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SHC Task 48 B2 - Three GOOD Practice examples of solar heat driven desiccant evaporative cooling systems

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Abstract

Within the activity B2 of IEA SHC Task48, an exhaustive report on GOOD Practice examples of existing solar heat driven desiccant cooling (SDEC) systems was written. Three SDEC systems from Austria, Australia and Italy are well documented from the design phase to the operational phase. The authors of the GOOD Practice SDEC systems belong to research entities and the selected SDEC projects were scientifically accompanied by these partners from the very beginning on. The energy performance of all three SDEC systems in operation is indicated by monthly energy fluxes and key performance indicator as a result from measurement data of a scientific monitoring campaign. The GOOD Practice SDEC report on each system closes with findings and lessons learned in order to guide next projects by answering; What quality and support measures lead to a successful SDEC system implementation with high energy performance figures, high quality of indoor comfort and high user friendliness for facility manager? The SHC Task48 B2 report is published on the official SHC Task48 website.

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Keywords: Solar-assisted air-conditioning; Desiccant Evaporative Cooling; GOOD Practice; Monitoring; IEA SHC Task 48;

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1. Introduction

The work plan of IEA SHC Task48 addresses quality assurance and support measures for 'Solar Cooling Technology' with a strong focus on solar heat driven chillers like ab- and adsorption cooling machines. Nevertheless, activity B2 of SHC Task 48 lead by Austrian partners is dedicated to keep an eye on the open cycle principle with respect to new technical research and developments and as well to produce an extensive report on GOOD Practice examples of existing solar heat driven desiccant evaporative cooling (SDEC) systems. A desiccant evaporative cooling (DEC) system fulfils all tasks of an air-conditioning system: a) temperature and humidity control and b) control of hygienic air quality by supplying fresh air. Generally speaking the DEC technique applies three thermodynamic principles to treat air without using conventional compression chiller technology: a) dehumidification of supply air with the help of sorption material, b) efficient sensible heat recovery and c) cooling of supply and return air by using evaporative cooling effect. The solar heat is introduced in order to discharge the sorption material loaded by water vapor of ambient air. A profound DEC technology introduction is written in the 3rd edition of the 'Solar Cooling Handbook' [1].

Nomenclature

Ref Letter	Definition	SHC Task 38
A	Enthalpy difference AHU	ΔHAHU
B	DHW production	Q4
C	Cold output backup chiller to AHU	Q10b
D	Heat rejection (cooling tower)	Q10c
E	Hot storage input to DEC system (regeneration)	Q6b
F	Chiller condenser input to DEC system (regeneration)	Q6c
G	Space heating consumption (conventional)	Q3a
H	Space heating consumption (ventilation)	Q3b
I	Hot output backup chiller to AHU	Q2D_RES
J	Backup heat into storage	Q2S
K	Backup heat bypassing storage	Q2D
L	Solar thermal output to hot storage	Q1
M	Solar irradiation on total collector aperture area	Qsol
N	Electricity consumption (overall)	Eoverall
O	Electricity consumption (total)	Etotal
P	Electricity backup chiller	E12
Q	Electricity cooling tower	E13b
R	Electricity backup coil (regeneration)	E21
S	Electricity Solar system	E1 + E2
T	Electricity backup heat pump	
U	Electricity of water treatment system for evaporative cooling	
V	Electricity of DEC operation	E16 – E19

2. GOOD PRACTICE SDEC systems

With this publication for the SHC Conference 2015 three selected 'Good Practice SDEC systems' from Austria, Australia and Italy are presented along the entire project phase, e.g. design and operational phase. The SDEC projects were scientifically accompanied by SHC Task48 participants, therefore first analysis of simulation results of the SDEC technology are documented. The SDEC systems are equipped with measurement devices which fulfil the requirements of the 3rd level evaluation according to the IEA SHC Task 38 monitoring procedure [2]. The energy performance of the SDEC systems operation is displayed by monthly values of both energy fluxes and key performance indicators. The GOOD Practice SDEC report on each system closes with findings and lessons learned in order to guide next projects; What quality and support measures lead to a success SDEC system implementation with high energy performance, high quality of indoor comfort and high user friendliness for facility manager. The B2 report is already published on the official SHC Task48 website.

2.1. SDEC system at Vienna/ Austria

The Austrian SDEC system has been put into operation 2008. With regard to the design principle the SDEC system is in charge to control only indoor humidity and to supply fresh air to an innovative office building located in the 21st district of Vienna. The SDEC system design parameters are:

- Two separate air handling units, each with a nominal air volume flow of 8,240 m³/hr
- Flat-plate collectors: 285 m² (South/ 33°) and one hot water tank with a volume of 15,000 liters
- Sorption wheel using Lithium-Chloride as sorption material

The simplified hydraulic scheme is shown in Figure 1.

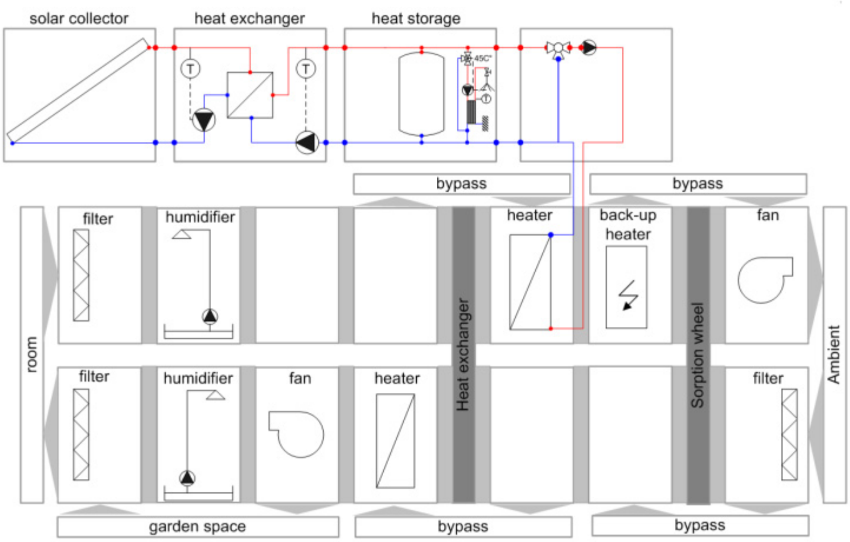

Fig. 1 Scheme of SDEC plant in Vienna, DEC Mode, Austria

Design principles for the SDEC System were [3]:

- Solar heat regeneration: 100% of the regeneration heat is supplied via solar thermal energy during the summer
- Sorption wheel: Used for dehumidification (summer operation) and humidity recovery (winter operation)
- Purpose of air handling unit: Control of the latent loads of the office building
- Design outdoor air conditions in summer (dry bulb temperature / humidity ratio): 35°C / 15 g per kg dry air
- Design set point of supply air (dry bulb temperature / humidity ratio): 23°C / 8 g per kg dry air
- Design volumetric air flow rate: Operate with a low constant flow rate (due to hygienic requirements) and to maintain an air change rate below 1 in the office areas
- DEC configuration: Standard desiccant cooling system (slightly adapted to make use of biological humidification during winter)
- DEC system provider: One provider delivers the complete package (including control strategy)

Operational phase

AIT designed an energy monitoring system for the assessment of the SDEC unit's energy performance. The SDEC system was equipped with measurement devices following the 3rd level evaluation specifications according to the IEA SHC Task 38 Monitoring Procedure for Solar Cooling Systems. Figure 2 displays the ENERGYbase SDEC monitoring system. The energy performance evaluation was based on data from 2010. Several selected key performance indicators were calculated including the collector field efficiency, the thermal seasonal energy efficiency ratio for both cooling and heating mode ($COP_{thermal,\ heating\ and\ cooling}$) and the electric seasonal energy efficiency ratio ($SEER_{electric}$). Table 1 and Table 2 list the relevant monthly energy data and key performance indicator over different time frames.

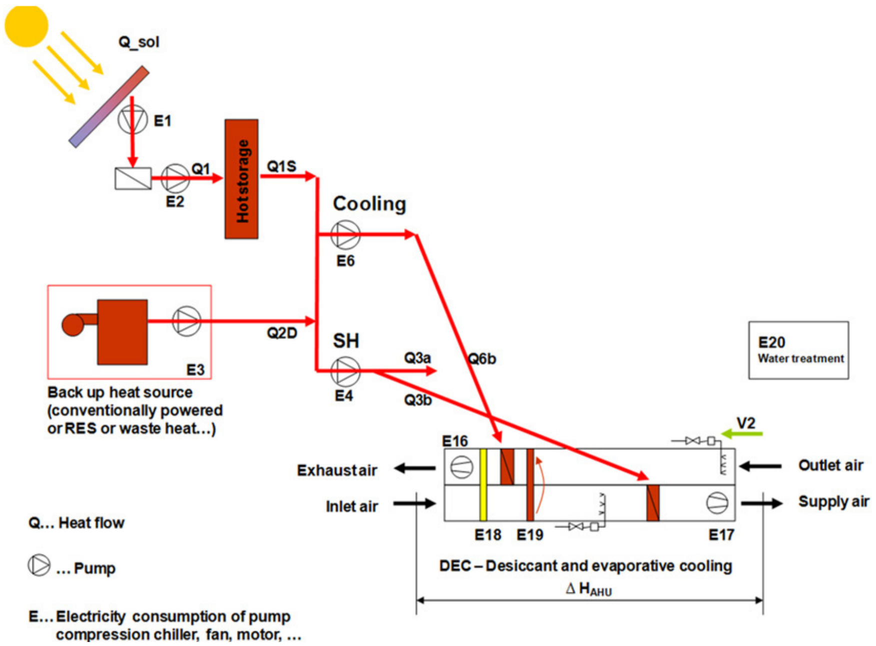

Fig. 2 Vienna SDEC system schematic according to the SHC task 38 monitoring procedure

During 2010, the operation of the SDEC systems consumed around 49.9 MWh of electricity. This included power supplied to the DEC system, the solar system and the ground water coupled heat pump used to post heat supply air in winter. In total, approximately 350 MWh of solar radiation incident was provided by the sun to the 285 m² of the flat-plate collector system. The solar system transferred around 70.9 MWh_{heat} to the hot water tank. This corresponds to an annual collector field efficiency of 20%. 507 kWh of electricity was consumed to operate the solar thermal system. From June to August 2010 the ENERGYbase SDEC system achieved a thermal coefficient of performance (COP_{th}) in the range of 0.50 to 0.54. The total electric seasonal energy efficiency ratio $SEER_{electric}$ was determined to be 5.05.

Key findings

The two solar heat driven DEC units - each with a nominal air flow of 8.240 m³/hr - installed on the roof top of the ENERGYbase office building have been operated since August 2008. They have been controlled, observed and monitored by the facility manager as well as researchers from AIT. The SDEC system and the accompanying concrete core activation fulfil all of the required services of an air-conditioning system (i.e., temperature and humidity control and providing high quality fresh air). The entire project, starting from the initial decisions and design concepts to the analysis of the recorded data has been achieved with help from researchers from AIT. The constant supervision by experts at all stages of development and operation was one of the factors contributing to the success of this building and promoted the transfer of knowledge and experience gained from research activities into practical applications.

Table 1 SDEC plant annual energy performance from 2010 (Monthly values are in kWh)
* Own calculation, n.m. not measured

	Task 38	total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
AH	0 > ΔHAHU	235,663	47,583	55,512	43,211	18,168	3,340	438	331	406	3,828	17,657	18,626	26,564
AC	0 < ΔHAHU	16,086	-	-	196	185	339	3,971	6,979	4,279	136	-	-	-
B	Q4 DHW	-	-	-	-	-	-	-	-	-	-	-	-	-
E	Q6b	31,868	-	-	37	316	1,220	7,990	12,994	7,924	1,359	-	26	2
H	Q3b	48,862	12,006	12,298	6,399	1,075	-	-	-	-	21	1,031	3,717	12,315
J	Q2D	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.	n.m.
L	Q1	70,915	1,261	3,862	8,752	6,864	3,981	8,654	14,348	8,516	3,780	6,617	2,936	1,344
M	Qsol	350,300	9,384	14,736	33,126	41,193	33,431	44,684	48,802	41,069	34,333	25,767	12,984	10,791
N	Etotal	49,899	6,542	7,413	5,738	3,550	2,388	2,580	2,881	2,614	2,166	2,562	3,999	7,467
S	E1 + E2	507	21	41	81	63	28	39	60	38	24	61	35	16
T	E3*	15,269	3,752	3,843	2,000	336	-	-	-	-	7	322	1,162	3,848
U	EWT*	1,020	85	85	85	85	85	85	85	85	85	85	85	85
V	E16 – E19	33,103	2,684	3,444	3,572	3,066	2,275	2,456	2,736	2,491	2,050	2,094	2,717	3,518

Table 2 SDEC key performance figures 2010 (Monthly values)

	total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Collector field efficiency L/M	0.202	0.134	0.262	0.264	0.167	0.119	0.194	0.294	0.207	0.110	0.257	0.226	0.125
COP thermal AC/E Cooling	0.50	-	-	5.30	0.59	0.28	0.50	0.54	0.54	0.10	-	-	-
COP thermal AH/H Heating	4.82	3.96	4.51	6.75	16.90	-	-		-	182.27	17.13	5.01	2.16
SEER electric (AC+AH)/T	5.05	7.27	7.49	7.57	5.17	1.54	1.71	2.54	1.79	1.83	6.89	4.66	3.56

Ten years of technical and scientific research into SDEC system design and operation has led to the development of the following principles to aid in the design of good practice systems:

- The design of the SDEC system and solar system was based on regenerating the sorption material using just solar heat with no thermal back-up and no use compression chiller backup systems;
- The sorption wheel should be used for both dehumidification, during summer operation, and humidity recovery, in winter operation (enthalpy recovery mode);
- The DEC system should remove the latent loads from the building while the sensible cooling of the offices should be provided by other heat extraction technologies (e.g. cooled ceiling, concrete core activation, etc.);
- Use moderate set points for the supply air to minimize energy consumption (i.e., 23°C and 9 g/kg dry air);
- The design volumetric air flow rate should be based on the minimal hygienic needs of outdoor air of the building (as determined by the number and activities of occupants, space function and building volume), the air flow rate of the SDEC system in the ENERGYbase building led to an air change rate of less than 1;
- DEC systems are complex air treatment units due to the large number of components and their dynamic interactions. A DEC system provider capable of delivering a complete package, including control strategy, supports a higher quality of system's operation;

- Transient system simulations should be used to support the design phase due to the limited design standards that are applicable to this type of system, (simulations are especially helpful in sizing solar systems and analyzing the a tradeoffs between cost effectiveness and technical feasibility);
- An energy monitoring system should be carefully designed to provide the data needed for a system performance assessment.

During the operational phase, the SDEC system performance was continually observed and improved by the facility management based on the acquired monitoring data. Success factors and lessons learned from the operational phase of the SDEC system are stated in the following bullets:

- Continuous cooperation and knowledge exchange between the facility management and researchers on site leads to constant improvements of the systems performance;
- In moderate climates, where the air treatment is dominated by heating of the supply air, the use of the sorption wheel in enthalpy recovery mode provides significant primary energy savings during the winter. 2010, the SDEC system's operation required approx. 122 MWh_{PE} whereas the primary energy consumption of a reference system, based on the primary energy calculation approach of SHC TASK 38, was calculated to be 309 MWh_{PE}.
- The monitoring data confirmed that the regeneration process for the SDEC system could be driven completely via solar heat, with the acceptance of variation in the temperature of the supply air.

The overall system including two DEC systems, a 285 m² solar thermal system, a control system, a water treatment system and the air ducts costs 400,000 EUR. This correlates to 24 € per m³/hr at a nominal air flow of 16.500 m³/hr. Using the good practice SDEC system experience gained at the ENERGYbase building, DEC technology been utilized in another innovative office building project called aspern IQ [4]. In this new system, the regeneration heat will be supplied by the local district heating system at approximately 60°C.

2.2. SDEC system at Newcastle, Australia

A solar heating, cooling and domestic hot water system has been installed and operating since 2012 at a vocational teaching institute (TAFE) in Hamilton, Newcastle. The new air-conditioning system consisted of two SDEC Tempered Air Conditioner units (labelled TAC 3 and TAC 7). TAC 7 supplied the kitchen, preparation room and store while TAC 3 served either the offices or the dining room if cooling/heating was requested (a request button was installed in the dining room). The system is designed for handling 12,000 m³/hr of fresh air. More details about the system can be found in [5]. The installed system is expected to reduce the existing compression chiller's energy consumption.

The summer operational schematic for the unit is shown in Fig. 3. Within each TAC unit, two desiccant wheels, in series, are used to achieve the required dehumidification. The air was cooled following each wheel by a cooling coil supplied with water from a cooling tower. This reduced the temperature increase of the process air due to the heat of adsorption. The cross-sectional area of the desiccant wheel was divided into two sections with 2/3 of the area being used for the supply air side and the remainder for the regeneration side. This ratio was selected to maximize the supply airflow for the given size of wheel without compromising dehumidification performance. The wheel rotates at a constant speed and both processes (dehumidification and regeneration) occur simultaneously. This allows for continuous operation. The desiccant wheel was regenerated by passing heated fresh air back through the wheel in a counter-flow arrangement. The air was heated by two heat exchangers located before each desiccant wheel, on the regeneration side, which were supplied by hot water from the hot water storage tanks. No backup heat source was used and thus, desiccant cooling only occurred when there was sufficient solar heat in the tank. Gas was never used for providing regeneration heat and was only used for space heating and domestic hot water.

After passing through the desiccant wheels, the resulting dehumidified air was cooled by a direct evaporative cooler. The air temperature decreased due to the latent heat of the water vaporizing into the air. If the air was above the supply temperature set point after these stages, further cooling was achieved using a chiller coil supplied by the existing mechanical chiller. This coil was located in the final section of TAC unit before the air was supplied to the ventilation duct.

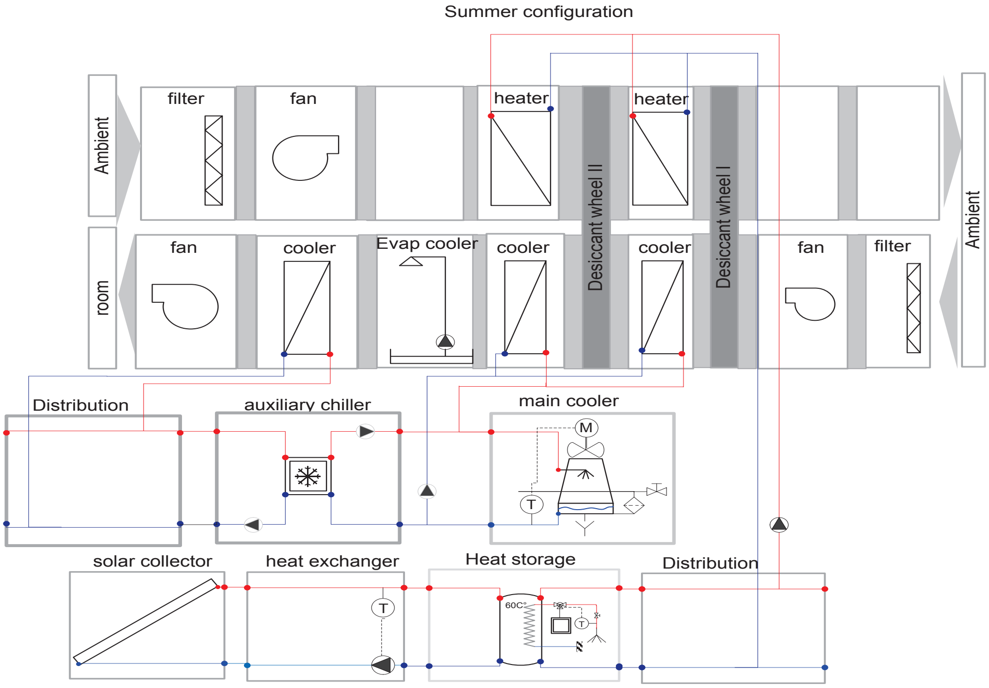

Fig. 3 SDEC system summer operational configuration at Newcastle, Australia

The desiccant system used the sensors recommended by the IEA SHC Task 38 monitoring procedure. Fig. 4 shows the thermal and electrical energy flows monitored by the BMS. The standard Task 38 schematic was adapted to include the unique features of this desiccant system. The energy performance and efficiency details of the unit during the cooling required months is provided in Table 3 and Table 4.

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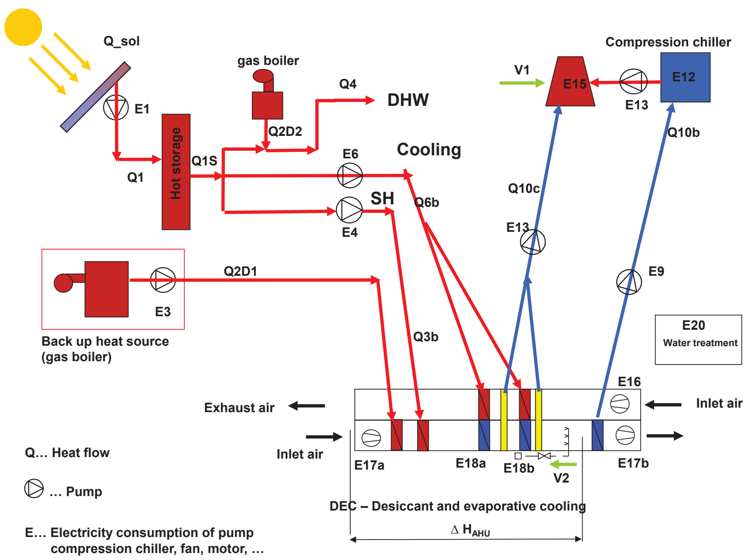

Fig. 4 Newcastle SDEC system schematic according to the SHC task 38 monitoring procedure

Table 3 TAFE SDEC system cooling and DHW performance during the monitoring period

	Task 38	Jan	Feb	Mar	Apr	Oct	Nov	Dec
(A) Delta Enthalpy cooling	(ΔHAHU)	1282	498	794	116	126	525	1340
(B) Delta Enthalpy heating)	(ΔHAHU	0	0	0	0	456	0	0
(C) solar DHW heat produced	(Q4-Q2D2)	222	4689	4906	3072	2222	2759	800
(D) total DHW heat produced	(Q4)	11967	19969	21034	17573	12921	14225	10005
(E) solar heat delivered to regen coils	(Q6b)	9904	3490	4035	1371	958	3542	9622
(F) Electricity consumption for SDEC		629	231	310	92	95	266	647
(G) overall electricity consumption		788	356	446	213	391	402	810
(H) Solar heat delivered (kWh)		24721	18603	20737	13048	22620	19487	24520

Table 4 TAFE SDEC system energy efficiency performance during the monitoring period

	Jan	Feb	Mar	Apr	Oct	Nov	Dec
(A/E) COP_{th} (SDEC)	0.13	0.14	0.20	0.08	0.13	0.15	0.14
(A/F) COP_e (SDEC)	2.04	2.16	2.56	1.26	1.33	1.97	2.07
(A+B+C+D)/G) SEERelectric (overall)	16.8	57.4	49.0	83.0	34.6	36.7	14.0

Data provided in Table 3 and Table 4 was consistent with the expected operation of the system. For example, highest cooling demand was between November and March whereas the DHW requirement was relatively consistent except for the holiday periods (e.g., December to January) where the usage was minimal. The desiccant air conditioning system provided nearly 10% of the total required cooling during the monitoring period.

Continuous monitoring of the system's performance has helped identify issues related to operational performance of the system. For example, the cooling tower set point was higher than the design point resulting in insufficient cooling of the process air between the dehumidification stages. Resolving such issues is expected to result in more efficient operation of the system in the coming years.

2.3. SDEC system at Milan, Italy

The Italian example of SDEC system coupled with an electrical heat pump is located in Milan and was commissioned in 2013 on a student dormitory.

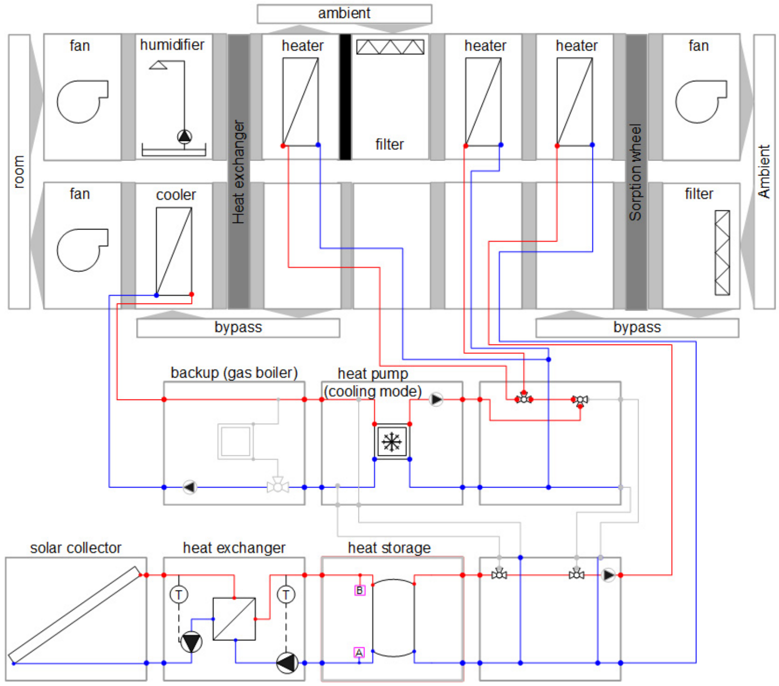

Fig. 5 Scheme of SDEC plant in Milan, Italy (summer configuration).

The system integrates a non-conventional DEC AHU with a solar thermal system and an electric-reversible heat pump (HP). During the summer (Fig. 5), the HP cools the supply air and pre-heats the regeneration air (when dehumidification is needed) in a separated channel. The remainder of the regeneration thermal energy is provided via solar energy. During the heating season, if needed, a heating coil heats the supply air, using thermal energy drawn from the solar tank, the HP or the back-up gas boiler.

The non-conventional configuration aims to high air quality achievement, avoiding supply air contamination and reducing hygienic risks, to low electricity consumption and a simpler control scheme.

The plant supplies 6,000 m³/hr of fresh air to the building. Supply air temperature is maintained in the range 20-24°C through climatic control, supply air humidity is intended to be limited at 9.5 g/kg dry air only when solar heat is available (102 m² of flat-plate collectors and solar tank of 5 m³). Since the system is used in a southern European climate, winter humidity control is not required.

The design phase defined the main characteristics and demonstrated the suitability of the plant, thanks to an extensive simulation of the system [6] and the calculation of the energetic performances compared to a conventional AHU. The complexity of the plant implies the need of a deep monitoring procedure, made possible thanks to a sensors equipment according to IEA SHC Task 38.

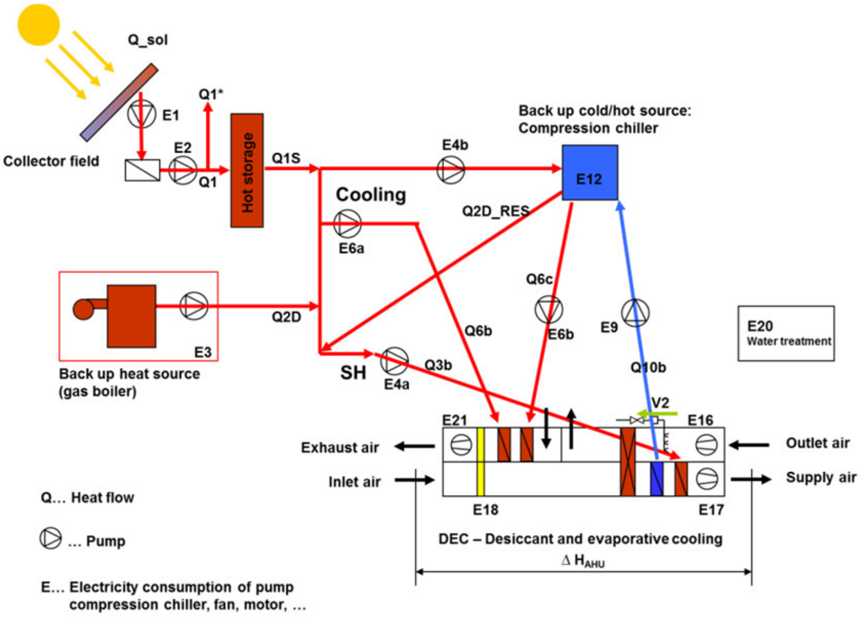

Fig. 6 Milan SDEC system schematic according to the SHC task 38 monitoring procedure

Table 5 SDEC plant monthly performance figures from 2014 to 2015. The values are in kWh.

	Jan	Feb	Mar	Apr(w)	Apr(s)	May	Jun	Jul	Aug	Sep	Oct(s)	Oct(w)	Nov	Dec
A	9560	10975	7842	4292	120	823	4243	5704	-	-	-	-	6590	6271
C	-	-	-	-	7	266	2895	4392	-	-	-	-	-	-
E	-	-	-	-	0	320	3971	5809	-	-	-	-	-	-
F	-	-	-	-	0	54	2676	4364	-	-	-	-	-	-
H	3243	3975	2181	876	-	-	-	-	-	-	-	-	1553	1987
I	449	1547	352	0	-	-	-	-	-	-	-	-	392	1115
K	2366	1879	386	0	-	-	-	-	-	-	-	-	216	851
L	1105	2320	3037	2574	-	5061	5512	6238	-	-	-	-	1321	1185
M	3833	6131	16185	14849	-	17955	17245	17104	14587	13937	8571	-	3790	3031
N	2105	1889	1978	1537	1261	1583	3171	3910	-	-	-	-	1784	1457
O	202	513	308	248	248	425	1609	2118	-	-	-	-	212	317
P	122	422	93	0	14	138	892	1302	-	-	-	-	113	265

Table 6 SDEC performance figures from 2014 to 2015.

	Jan	Feb	Mar	Apr(w)	Apr(s)	May	Jun	Jul	[no operation]	Nov	Dec
Collector field efficiency, L/M	29%	38%	19%	17%	17%	28%	32%	36%	-	35%	39%
Total Elec COP, (A+B)/O	47 .41	21 .40	25.43	17.30	0.48	1.94	2.64	2.69	-	31.05	19.75
Thermal COP, (A-C-D)/(E+F)	-	-	-	-	-	1.49	0.20	0.13	-	-	-
Chiller average EER, C/P	-	-	-	-	0.51	1.93	3.25	3.37	-	-	-
Chiller average COP, I/P	3.69	3.66	3.80	-	-	-	-	-	-	3.47	4.21
Summer Solar Fraction, L/(L+P+Q+R)	-	-	-	-	0.99	0.97	0.86	0.83	-	-	-
Winter Solar Fraction, L/(L+J+K+P)	0.31	0.50	0.86	1.00	-	-	-	-	-	0.80	0.51

This also allowed the calculation of the performance indices presented below. The monthly performance indicators show the first operation difficulties and make possible to obtain the most sensitive points where to focus the future optimization efforts.

From August to October the results are not presented due to maintenance efforts that prevented the plant from operate regularly. Despite in the remainder of the cooling season the performance factors (thermal COP) appear quite low, primary energy savings are fully positive, showing a great potential for future optimized summer operation. This is partly due to the particular configuration that preserves the indoor air quality, partially sacrificing the effectiveness of the cooling modes (especially for the static heat exchanger and for the unconventional regeneration process). During winter, the savings potential is strongly constrained to the solar radiation availability; when the back-up heater powers the plant, the performances are quite similar to a conventional AHU (higher fan consumption due to greater pressure drops).

At the end of the first commissioning period, it is possible to summarize some findings. Relationship with facility staff is a primary issue; the system is complex and it is necessary to build monitoring tools and precise maintenance program. Concerning the complexity of the plant, monitoring and commissioning difficulties should be tackled with a robust commissioning procedure [7]., in order to verify the components behavior compared to the manufacturer declared performance, especially for sorption wheel, solar subsystem and heat pump. As an outcome, the sorption wheel resulted the most sensitive element on the overall system performance. As a further hurdle, the designer has to deal with air streams parameters evaluation, which could bring not-easily solvable measurement issues. Moreover, the Milan SDEC example was commissioned on an existing old building, which brings strong design and realization constraints, followed by higher investment and operational costs. In conclusion, the observed saving potential is highly promising, especially during cooling season (over 60% of fractional savings). This potential is fully achievable designing and realizing the system in parallel with the building, and the consolidation of this technology could decrease investment costs rising the market interest.

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References

[1] Henning H.-M., Motta M., Mugnier D., Solar Cooling Handbook - A Guide to Solar Assisted Cooling and Dehumidification Processes, AMBRA, 2013, ISBN: 978-3-99043-438-3
[2] Napolitano A., Sparber W., Thür A., Finocchiaro P., Nocke B., SHC Task38 publication, A3a-B3b: Monitoring Procedure for Solar Cooling Systems, A joint technical report of subtask A and B (D-A3a / D-B3b), October 2011 Posted: 2012-04-13 –see http://task38.iea-shc.org/publications
[3] Selke T., Preisler A., Schneider U., 'ENERGYbase – Sunny Office Future', Eurosun 2008, 1st International Conference on Solar Heating, Cooling and Buildings, Lisbon, 7th to 10th October 2008, Book of Abstracts, Nr. 357
[4] http://www.asperniq.at/wp-content/uploads/2013/12/aspern-IQ-Folder-Engl.pdf - Access 24th, Nov 2015
[5] Hands, S., Sethuvenkatraman, S., Peristy, M., Rowe, D., & White, S. (2016). Performance analysis & energy benefits of a desiccant based solar assisted tri-generation system in a building. Renewable Energy, 85, 865-879.
[6] Aprile M., Scoccia R., Motta M., Modelling and control optimization of a solar desiccant and evaporative cooling system using an electrical heat pump. Energy Procedia, Volume 30, 2012, p. 478–489
[7] Antoine Frein, Marcello Aprile, Matteo Muscherà, Rossano Scoccia, Mario Motta, *A continuous commissioning analysis and its application to a new installed solar driven DEC system coupled with heat pump*, Energy Procedia 70 (2015) 435 – 444