SorTech package solution description

Version 2.0

Edited by:

Jörg Rupp

SorTech AG

Lotta Koch, Edo Wiemken, Björn Nienborg

Fraunhofer ISE

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Identification of most promising markets and promotion of standardised system configurations for the market entry of small scale combined solar heating & cooling applications
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1 Introduction

The commercial project partner SorTech has developed a detailed concept for small scale thermally driven cooling systems, using **ad**sorption technology. The concepts are based on the integration of the own produced adsorption chillers of the model type ACS 08 (8 kW rated chilling capacity) and ACS 15 (15 kW rated chilling capacity). The smaller model was subject of the virtual case study in this project.

As SorTech is not a provider of solar thermal collectors and appropriate components, no direct recommendations on the type of collectors, storages etc. are given, but the possible use of this heat source is integrated into the system schemes. SorTech focuses rather more on the appropriate combination of chiller and type of heat rejection system, in order to optimize the electrical efficiency of the entire system. From previous investigations as well as from the results of the virtual case study in this project, the significance of a well designed heat rejection system is well known.

Furthermore, SorTech presents recommended hydraulic schemes giving the possibility for the integration of different heat sources.

The SorTech package solution is described in detail in the documents

- SolarCombiPlus_SORTECH_Design Manual_ACS_V1.9.pdf
  (language: english, status: confidential)
- SolarCombiPuls_SORTECH_Installation Guide_ACS_V1.4.pdf
  (language: english, status: confidential)
- SolarCombiPlus_SORTECH_ServiceManual_ACS_V1.2.pdf
  (language: german, status: **public**)
- SolarCombiPlus_SORTECH_HeatPump_PlanningGuide_ACS_V1.3.pdf
  (language: english, status: confidential)

Due to the comprehensive information on the system solutions in the above listed documentation, only brief information will be summarized in the following.

2 The Chiller

Central components of the package solutions are the adsorption chillers ACS 08 and ACS 15 (figure 2.1). The chillers use silica gel as sorption material and the internal structure follows a 4-compartment principle: evaporator, condenser and two compartments, interchanging periodically between adsorber and desorber function. All hydraulic components, necessary for the internal switchings, are installed inside of the chiller; this allows an easy connection of the chiller to the external three hydraulic circuits (high temperature source HT, heat rejection circuit MT and chilled water circuit LT). The basic hydraulic structure of the chillers is presented in figure 2.2.

The chiller is equipped with an internal control unit, thus no additional cost for the chiller operation control have to be taken into account.

A special feature of the chiller is the possible reverse operation in a heat pump mode, applicable for low temperature heating systems such as floor heating, etc. The low temperature circuit, providing chilled water during summer cooling operation, is then used as low temperature heat source.

Table 2.1 summarises the main technical features of the two chiller products under rated operation conditions.

Figure 2.1 Adsorption chillers of the SorTech package solutions. Left: ACS 08, right: ACS 15. Source: SorTech AG.

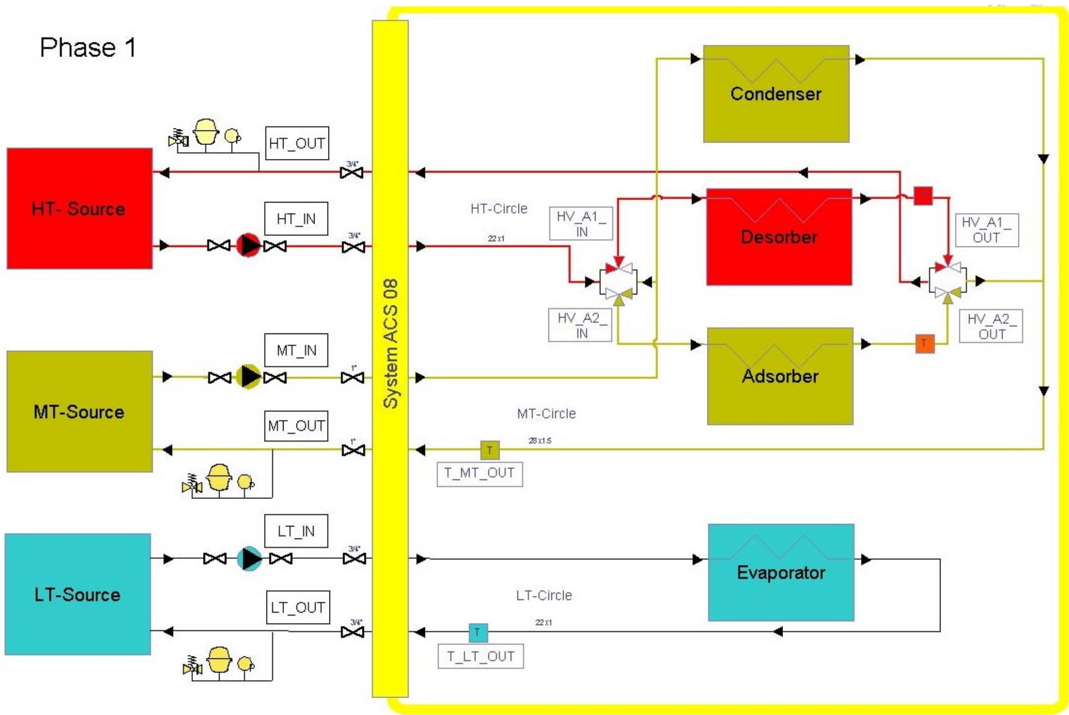

Figure 2.2 Main internal hydraulic components of the SorTech chiller and external connections. The figure presents the operation phase, of which the upper of the two sorption compartments is currently being desorbed by applying hot water and the lower sorption compartment is working as adsorber, thus taking up the vaporized refrigerant. The refrigerant circle, either fluid or vaporized, is not included into the figure. Source: SorTech AG.

			ACS 08	ACS 15
	Cooling capacity, nominal	kW	8	15
	COP_{therm}, nominal		0.60	0.60
Chilled water circuit	Temperature in/out	°C	18/15	18/15
	Volume flow	m³/h	2.0	4.0
	Pressure loss	mbar	300	500
	Operating pressure max.	bar	4	4
	Connection external thread		1"	5/4"
Heat rejection circuit	Temperature in/out	°C	27/32	27/32
	Volume flow	m³/h	3.7	7.0
	Pressure loss	mbar	350	440
	Operating pressure max.	bar	4	4
	Connection external thread		1"	5/4"
Driving heat circuit	Temperature in/out	°C	72/65	72/65
	Volume flow	m³/h	1.6	3.2
	Pressure loss	mbar	230	260
	Operating pressure max.	bar	4	4
	Connection external thread		3/4"	5/4"
Electricity supply	Voltage	V	230 ~	230 ~
	Frequency	Hz	50	50
	Power consumption Ø	W	7	14
Dimensions	Length	mm	790	790
	Width	mm	1060	1340
	Height	mm	940	1390
	Weight (empty)	kg	265	530
	Operating weight	kg	295	590

Table 2.1 Technical data for nominal operation conditions of the adsorption chillers ACS 08 and ACS 15. Source: SorTech AG.

3 System's Components

3.1 Heat rejection

The package solution includes special adapted coolers for the heat rejection during chiller operation. SorTech delivers appropriate dry coolers for this reason in two sizes for the two chiller products ACS 08 and ACS 15. Figure 3.1 shows one of the dry coolers, and table 3.1 presents the technical data. The main features of this heat rejection unit are

- Under moderate climate conditions, no demand for fresh water for the heat rejection. Only at high ambient temperatures, a fresh water spraying system is activated in order to allow a continuous operation of the chiller.
- In comparison to wet cooling towers, little demand for maintenance only and minimised risk of legionella and other bacterial growth. Consequently, higher acceptance especially for small scale system installations in the residential sector
- Minimised electricity consumption through use of high efficient motor technology of the fans (EC-motors) and an appropriate control strategy of the fans (rotation-speed controlled in a wide range)
- Control of the dry cooler direct through the internal control of the ACS chiller
- Freezing protection is done by an additional drain box (to be installed inside the building), which replaces the cooling water by a water-glycol mixture in case of freezing danger.

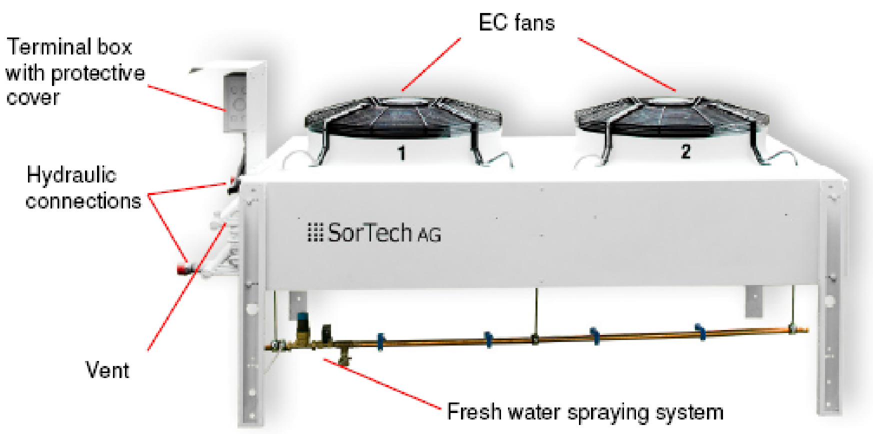

Figure 3.1 Dry cooling heat rejection unit with spraying system. Special adapted to the SorTech adsorption chillers. Source: SorTech AG.

Technical data at nominal working point

		RCS 08	RCS 15
Re-cooling capacity	kW	21	42
Type of fans		2x EC- fan 650	3x EC-fan 650
Noise pressure level at 10 m distance	dB(A)	43	45
Re-cooling medium		water	
Water consumption, max.	m³/year	20	30
Nominal volume flow	m³/h	3.7	7.0
Pressure loss at nominal volume flow	mbar	150	100
Triggering voltage standard signal (speed control)	V	0-10	
Hydraulic connection (in/out)	mm	35.0 * 1.5	42.0 * 1.6
Operating pressure for water connection (spraying system)	bar	min. 3-6	
Connection (spraying system)	mm	22.0 * 1.0	
Electricity supply	V	230 ~	
	Hz	50	
Power consumption, max.	kW	0.65	1.2
Length	mm	2000	4125
Width	mm	1145	1145
Height	mm	950	950
Weight (empty)	kg	188	330
Operating weight	kg	225	390

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Table 3.1 Nominal technical data of the dry coolers for heat rejection for the adsorption chillers ACS 08 and ACS 15. Source: SorTech AG.

Figure 3.2 shows the schematic connection of the dry cooling heat rejection unit with the chiller. However, the application of dry coolers is limited to moderate to slightly hot site, as in areas with prevailing extreme ambient temperatures either the spraying system would exceed the preset maximum value of 400 spraying hours per year, or the cooling temperature exceeds the maximum level, leading to unfavourable low chiller performances.

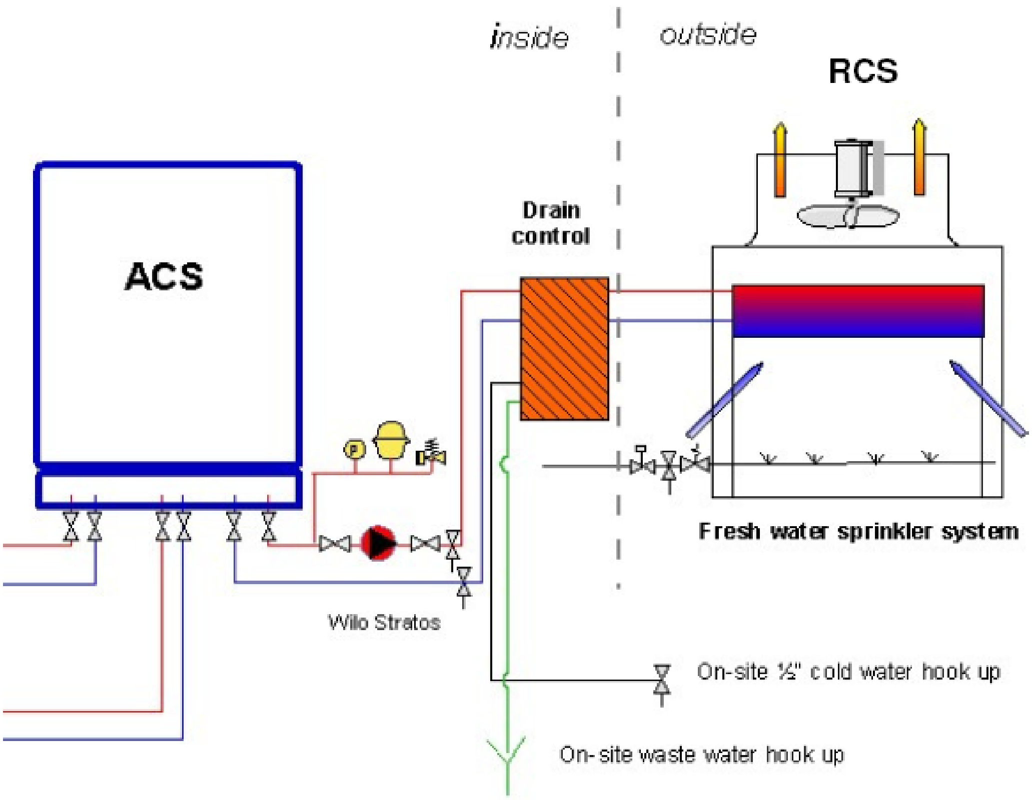


Figure 3.2 Scheme of the heat rejection circuit of the SorTech adsorption chillers. Source: SorTech AG.

Depending on the location and on the type of application (e.g., chilled ceiling or fan coil), the set values for starting the spray function of heat rejection unit are determined by the authorized installation service.

4 System schematics

In general, the adsorption chillers can be connected to different heat sources, such as solar thermal collectors, district heating networks, waste heat from industrial processes or from combined heat and power production. On the other hand, also different use of the chilled water is possible, either in chilled ceilings, fan coils or in other systems. This variety of applications is shown in figure 4.1. However, the preferred application is the use in chilled water distribution systems with high chilled water temperature (e.g. > 15°C for chilled ceilings), since the system works with highest performance under these conditions.

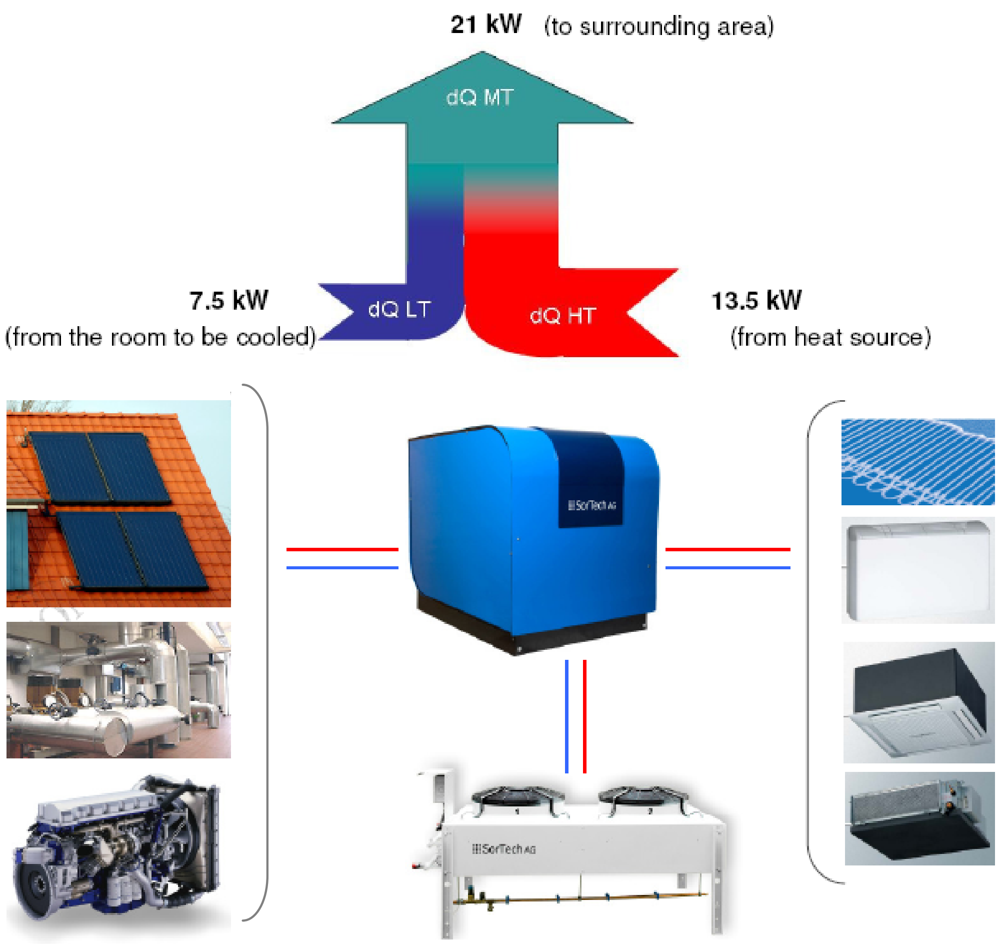


Figure 4.1 Example on heat sources and chilled water distribution systems for the SorTech adsorption chillers. Source: SorTech AG.

The proposed system scheme of a SorTech adsorption chiller system with solar heat input corresponds in general to the standard configuration scheme E1, as described and simulated in the virtual case study of the SolarCombi+ project. This configuration scheme is repeated in figure 4.2.

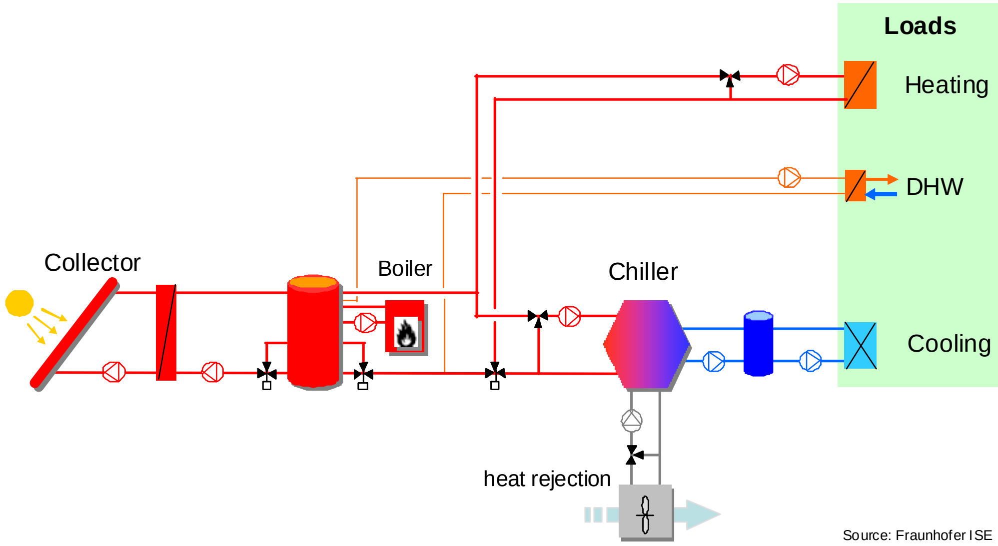


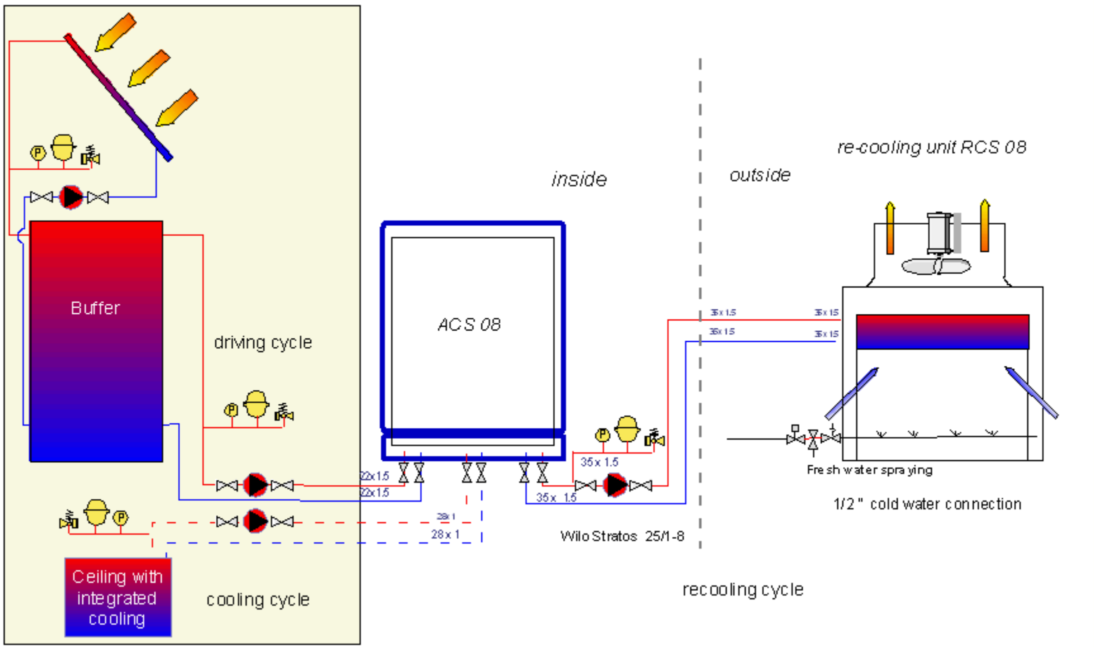
Figure 4.2 Standard configuration scheme E1 of the virtual case study, similar to the recommended scheme of SorTech for the integration of their adsorption chillers.

The corresponding system scheme from SorTech is shown in figure 4.3 (without domestic hot water and space heating connections). The figure includes recommendations on pipe dimensions, volume flow rates and on the type of heat rejection circuit pump for the two chiller types ACS 08 and ACS 15.

Additionally, schemes are available for using the heat pump operation modus during the heating season. This option is possible in combination with low temperature heating systems, such as floor heating or supply air heating. Figure 4.4 thus presents two different possibilities:

a) Use of the heat rejection unit as low temperature heat source. The driving circuit in this case may consist of a backup heating system with solar thermal assistance for example (not shown in detail)

b) Use of the solar thermal collectors as low temperature heat source. The driving circuit in this case is a backup heating system. The dry cooler is not activated in this mode.



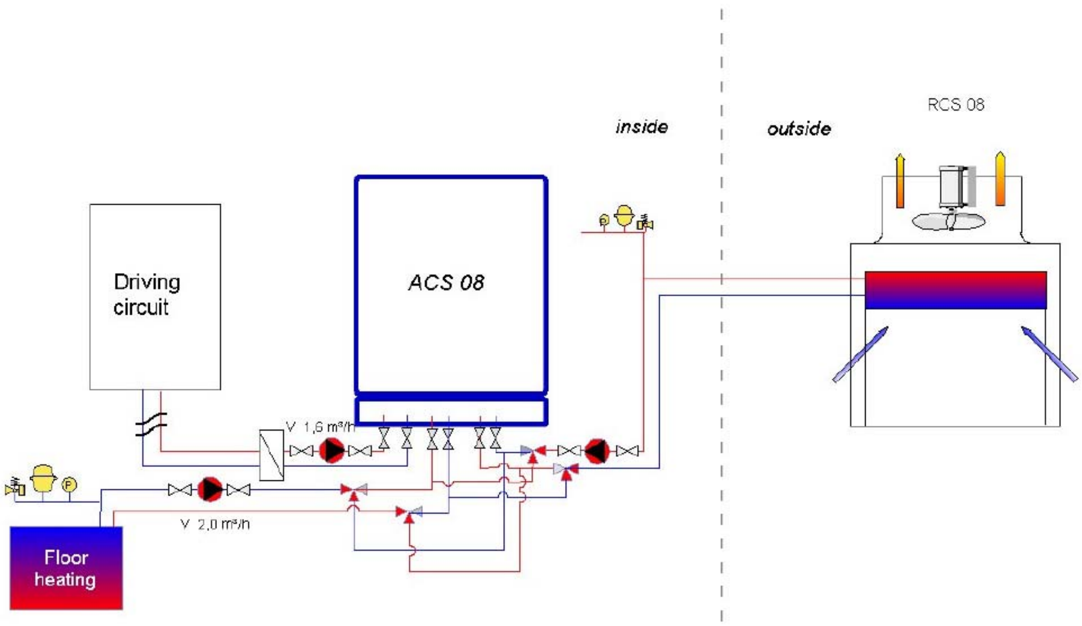


Figure 4.3 Recommend integration of the SorTech adsorption chillers ACS 08 into the solar cooling system. Source: SorTech AG.

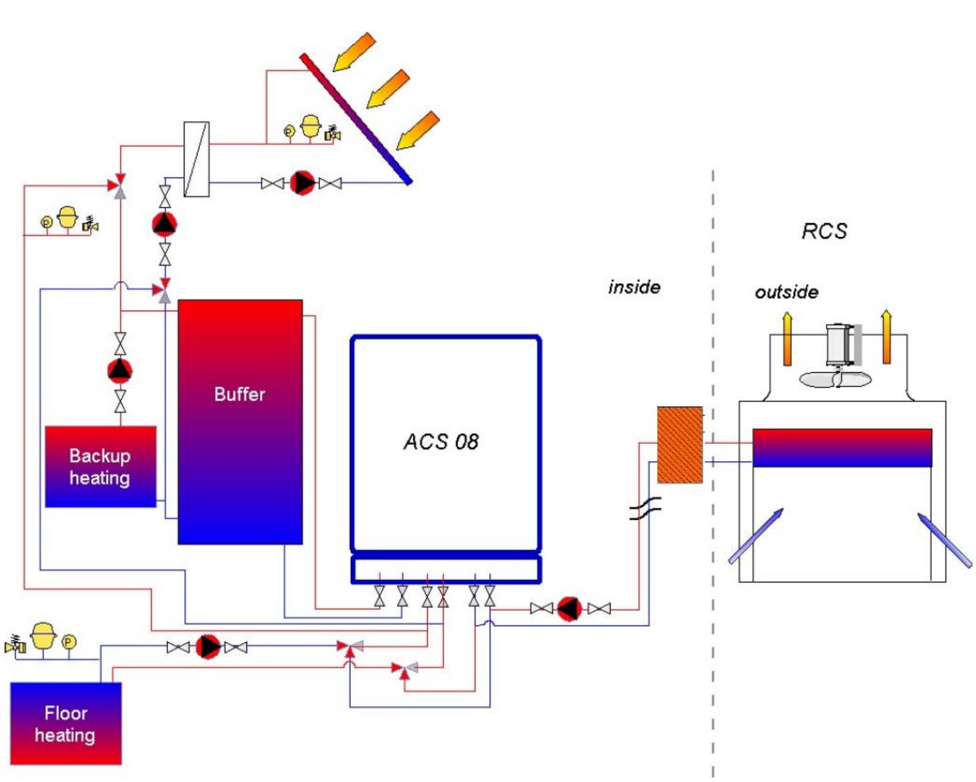


Figure 4.4 Possibilities for heat pump operation of the ACS adsorption units in combination with floor heating systems (alternatively: supply air heating systems). In the configuration at the top, the dry cooler is the low temperature heat source; the system is driven either by a conventional heating system or with solar thermal assistance. Bottom: in this application, the solar thermal collectors are used as low temperature heat source, whereas the dry cooler is not in function. Source: SorTech AG.

5 Proposed Package Solution

In the virtual case study of the SolarCombi+ project a wide range of applications and system size was analyzed. All calculations in this study were performed under the condition that the cooling load is covered to 100%, either by solar heat or with a heat backup, which normally for small scale applications is identical with the space heating unit for winter application, e.g., a fossil fuelled boiler. Whenever in the calculations the solar heat is not available at a sufficient temperature level, the heat backup is in operation. Consequently, primary energy is used in the solar cooling system not only for the operation of the electrical components such as pumps and fans in the heat rejection unit, but also for the backup heating system to cover the load to 100%.

In the calculation results presented below, a gas boiler is assumed as fossil heat backup system. The evaluation parameters used in the figures are defined as follows:

Collector efficiency [%]

Annual gross collector yield, divided by the annual radiation sum in collector plane

Relative primary energy saving [%]

Relative savings on annual primary energy demand of the SolarCombi+ system in comparison to a conventional reference system (gas boiler + electrically driven compression chiller)

Specific costs CPE: Costs per saved kWh primary energy [€/kWh$_{PE}$]

Difference in annual cost of the SolarCombi+ system and the reference system, related to the annual primary energy savings. The annual cost includes capital cost (determined by annuity calculation), operation and maintenance cost. Under the pre-condition that primary energy will be saved by the solar combi+ system, the costs are positive in case the annual cost of the solar combi+ system exceed the annual cost of the reference system

Solar fraction cooling [%]

Relative share of annual cooling load, which is covered by solar thermal heat. The remaining fraction is thus covered by the heat backup system.

A more detailed description of the evaluation parameters can be found in the report of the methodology of the virtual case study within the project.

For all investigated sizes and configurations, the electrical energy ratio for the cooling operation (produced cold / sum of all electricity consumers, i.e., circulation pumps, fan of heat rejection unit, etc.) was in the range from 8 to 12 kWh$_{cold}$/kWh$_{electricity}$, by considering the specified pressure drops, SorTech heat rejection power specification and control strategy.

However, different control strategies may lead to higher ratios. In addition geothermal recooling or recooling with a swimming pool could boost this ratio further as the fans as electricity consumers would be eliminated.

Important note

In the discussion of the results from the virtual case study, as shown in some example graphs below, it has always to be considered that

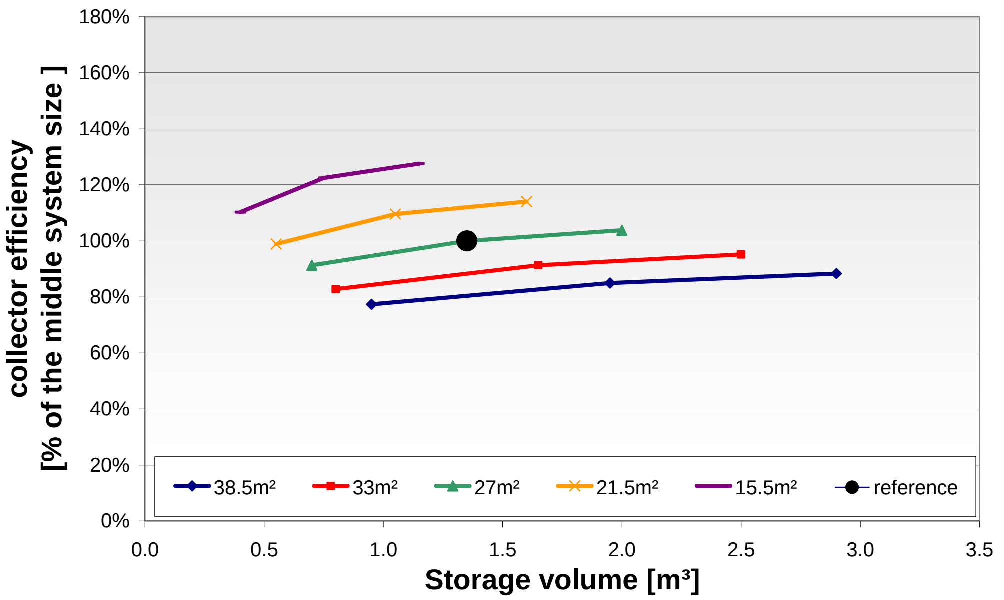
- The cost figures, e.g., the specific costs per saved kWh primary energy, are depending to a high degree on the cost input data (component cost, energy cost, interest rate,..). The figure is used here in order to discuss a reasonable size of the system, but does not allow to determine real system cost since average costs or costs from pilot production stocks were used;
- The most useful applications are solar autonomous cooling modes wherever applicable, which means that no heat backup is used for the operation of the cooling system in summer. For practical reasons and for reasons of a better comparability of the results, this mode was not considered in the virtual case study. Any application of a solar autonomous cooling mode will improve the primary energy savings as well as the cost figures;
- The used of non fossil-based heat sources such as biomass or waste heat, will also lead to increased primary energy savings;
- For reasons of comparability of the results from the virtual case study, the heat pump mode of this chiller was not considered in the calculations. If this mode can be activated in a real installation, some more primary energy savings may be achieved.

As the simulation results are very sensitive to these factors, but the tendencies remain the same, the following figures show only relative figures. The reference system (100%) is always the system with a collector size of 3.5 m²/kW reference chilling power (medium size) and a storage size of 50 l/m² collector area (medium size). In the graphs the reference system is indicated with a black dot.

The most promising applications for the SorTech system solution were found for conditions, where cooling demand occurs predominantly during daytime, thus no active cooling at night is necessary. This situation occurs regularly at the Toulouse site in the calculations. For this site (and climatic similar sites), the following figures present results for one of the simulated residential buildings with chilled ceilings as cold distribution component.

Figure 5.1 presents the evaluation parameters as defined above for a system, using flat plate collector, whereas figure 5.2 presents the results for the same application, comparing to a system using evacuated tube collector. The presented graphs in figure 5.2 obey this systematic: The continuous line shows the relative difference of the largest collector area (5 m²/kW chilling power) to the reference system. The dotted line represents the relative difference of the smallest collector area (2m²/kW chilling power) to the reference system. The medium sized reference system remains in all graphs the same system with flat plate collector. Thus the reader gets an impression of the relative influence of a differently sized system and of different types of collector.

In each application, dry heat rejection is applied (with spray function as foreseen in the package solution).



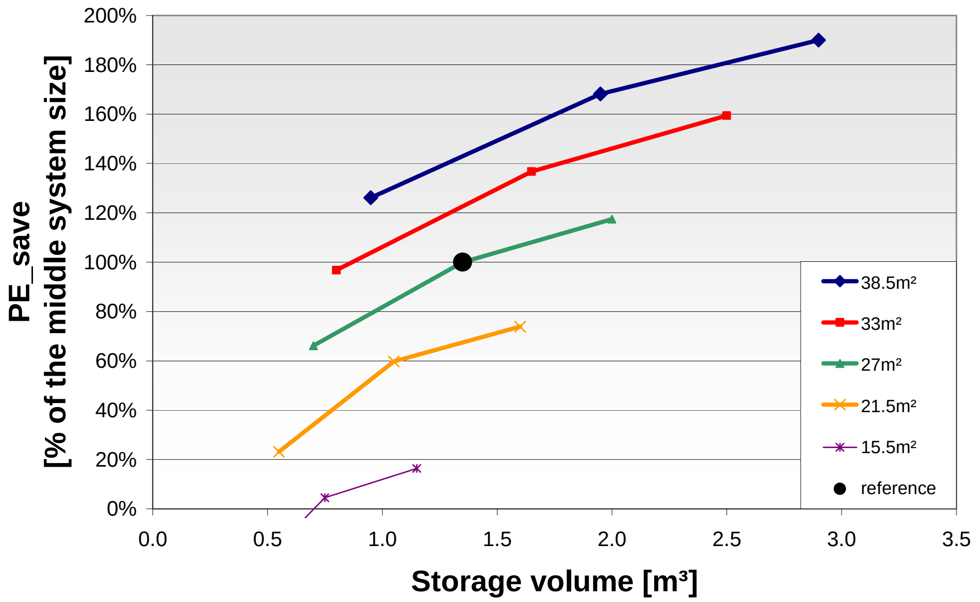


Figure 5.1a Results from the virtual case study for a solar combi+ system in a residential building with chilled ceilings (site: Toulouse), using the SorTech adsorption chiller ACS 08 with dry heat rejection. Top: gross collector efficiency referenced to the values of the middle system size (27 m² collector area, 1.4 m³ storage volume – black dot); bottom: annual values of relative primary energy savings referenced to the values of the middle system size (27 m² collector area, 1.4 m³ storage volume – black dot) as a function of the heat storage size. The influence of the collector area is indicated by the set of curves (value: m² of aperture area). Type of collector: **flat plate**.

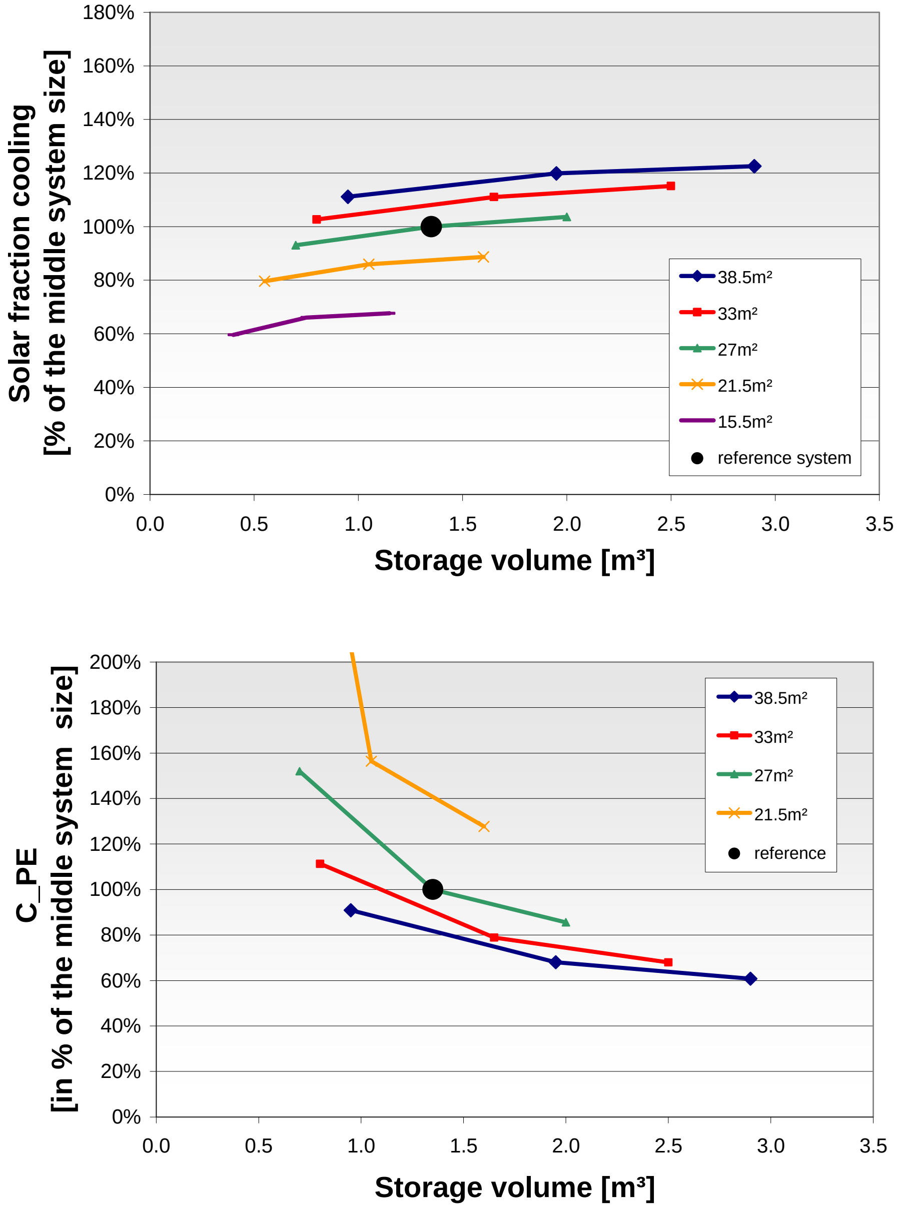
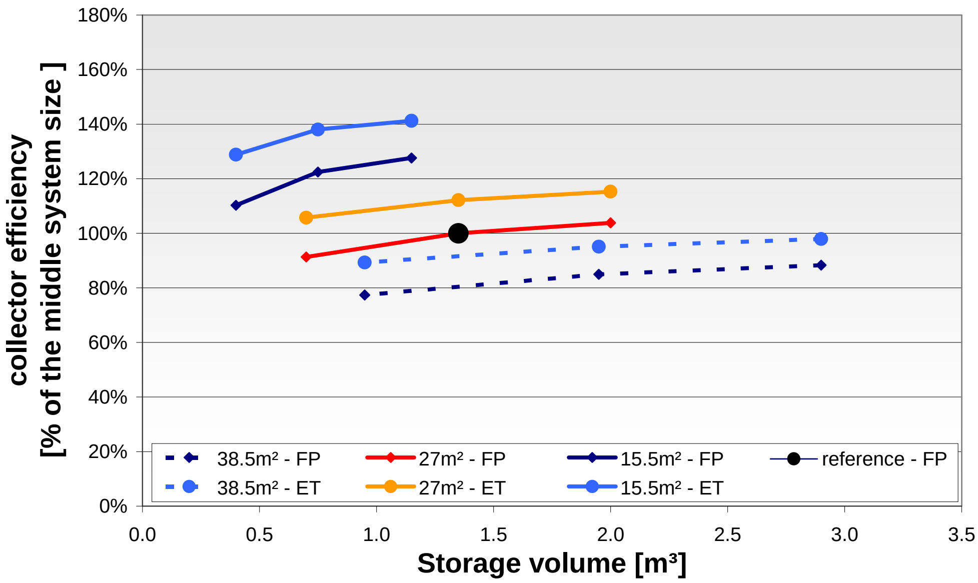


Figure 5.1b Results from the virtual case study for a solar combi+ system in a residential building with chilled ceilings (site: Toulouse), using the SorTech adsorption chiller ACS 08 with dry heat rejection. Top: annual values of the solar fraction in the cooling period referenced to the values of the middle system size (27 m² collector area, 1.4 m³ storage volume – black dot); bottom: specific costs per saved kWh primary energy referenced to the values of the middle system size (27 m² collector area, 1.4 m³ storage volume– black dot) as a function of the heat storage size. The influence of the collector area is indicated by the set of curves (value: m² of aperture area). Type of collector: **flat plate**.



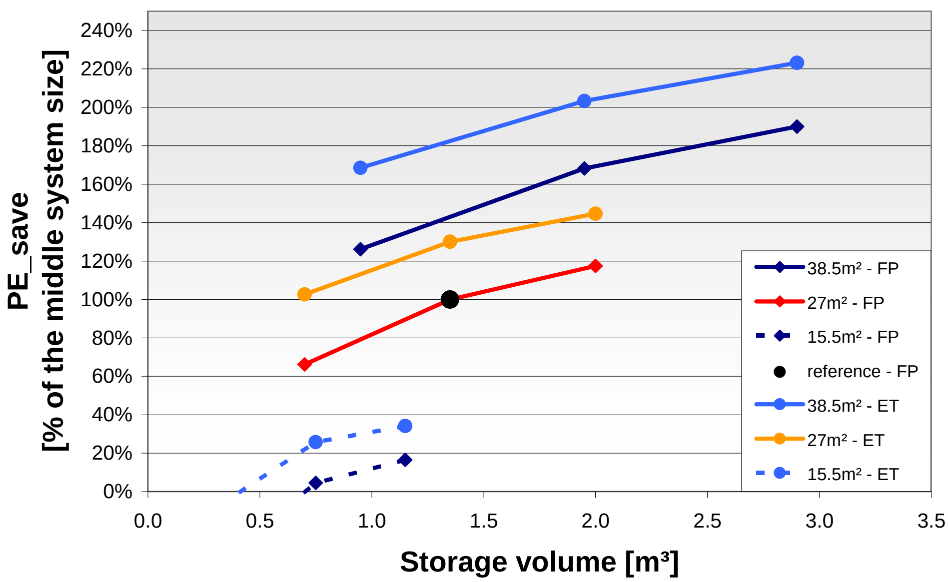
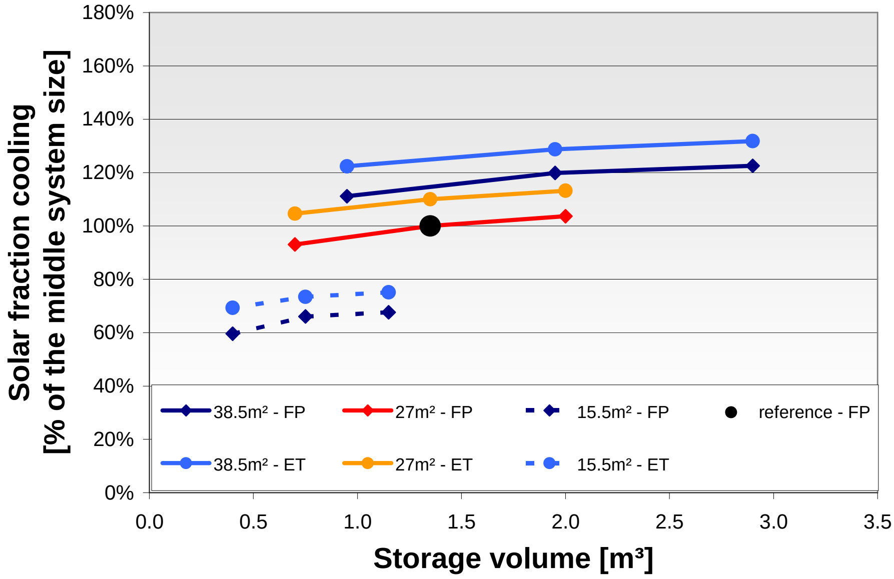
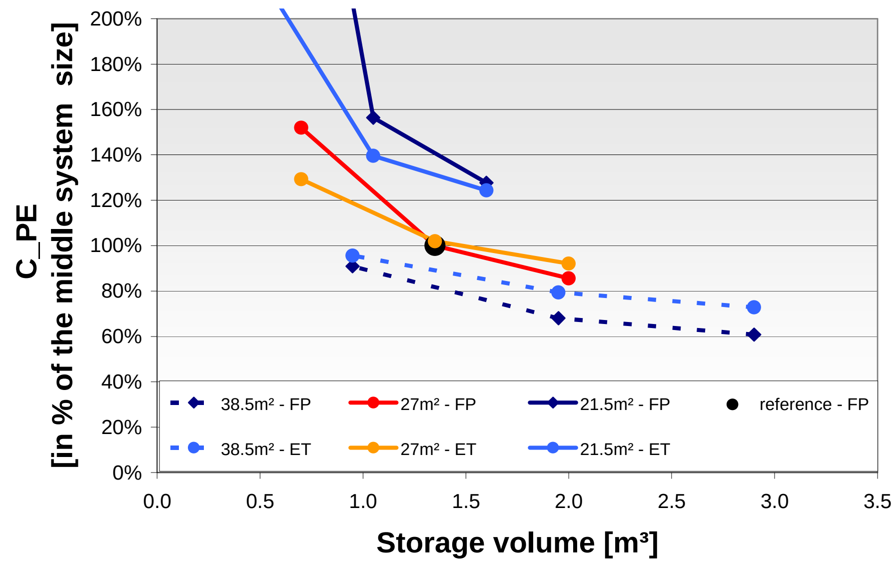


Figure 5.2a Results from the virtual case study for a solar combi+ system in a residential building with chilled ceilings (site: Toulouse), using the SorTech adsorption chiller ACS 08 with dry heat rejection. Top: gross collector efficiency referenced to the values of the middle system size (27 m² flat plate collector area, 1.4 m³ storage volume – black dot); bottom: annual values of relative primary energy savings referenced to the values of the middle system size (27 m² flat plate collector area, 1.4 m³ storage volume – black dot) as a function of the heat storage size. The influence of the collector area is indicated by the set of curves (value: m² of aperture area). Type of collector: **flat plate -FP- and evacuated tube -ET-**.





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The presentation of the specific costs per saved kWh of primary energy allows detecting a sizing area, where the specific costs are approaching a minimum.

From the figures above can be concluded that for both, evacuated tube collectors as well as for flat-plate collectors, this optimised sizing area is connected more with the large size of the collectors (> 30 m² aperture area) and with storage sizes > 1.5 m³. Smaller configurations may lead to low energy savings. However this depends also strongly on the control strategy.

Although a further increase in system size beyond the maximum of calculated collector and storage size may reveal the absolute minimum of the specific costs, this increase in component size will in parallel increase the collector stagnation periods and furthermore increase the total investment cost. Consequently, for this type of application and with the SorTech ACS 08 chiller, a collector area between 30 m² and 35 m² and a heat storage volume of 1.5 m³ to 2 m³ is recommended. The high solar fraction in coverage of the cooling load of > 75% indicates additionally that solar autonomous summer cooling may be an option. This is in particular true if the control strategy is adapted accordingly.