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Potential and Simulation of Open-Cycle Solar-Assisted Climatisation-Plants in Single-Family-Houses

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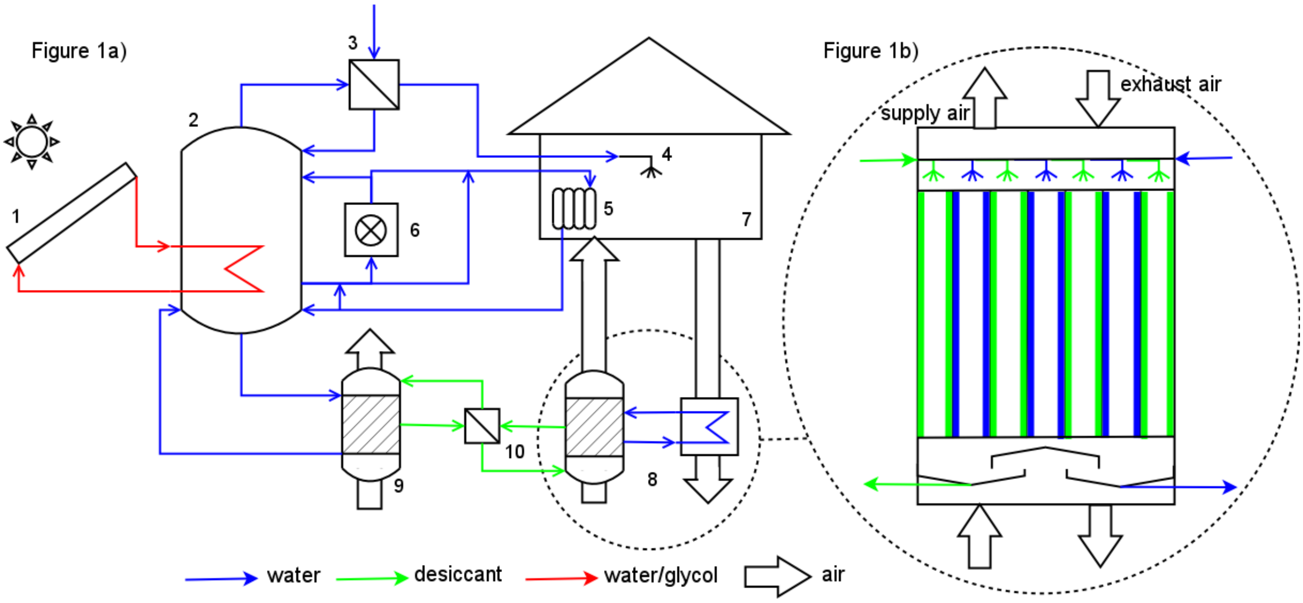
Introduction and Description of the Investigated System and Component Models

Until now investigations of solar climatisation have mainly focussed on office buildings, regarding to the high sensible and especially latent climatisation load during summer time. Nevertheless the market for residential climatisation is also increasing, not only in the USA and southern countries, but also in the European countries, due to higher comfort demands. Thus this study concentrates on the potential of solar climatisation in Single-Family-Houses in different climates.

A liquid desiccant and evaporative cooling (LDEC) system is investigated theoretically by means of TRNSYS [3] simulations. The LDEC system is composed of an absorber, a regenerator and a heat recovery unit. The absorber and regenerator are designed as parallel plate sorption reactors. The absorber (Figure 1b) combines the functionality of cooling and dehumidifying the outside air in one component. Supply and exhaust air are operated in counter-current. On the front side of the plate the salt-solution pours down and dehumidifies the supply air while on the back side of the plate water is applied in the exhaust air stream. Therefore the evaporative cooling is done within the absorber component. The regenerator is operated with fresh air. The desiccant and the air are heated internally directly by hot water from the tank. Between absorber and regenerator a heat recovery is installed in the desiccant cycle.

The LDEC system is integrated in a solar combi system for domestic hot water (DHW) preparation and space heating. In Figure 1a) a schematic of the investigated **S**olar **H**eating and **C**ooling system (SHC) is shown.

The hot water store has a volume of 860l. The space heating cycle ($T_{set,flow}$=40°C, $T_{set,return}$=30°C) is coupled with an auxilliary gas burner. The investigated building is based on the building model developed in an expert group of the International Energy Agency in the Solar Heating and Cooling Programme (IEA-SHC, Task 26) [1], with a ground area of 140m² and an annual heating demand of 60 kWh/m²a at the location Zurich. In the present study the collector area is varied from 10m² to 30m². The component models are taken either from the standard TRNSYS package or are existing validated user-written components.



1 : solar thermal collector
2 : water storage tank
3 : variable flow HX for DHW
4 : DHW profile
5 : radiator

6 : auxilliary gas burner
7 : single family house
8 : liquid desiccant absorber
9 : liquid desiccant regenerator
10 : heat recovery

Figure 1a: Important components and sample configuration of the Solar Heating and Cooling system

Figure 1b: Absorber component of the liquid desiccant and evaporative cooling system

For the cooling and dehumidification device a new model was developed. In this model the heat and mass transfer of each component of the climatisation plant is described by a constant effectiveness factor. This factors are set to values of 0.8 in the present potential study which are quiet pretentious values. For modelling the thermodynamical properties of lithium-chloride are taken from a study of M. Conde [2].

Methods of Investigation

The reference building was investigated in three different climates: Adelaide (Australia), Ottawa (Canada) and Zurich (Switzerland). The meteorological data of these locations were supplied by the METEONORM software tool [4].

Annual simulations were undertaken on basis of a TRNSYS system model which included component models of the hot water store, collector, auxilliary heater, heat exchangers, building, pumps, ventilators, LDEC system and controllers. The climatisation plant can be operated in three different modes:
1.) free ventilation 2.) indirect evaporative cooling 3.) LDEC operation
The regeneration process was operated at a constant temperature of 70°C. In case that the energy delivered by the solar collectors is insufficient to maintain this temperature level, the store is heated by the auxilliary gas burner.
The climatic room conditions set by the user were assumed to a room temperature of 23.5°C and a relative humidity of 50%. In order to maintain these conditions the ventilation rates were set to a value of 1.5 h^{-1} in Zurich and 2.5 h^{-1} in Adelaide and Ottawa. Deviations from the set conditions were accepted within the comfort zone.
The fractional energy savings for the entire SHC system $f_{sav,SHC}$ were defined by the fraction of the primary energy demand for thermal and electrical consumers, Q_{HU} and W_{aux}, in the solar system and the primary energy demand of a conventional reference system $Q_{PE,ref}$:

$$f_{sav,SHC} = 1 - \frac{Q_{HU} + \frac{W_{aux}}{\eta_{el}}}{Q_{PE,ref}}$$

To determine $Q_{PE,ref}$ additional simulations were carried out for a conventional reference system. Compared to the SHC system, the collector loop is eliminated in the conventional reference system, the water store volume is reduced and a conventional compression chiller with a coefficient of performance of 3.2 is used.

Simulation Results

In figure 2 the fractional energy savings are plotted over the collector area for the investigated SHC system. In Zurich the fractional savings increase from 19% at a collector area of 10 m² to 31% at 30 m². For the same collector areas in Ottawa there is an increase from 25% to 42% and in Adelaide from 59% to 70%. These values are slightly higher than these of solar combi systems. This effect increases with a longer operation time of the solar and the conventional air conditioning system.

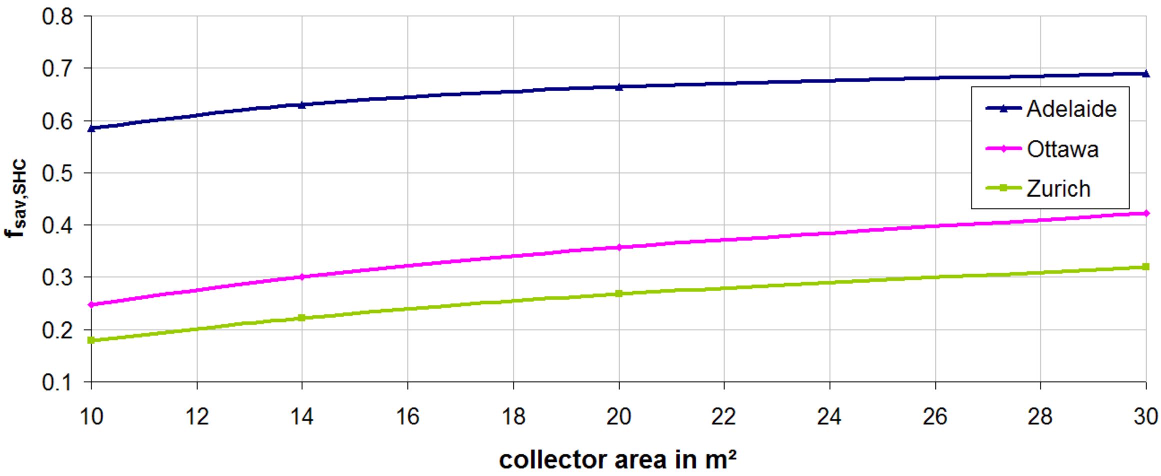


Figure 2: Fractional energy savings over the collector area for different climates

Table 1 shows the percentage of operation time for each operation mode for the LDEC system. Most of the time the system operates in the evaporative cooling mode, in Adelaide and Zurich 83% of the time and in Ottawa 74% of the time. The LDEC mode is used in 13% of the entire operation time in Adelaide, in 22% in Ottawa and in 15% in Zurich. Furthermore it can be seen, that the climatisation system is only seldomly operated in the ventilation mode at all locations.

	Ventilation	Evaporative Cooling	LDEC
Adelaide	4%	83%	13%
Ottawa	4%	74%	22%
Zurich	2%	83%	15%

Table 1: Percentage of operation time for each operation mode

With the investigated LDEC system it was possible to condition the room climate according to the comfort zone demands giben in DIN 1946 [5].

Due to the fact that according to the results shown the evaporative cooling is dominant for all locations, additional simulations were carried out without operation of the LDEC (mode 3).

Figure 3 shows the absolute humidity of the room air over the cummulated operation time of the climatisation plant which consists of an indirect evaporational cooler only.

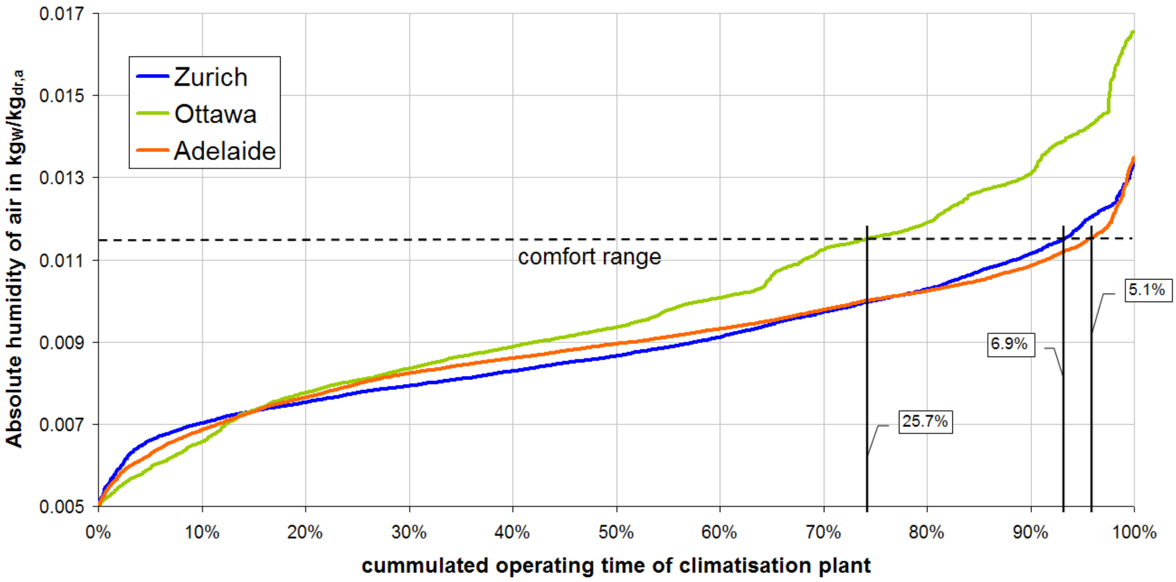


Figure 3: Absolute humidity of the room air over the cummulated operation time of the climatisation plant which consists of an indirect evaporational cooler only

Regarding the humidity the comfort range is exceeded in Adelaide only in 5.1% and in Zurich in 6.9% of the entire operation time. In Ottawa the humidity exceeds the comfort range 25.7% of the operation time. In this location a LDEC system is necessary to maintain a comfortable room climate.

Conclusions

Fractional energy savings $f_{sav,SHC}$ have been evaluated for a SHC system, applying a liquid desiccant and evaporative cooling unit. Due to the fact that humidity values of the climate in Adelaide and Zurich are too high only for a very limited amount of time during the year, indirect evaporative cooling might be sufficient for a wide variety of applications.

Literature

[1] IEA-SHC Programme; Weiss, Werner (Editor): Solar Heating Systems for Houses - A Design Handbook for Solar Combisystems, James & James Science Publishers Ltd., London, 2003

[2] Conde M. R.:Properties of aqueous solutions of lithium and calcium chlorides: formulations for use in air conditioning equipment design, International Journal of Thermal Sciences, Elsevier SAS, 2003

[3] Solar Energy Laboratory (2002). TRNSYS 15.3. University of Wisconsin-Madison

[4] Meteotest (1997). METEONORM 3.0. Global Meteorological Database for Solar Energy and Applied Meteorology.

[5] DIN 1946 Teil 2 (1994). Raumlufttechnik, Gesundheitstechnische Anforderungen (VDI-Lüftungsregeln). Beuth Verlag GmbH Berlin.