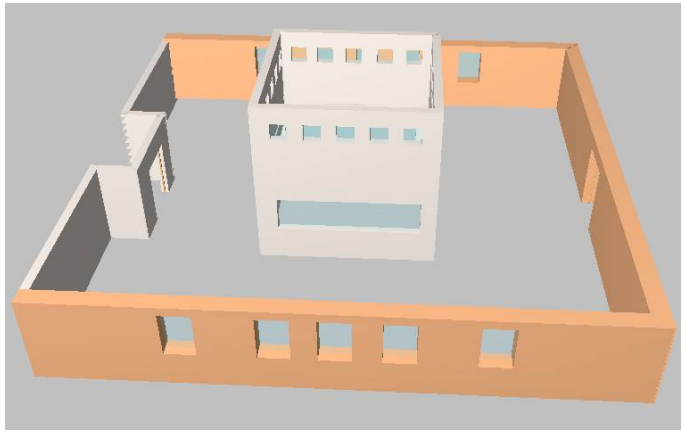
Freescoo is a patented solution by the startup company SOLARINVENT

Description of the project

The library at AMEE in Marrakech

MAIN BUILDING DATA	
Internal area	300 m^2
Existing air distribution system	plaster air ducts
Installed cooling power of split system	18 kW
Existing HVAC system	Ventilation AHU + split system
Occupation pattern	Library 9:00 -16:00





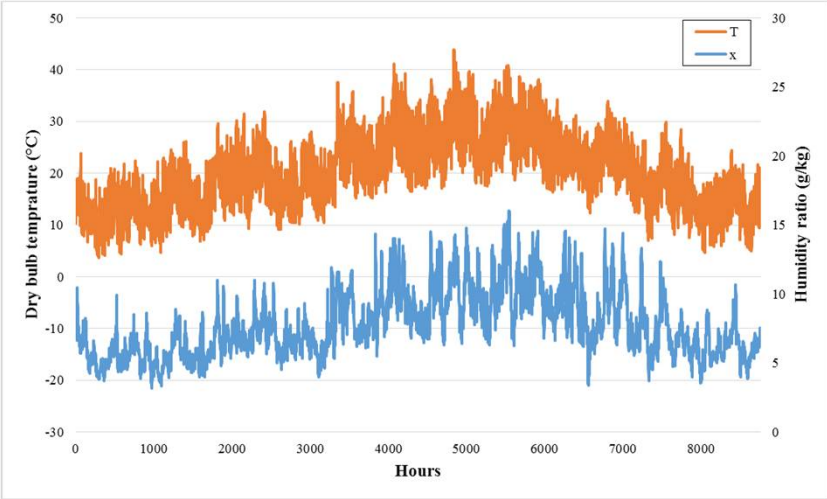
Description of the project

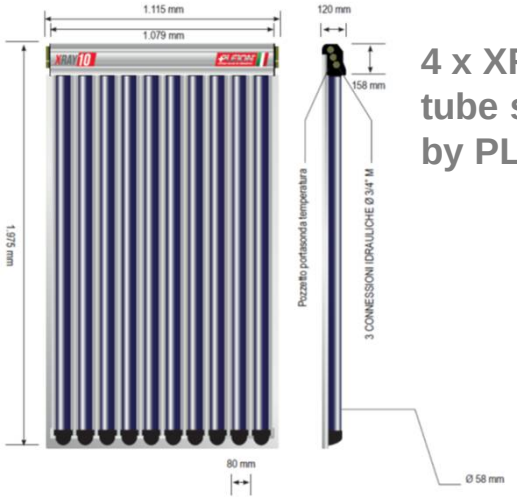
System installed in November 2016
Monitoring data available from 10.2016 to 10.2017

Design of the freescoo AHU

Description		
Supply air flow rate	0-1000	m³/h
Rate of fresh air	50	%
Total max cooling power	5800	W
Heating power required for the regeneration	3000	W
Installed solar collector power	4800	W
Power absorbed	360	W
Thermal COP	1.9	[-]
EER	16,7	[-]

Performance at design summer conditions typical for Marrakech ($T_{outside}$ = 45°C x $_{outside}$ = 10,5 g/kg, T bui = 27°C x $_{bui}$ = 10,5 g/kg)



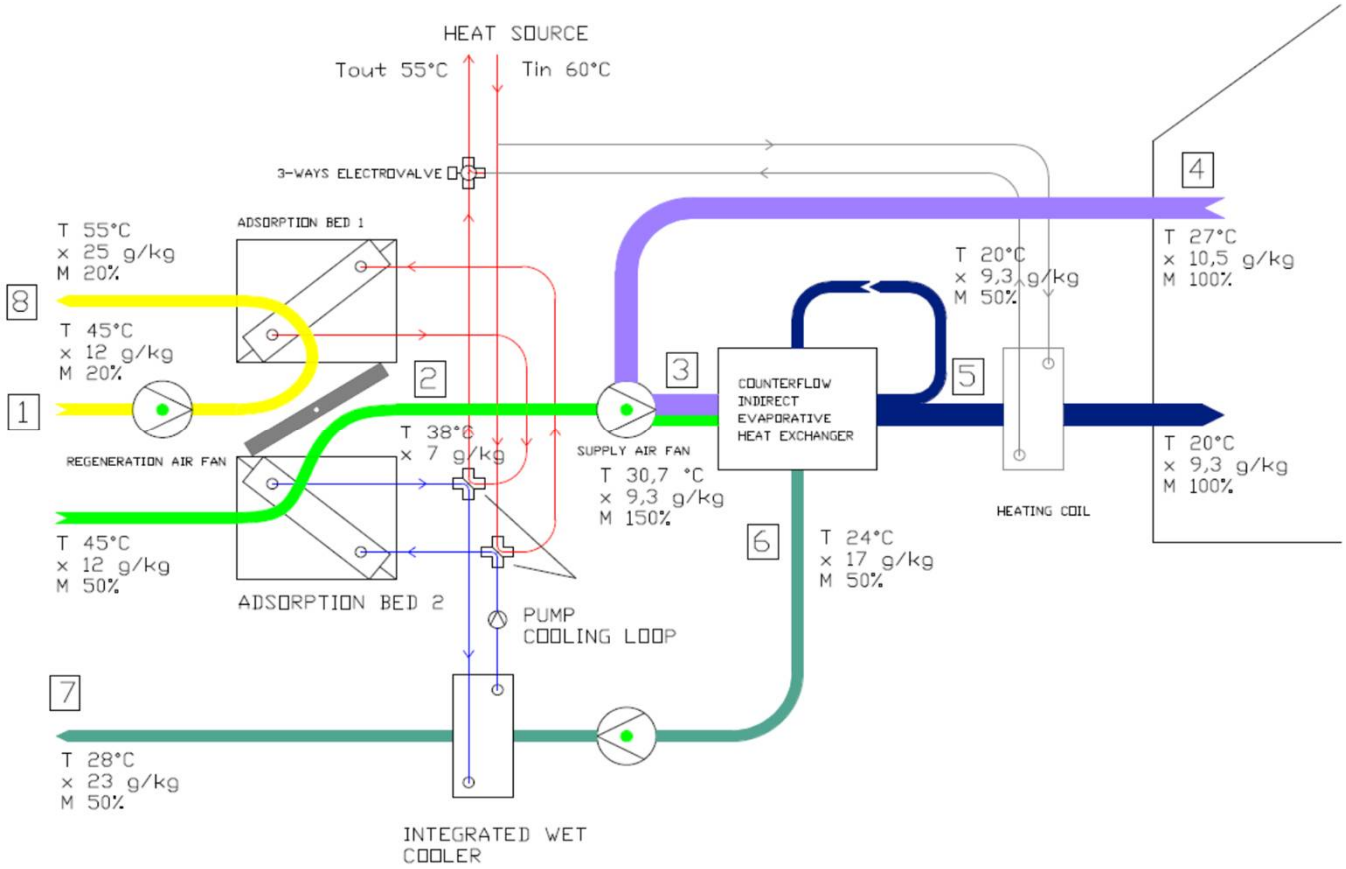


4 x XRAY 10 evacuated tube solar collectors by PLEION

SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

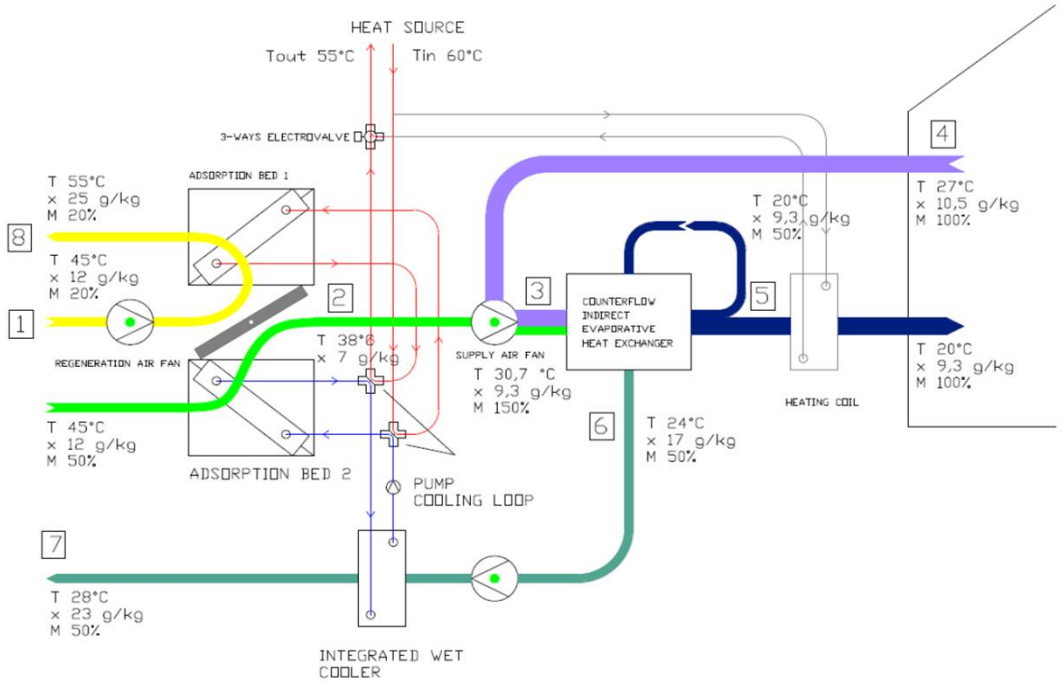
Thermodynamics

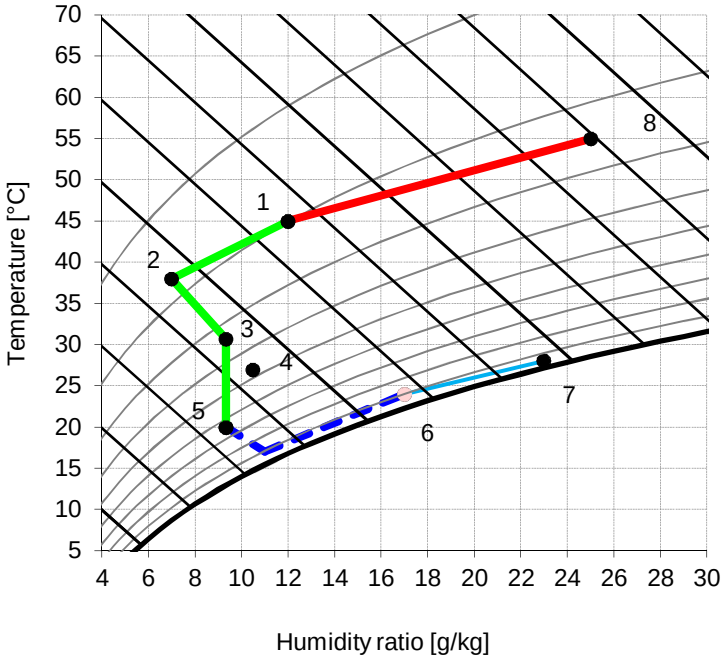
Summer cycle



Thermodynamics

Summer cycle

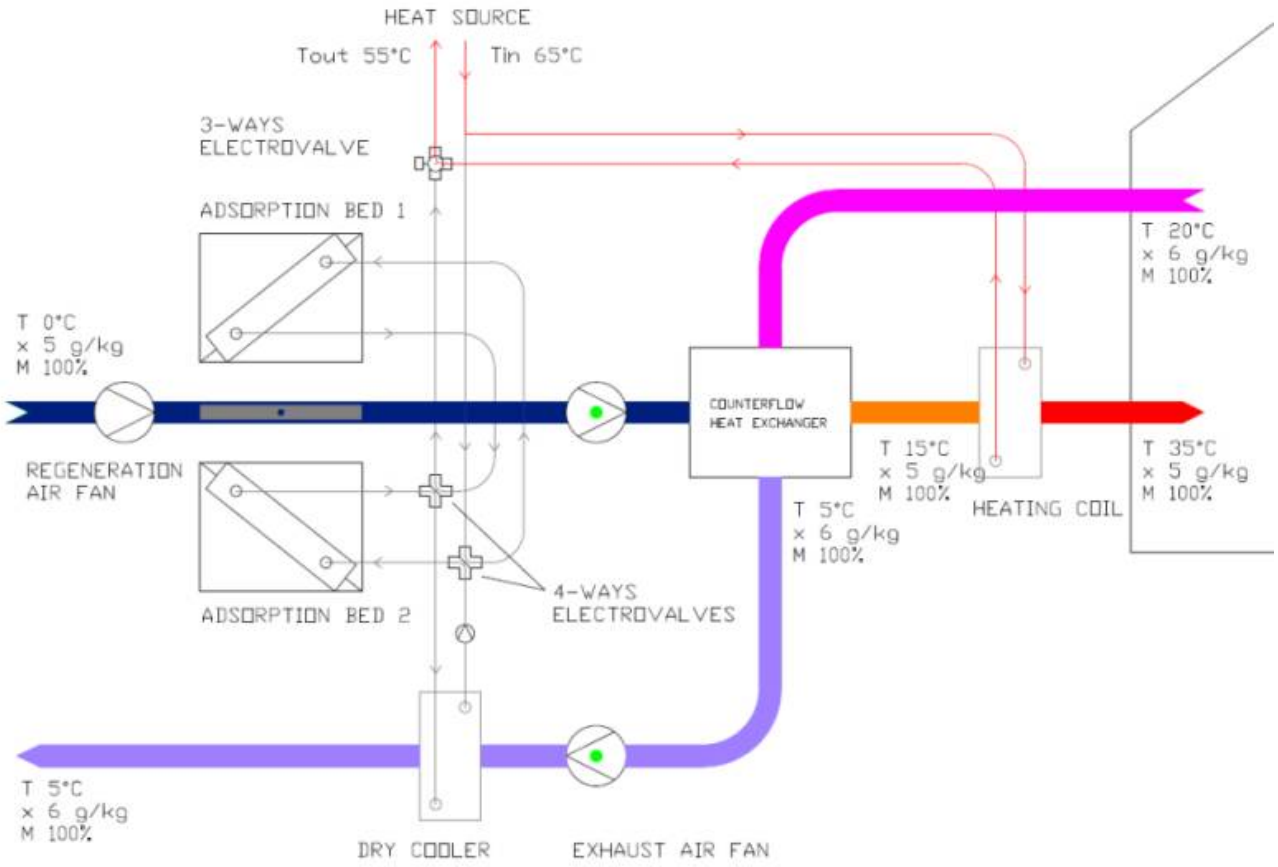




Description	x	T	h	Pos.
-	g/kg	°C	kJ/kg	-
Outside air	12	45.0	76.2	1
Outlet ADS bed	7.0	38.0	56.2	2
Mixing	9.3	30.7	54.7	3
Outlet EVA HX	9.3	20	43.8	5
Building	10.5	27.0	53.9	4
Inlet EVA – sec. side	9.3	20.0	43.8	4
Outlet EVA – sec. side	17	24	67.4	6
Outlet wet cooler	23.0	28.0	86.8	7
Outside air	12.0	45.0	76.2	1
Regeneration	25.0	55.0	120.3	8

Thermodynamics

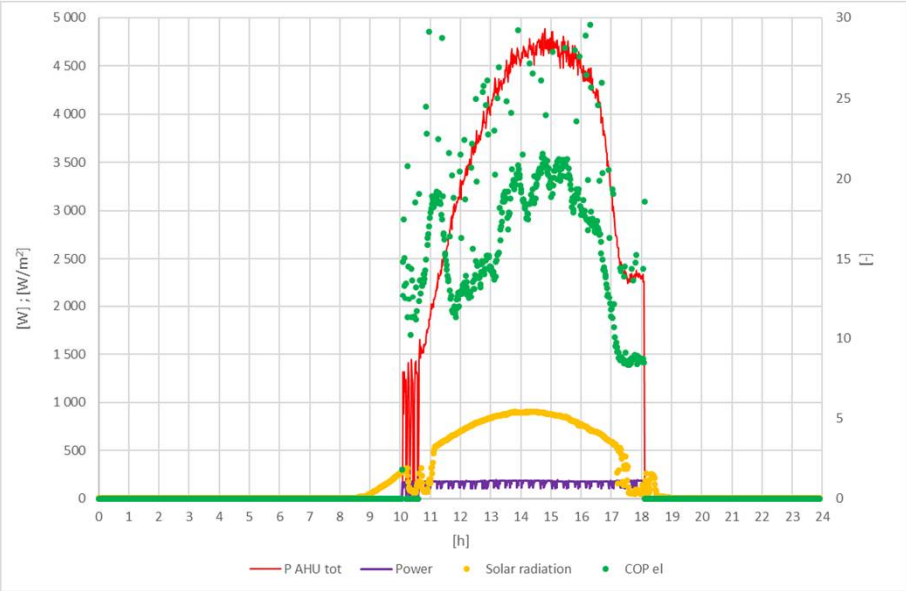
Winter cycle

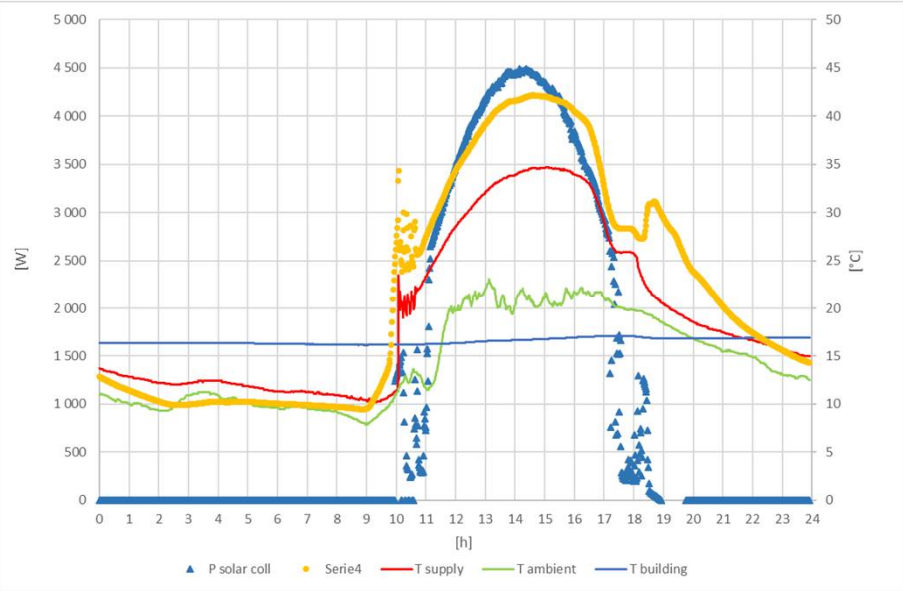


Energy performance

Results for a day 1 in Winter

03/02/2017





Electricity consumed	1.31kWh
Solar radiation	40.6kWh
Heat produced by the AHU	22.0kWh
Heat delivered to the building	27.8kWh
Heat produced by solar collectors	25.3kWh
Operation hours	7.9h
COP el	16.8[-]
Eff coll	62%[-]

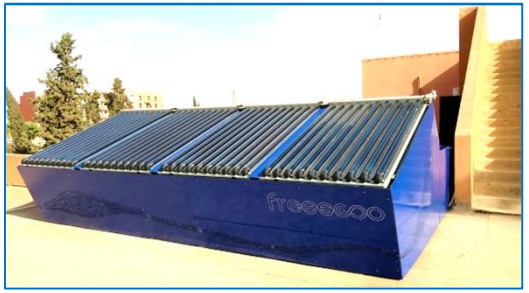
COP el = 16,8

Energy performance

Seasonal results and comparison with a conventional HVAC for Winter

Dec – Jen 2017

Thermal energy - AHU	kWh	960
Thermal energy - BUI	kWh	1109
Average flow rate	m3/h	623
Incident solar radiation	kWh	2008
Solar collector heat	kWh	1235
Electricity consumed	kWh	90
Specific power consumption for ventilation	W/m³/h	0.35
Hours of operation	h	412
EER	[-]	10.7
COP th	[-]	0.78
Eff. solar collector	[-]	61%



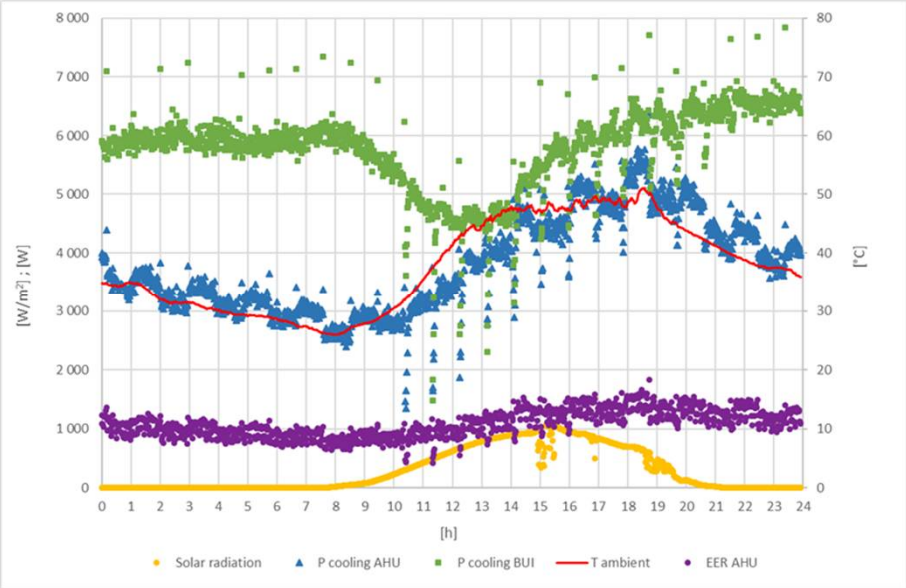
Energy saving assessment

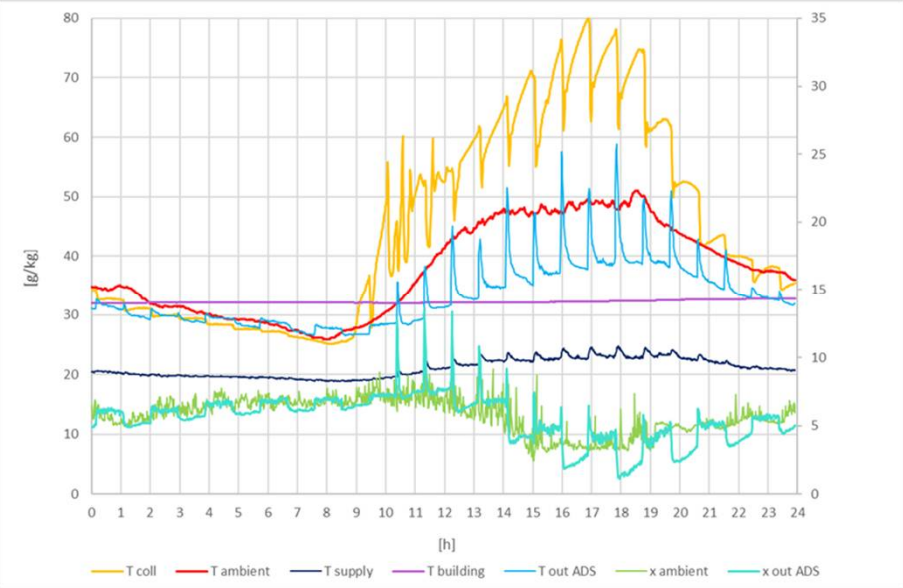
EER chiller		3
Electricity consumed by the chiller	kWh	320
Specific power consumption for ventilation	W/m3/h	0.30
Electricity consumed for ventilation	kWh	77
Total electricity consumed	kWh	397
Electricity saving		**77%**

Energy performance

Results for a day 1 in Summer

16/07/2017



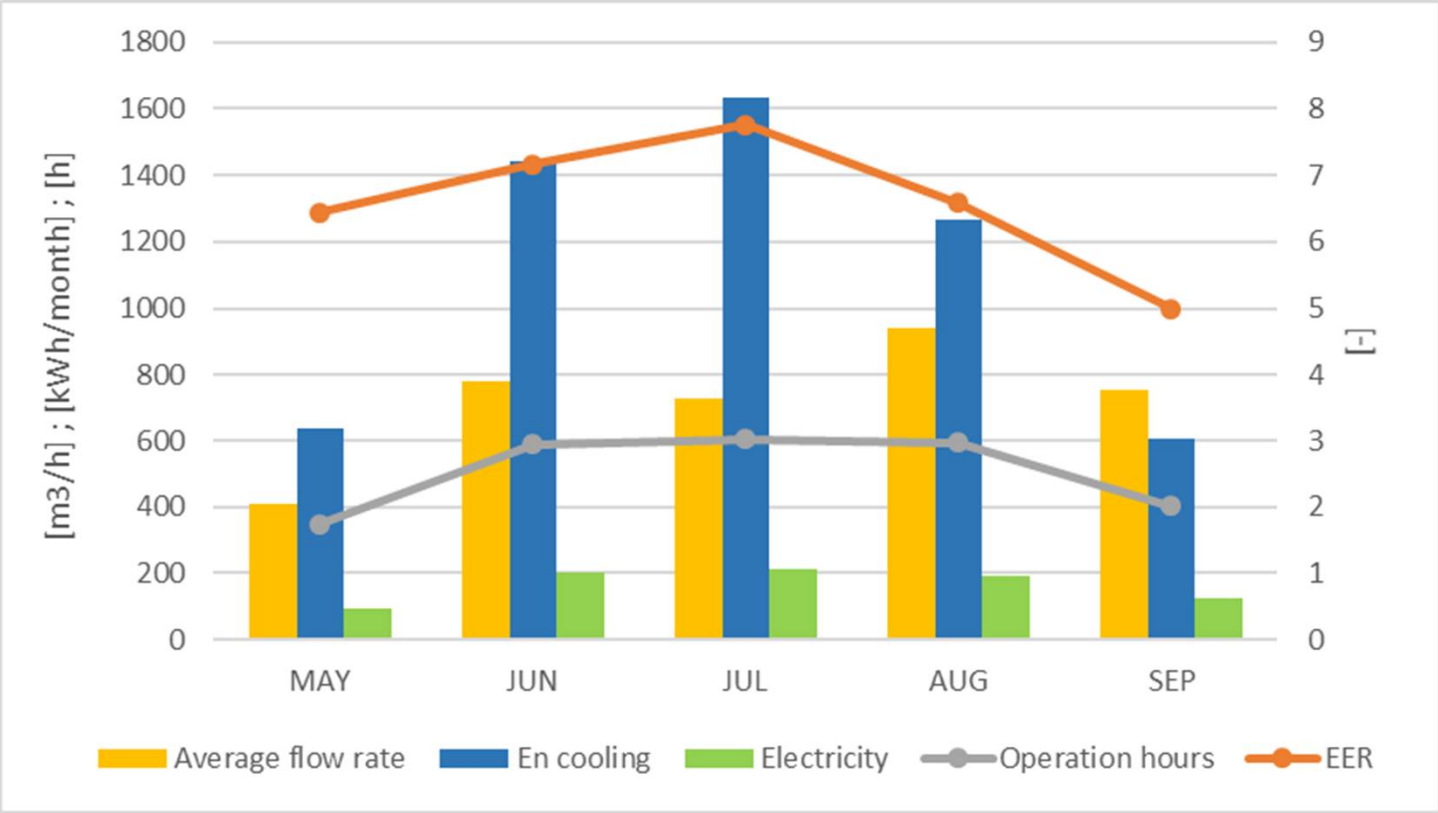


Cooling energy - AHU	kWh	87
Cooling energy - BUI	kWh	117.5
Average flow rate	m3/h	883
Incident solar radiation	kWh	46.6
Solar collector heat	kWh	27.8
Electricity consumed	kWh	8.4
Specific power consumption for ventilation	W/m³/h	0.40
Hours of operation	h	24
EER	[-]	10.4
COP th	[-]	3.14
Eff. solar collector	[-]	60%

EER = 10,4

Energy performance

Seasonal performance results for Summer

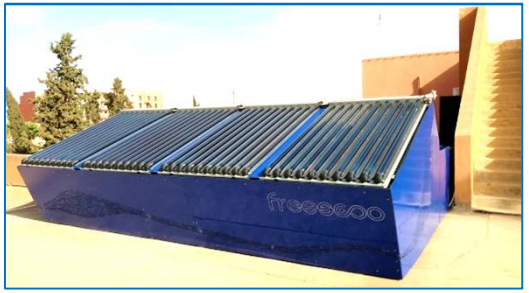


SHC SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY

Energy performance

Seasonal results and comparison with a conventional HVAC for summer

		May - Sep 2017
Cooling energy - AHU	kWh	5589
Cooling energy - BUI	kWh	2390
Average flow rate	m3/h	717
Incident solar radiation	kWh	6868
Solar collector heat	kWh	3973
Electricity consumed	kWh	825
Specific power consumptio for ventilation	W/m³/h	0.453
Hours of operation	h	2538
EER	[-]	6.8
COP th	[-]	1.41
Eff. solar collector	[-]	58%



Energy saving assessment

EER chiller		3
Electricity consumed by the chiller	kWh	1863
Specific power consumption for ventilation	W/m³/h	0.30
Electricity consumed for ventilation	kWh	546
Total electricity consumed	kWh	2409
Electricity saving		**66%**

Energy performance

Yearly results and comparison with a conventional HVAC for summer

		Cooling	Heating	Year
Thermal energy - AHU	kWh	5527	960	6487
Thermal energy - BUI	kWh	2250	1109	3359
Average flow rate	m3/h	714	623	668
Incident solar radiation	kWh	6859	2008	8867
Solar collector heat	kWh	3966	1235	5200
Electricity consumed	kWh	820	90	910
Seasonal water consumption	m3	11.6	0	11.6
Daily mean water consumption	liters/day	83	0	
Specific power consumption for ventilation	$W/m^3/h$	0.46	0.35	0.40
Hours of operation	h	2524	412	2937
Day of operation	day	139	59	198
EER	[-]	6.7	11	7.1
COP th	[-]	1.39	0.78	
Eff. solar collector	[-]	58%	61%	59%

Energy saving assessment

EER chiller		3
Electricity consumed by the chiller/HP	kWh	2162
Specific power consumption for ventilation	W/m3/h	0.30
Electricity consumed for ventilation	kWh	589
Total electricity consumed	kWh	2751
Electricity saving		**70%**

TASK 53 tool

Summary report for system in Morocco

Perfomances Figures					
Technical key figures		**T53 Standard**		**specific values**	
Electrical equivalent SPF	SPFequ Cooling	7.42	-	7.42	-
	SPFequ Solar Cooling	10.24	-	10.24	-
	SPFequ Cooling Grid	0.00	-	0.00	-
	SPFequ Solar Cooling Grid	0.00	-	0.00	-
	SPFequ DHW	0.00	-	0.00	-
	SPFequ Solar DHW	0.00	-	0.00	-
	SPFequ Space Heating	0.00	-	0.00	-
	SPFequ Solar Space Heating	0.00	-	0.00	-
	SPFequ Heating Grid	5.77	-	5.77	-
	SPFequ Solar Heating Grid	3.33	-	3.33	-
	SPFequ System	7.12	-	7.12	-
Economic key figures					
Investment costs SHC System	Total investment	34 337.24	€	18 232.80	€
	Annualized costs	2 395.69	€/a	1 208.36	€/a
	Costs per kW cold	5 920.21	€/kWc	3 143.59	€/kWc
	Costs per m² floor area	171.69	€/m²	91.16	€/m²
Investment costs Reference System	Total investment	11 718.16	€	8 667.00	€
	Annualized costs	1 406.12	€/a	984.78	€/a
	Costs per kW cold	2 020.37	€/kWc	1 494.31	€/kWc
	Costs per m² floor area	58.59	€/m²	43.34	€/m²
Energy Costs					
SHC System		0.37	€/kWh	0.19	€/kWh
Reference System		0.22	€/kWh	0.15	€/kWh
Cost Ratio		1.70	-	1.23	-
Avoidance costs					
Primary energy		0.16	€/kWhprim	0.12	€/kWh
CO2		0.71	€/kg CO2	0.39	€/kg CO2

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

TASK 53 tool

Summary report for system UNIPA in Lampedusa

Perfomances Figures

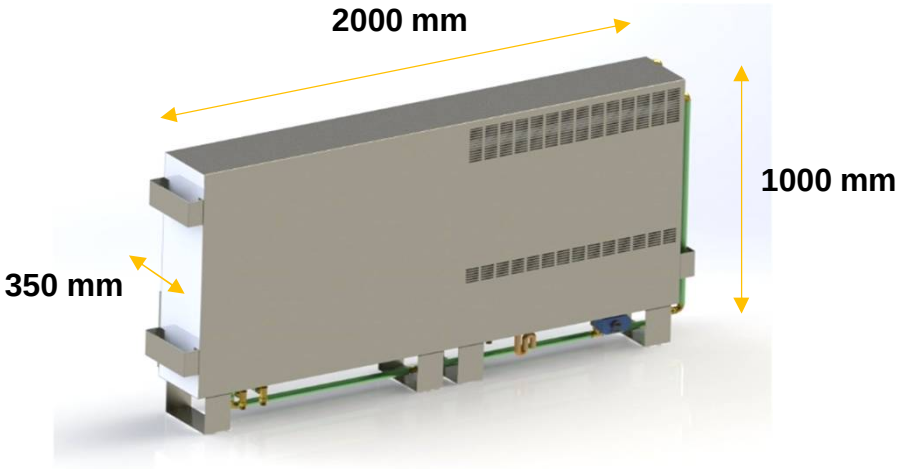
Technical key figures		T53 Standard		specific values	
Electrical equivalent SPF	SPFequ Cooling	61.55	-	61.55	-
	SPFequ Solar Cooling	62.75	-	62.75	-
	SPFequ Cooling Grid	0.00	-	0.00	-
	SPFequ Solar Cooling Grid	0.00	-	0.00	-
	SPFequ DHW	0.00	-	0.00	-
	SPFequ Solar DHW	0.00	-	0.00	-
	SPFequ Space Heating	61.55	-	61.55	-
	SPFequ Solar Space Heating	56.91	-	56.91	-
	SPFequ Heating Grid	0.00	-	0.00	-
	SPFequ Solar Heating Grid	0.00	-	0.00	-
	SPFequ System	61.55	-	61.55	-
Economic key figures					
Investment costs SHC System	Total investment	12 651.71	€	4 792.00	€
	Annualized costs	832.09	€/a	303.83	€/a
	Costs per kW cold	5 060.69	€/kWc	1 916.80	€/kWc
	Costs per m² floor area	281.15	€/m²	106.49	€/m²
Investment costs Reference System	Total investment	6 496.39	€	3 644.55	€
	Annualized costs	607.32	€/a	376.81	€/a
	Costs per kW cold	2 598.55	€/kWc	1 457.82	€/kWc
	Costs per m² floor area	144.36	€/m²	80.99	€/m²
Energy Costs					
SHC System		1.26	€/kWh	0.46	€/kWh
Reference System		0.92	€/kWh	0.57	€/kWh
Cost Ratio		1.37	-	0.81	-
Avoidance costs					
Primary energy		0.35	€/kWhprim	-0.16	€/kWh
CO2		1.56	€/kg CO2	-0.63	€/kg CO2

SPFequ Heating Grid 0.00 - 0.00 -
SPFequ Solar Heating Grid 0.00 - 0.00 -
SPFequ System 61.55 - 61.55 -
Economic key figures
Investment costs SHC System Total investment 12 651.71 € 4 792.00 €
Annualized costs 832.09 €/a 303.83 €/a
Costs per kW cold 5 060.69 €/kWc 1 916.80 €/kWc
Costs per m² floor area 281.15 €/m² 106.49 €/m²
Investment costs Reference System Total investment 6 496.39 € 3 644.55 €
Annualized costs 607.32 €/a 376.81 €/a
Costs per kW cold 2 598.55 €/kWc 1 457.82 €/kWc
Costs per m² floor area 144.36 €/m² 80.99 €/m²
Energy Costs
SHC System 1.26 €/kWh 0.46 €/kWh
Reference System 0.92 €/kWh 0.57 €/kWh
Cost Ratio 1.37 - 0.81 -
Avoidance costs
Primary energy 0.35 €/kWhprim -0.16 €/kWh
CO2 1.56 €/kg CO2 -0.63 €/kg CO2

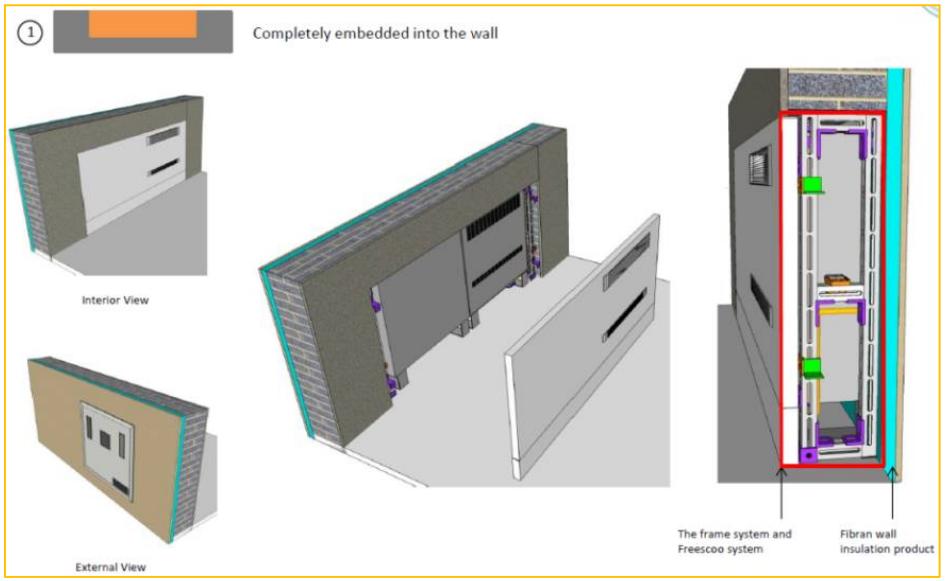
Last freescoo project

Freescoo façade

Description		
Supply air flow rate	0-500	m^3/h
Rate of fresh air	50	%
Total max cooling power	2500	W
Heating power required for the regeneration	2000	W
Installed solar collector power	2400	W
Power absorbed	200	W
Thermal COP	1.25	[-]
EER	12,5	[-]



- Designed for building integration
- Regeneration based on water
- Integration possible with different heat sources (gas boiler, heat pump, district heating, waste heat source)



Last freescoo project

Freescoo at ENEA Research Centrer in Lampedusa island

Contributions to Task 53

- Subtask A - Data provided for the LCA (Freescoo façade) DONE
- Subtask B – to provide data and simulation results (TRNSYS) NOT YET
- Subtask C - Monitoring data coming from the demo projects
  - Data already into the tool for:
    - System 1 - Stand alone freescoo unit (UNIPA, 2015) DONE
    - System 2 - AHU in Marrakech, 2017 DONE
  - Data already not yet in the tool but soon available:
    - System 3 – Freescoo façade in Lampedusa, 2017 (POSSIBLE IN NEAR FUTURE)

www.iea-shc.org

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Task 53