A COMPARATIVE ANALYSIS OF MARKET AVAILABLE SOLAR THERMAL HEAT PUMP SYSTEMS

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Abstract

During the last years, many combined solar thermal heat pump systems have entered the market for residential heating systems. Regarding testing and assessment of these systems, existing methods and standards are limited on national and international level. Currently, several approaches are developed and presented. The precondition for any such work is a thorough review of the existing market, revealing for example the relevance of non-standard components and configurations.

More than 100 SHP systems were researched and documented recently, and a comparative analysis is presented in this paper. The systems' concept and function is analysed as well as collector and heat pump characteristics. More "classical" configurations are found to be dominating within all analyses. Nevertheless, it can be shown that non-standard concepts – e.g., utilising solar energy as heat pump source or incorporating unglazed or PVT collectors – are most various. As a result, the need for suitable testing and assessment methods is motivated.

1. Introduction

During the last years, many combined solar thermal heat pump (SHP) systems have entered the market for residential heating systems. The idea to combine solar thermal systems and heat pumps was already reported decades ago (cf. [1, 2]). Regarding testing and assessment of these systems, existing methods and standards are limited on national and international level. For example, the "indirect" use of solar energy – i.e., as source for heat pumps – is ignored by today's standards, though found in various configurations on today's market.

Against this background, Task 44 of the Solar Heating and Cooling Programme of the International Energy Agency (IEA) was organised[a], simultaneously as Annex 38 of the IEA Heat Pump Programme. The objectives comprise, among other topics, the definition of performance figures and test methods for SHP systems. The precondition for any such work is a thorough review of the existing market, revealing for example the relevance of non-standard components and configurations.

In two reviews restricted to Germany and Austria, both published in 2009, the number of identified systems amounted to 13 [3] and 19 [4], respectively. More recently, again 19 – not necessarily identical – systems were presented [5]. In this paper, 107 systems are analysed, offered from about 64 companies.

[a] www.iea-shc.org/task44

Like the activities of Task 44 / Annex 38, the analyses and the preceding market survey are limited to SHP systems that are

- equipped with electrical-driven heat pumps and
- designed for domestic hot water (DHW) preparation and/or residential space heating[b].

In principle, any heat pump can be combined with any solar thermal collector for this purpose. Therefore, only those companies were taken account of which genuinely provide at least one of the main components (collector, heat pump, storage and/or controller).

2. Methodology

The systems presented in this paper were surveyed by more than 10 participants of Task 44 / Annex 38 between October 2011 and June 2012. This means that companies were preferably researched and contacted by native speakers who are, at the same time, proven experts in the field of heating technology. The characteristics of each SHP system were documented in a harmonised way on two-sided fact sheets, including data concerning the overall concept, hydraulics, dimensioning and system control, as well as technical specifications mainly of the collector, heat pump and storage(s).

Most data are derived from online or print sources, though personal contact to representatives of the companies could be established in most of the cases. Anyhow, it is clear that all analyses presented in this paper are based on information whose correctness cannot be checked systematically and independently. Moreover, completeness cannot be claimed. The fact that virtually all identified companies[c] originate from countries that officially participate in Task 44 / Annex 38 might possibly be explained by the barrier of language, which might have restricted the survey substantially to participating countries, resulting in certain regions (e.g. Asia) erroneously not being represented at all.

It has to be noted that in the following analyses, all systems are treated equally, i.e., without respecting the number of installations. Respecting the number of installations for each system would distort all presented parameters. The data base is incomplete here, but when it comes to market penetration, most conventional approaches (e.g., applying flat-plate collectors in "parallel" configurations) – as can be expected – heavily outnumber the less classical configuration. Finally, it has to be noted that, due to imperfect data procurement, the "sample size" is not necessarily constant for the examinations presented in this paper. From the 64 researched companies, all appear in Figure 1 but only 43 in Figure 2. The 107 SHP systems presented in Figure 3 are identical to those in Figure 4, Figure 5 and Figure 6, whereas in Table 1, only a subset is compiled.

3. Comparative Analysis

As it can be seen in Figure 1, most of the surveyed companies are based in Germany or Austria. Yet, only a minority of all companies restricts their market to one or two countries. The strong majority distributes their systems in three or more (specified) countries, even beyond those already named below, e.g. to Croatia or Greece. A less differentiated claim of being available in "Europe" or "worldwide" was given in rare cases.

[b] passive or active cooling functions were documented, though as supplementary information only
[c] confer Figure 1; all presented countries officially participate in Task 44 / Annex 38

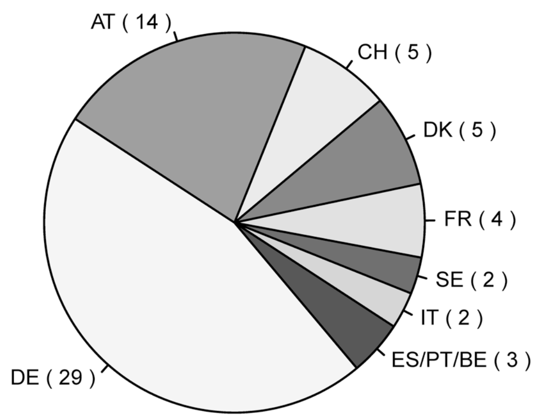

Figure 1: Surveyed companies by country

Figure 2 shows that most companies entered the SHP market in recent years. However, many systems were withdrawn from the market before or during the time the survey was conducted. The respective companies, which would probably be allotted to earlier years in this figure, are consequently ignored.

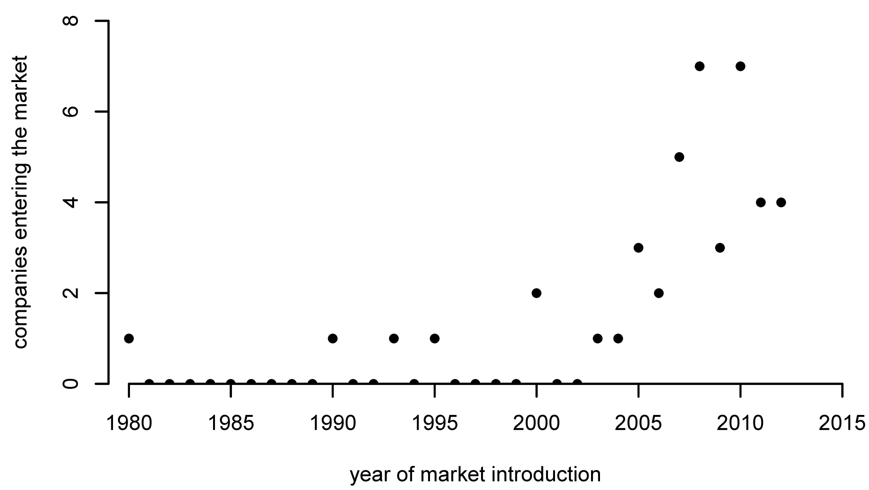

Figure 2: Companies entering the market of solar heat pump systems for residential applications[d]

The following list comprises parameters repeatedly used to characterise SHP systems (cf. [6]):

- system functions, e.g. space heating or preparation of domestic hot water
- heat pump characteristics, e.g. its source or refrigerant
- collector characteristics, e.g. its type or fluid
- storage characteristics, e.g. their number or medium
- the interaction of heat pump, collector and storages, i.e. the system concept
- additional heat generators, i.e. backup components

[d] The oldest system offered by each company is used as indicator, provided that it is still market available today.

Out of this list, the systems' functions, certain heat pump characteristics, collector types as well as the system concepts are presented in this paper. Storage characteristics and backup components are not within the scope.

In the introduction it was mentioned that many companies offer more than one system. So, the question arises which parameters are defined as being distinctive. Within the scope of the survey, a different source of the heat pump or a different concept justified a "distinguishable" system. This decision is to some extent arbitrary. Certainly, the refrigerant of the heat pump, the storage type or the available variety of backup components are interesting parameters as well, and their consideration would indeed result in a multiple of "distinguishable" and thus documented systems.

3.1 System Functions

The main functions for SHP systems, especially for residential applications, are space heating and the preparation of domestic hot water (DHW). Figure 3 shows that both functions are featured in most cases. In contrast, few market-available systems are exclusively designed for DHW preparation. The fact that virtually all of these originate from Mediterranean countries is identified as strong indicator for climate- and market-specific system design.

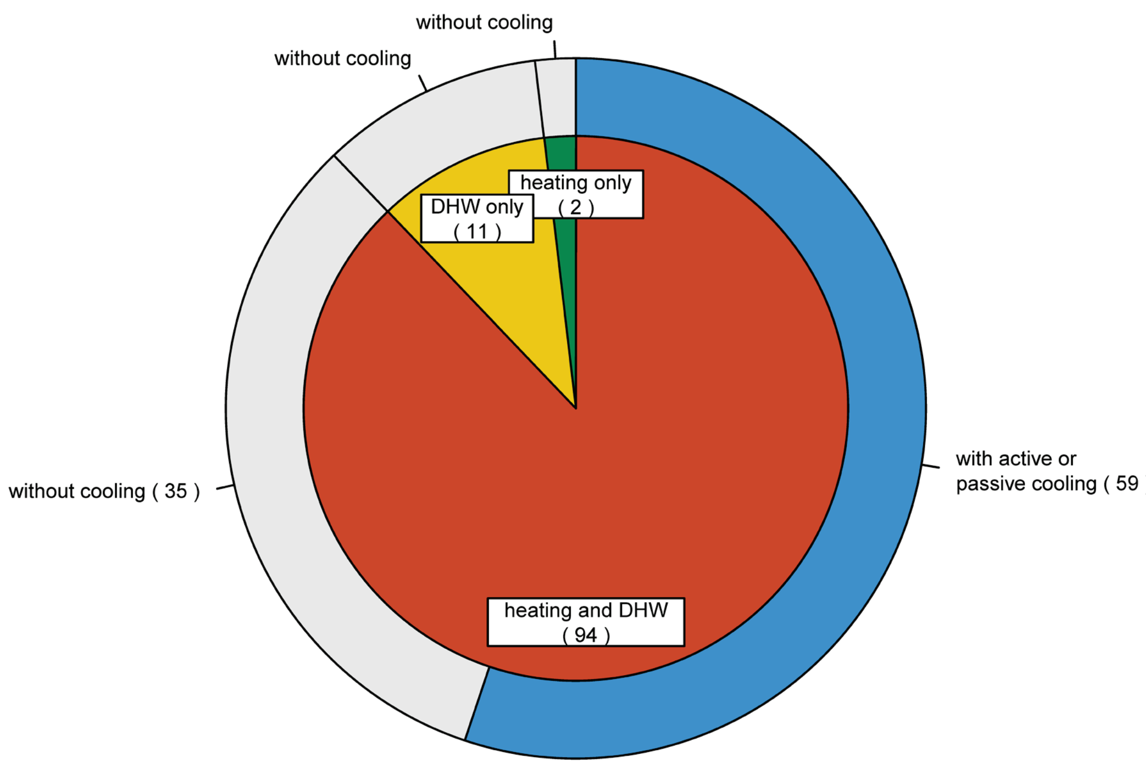

Figure 3: Surveyed systems by function

Space cooling functions were surveyed supplementary. Interestingly, nearly half of the systems do present this capability, mostly as additional option. As it is seen in Figure 3, this applies only to systems that also offer both DHW and space heating. In this paper, no distinction is made between "active" cooling via heat pump operation and "passive" cooling via ground or water source.

Heating distribution systems are no integral part of SHP systems. Thus, the type of heating distribution usually remains undefined, though floor-heating systems are repeatedly recommended. As to the DHW preparation, it was found that more than half of the offered systems incorporate either external fresh water stations or heat exchangers integrated in storages, e.g. corrugated pipes. One of these two solutions applies to virtually all Austrian, Italian and Swiss systems.

3.2 Heat Pump Characteristics

As it is shown in Figure 4, either pure air-source or pure ground-source heat pumps are applied in half of the surveyed systems. Water or exhaust air are also utilised as source in some systems. SHP systems with waste-water sources are not found.

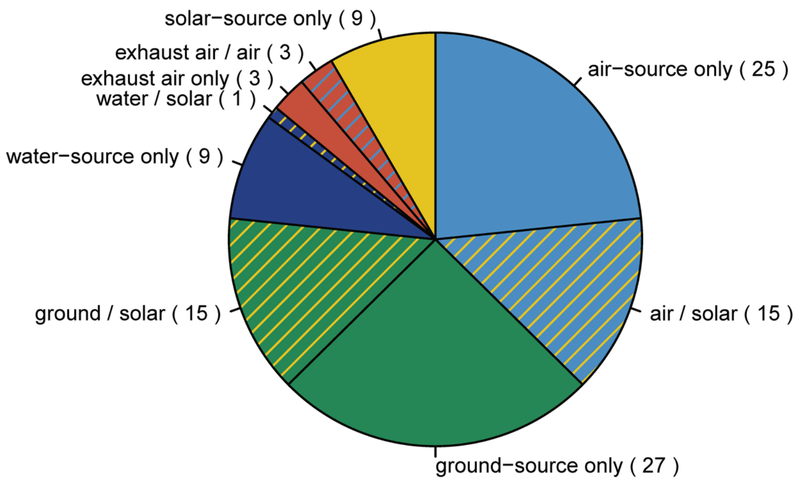

Figure 4: Surveyed systems by source

In manifold systems, solar energy is (also) used as source, either exclusively or additionally to other ones. Such concepts will be described in further details below ("serial"). The technical solutions are, for example, given by source-side heat exchangers, joint source-side brine cycles for solar collector and boreholes, directly-evaporating solar collectors or even by multi-source evaporators.

Various refrigerants are used in the surveyed heat pumps. It appears that regularly, various alternatives are offered by a company to fulfil different demands, e.g. R134a for high-temperature solutions instead of R407C for standard applications. Table 1 provides an overview of the refrigerants, further categorised according to the heat pumps' sources. Here, only the refrigerant that is installed most often is evaluated for each system, ignoring those alternatives that were explained above.

Table 1: Surveyed systems by refrigerant

	R134a	R404A	R407C	R410A	R417A
Air/Water	2	4	11	9	
Brine/Water	2	1	14	6	1
Water/Water			3	2	
Total	4	5	28	17	1

3.3 Collector Types

Within the conducted survey, the collector type was chosen as most significant parameter to compare the applied collectors. The results are shown in Figure 5. Questions on additional characteristics – e.g. regarding the circulating fluid, Solar Keymark certification or handling of stagnation – were answered incomprehensively, and thus, these parameters cannot be presented in comparative form.

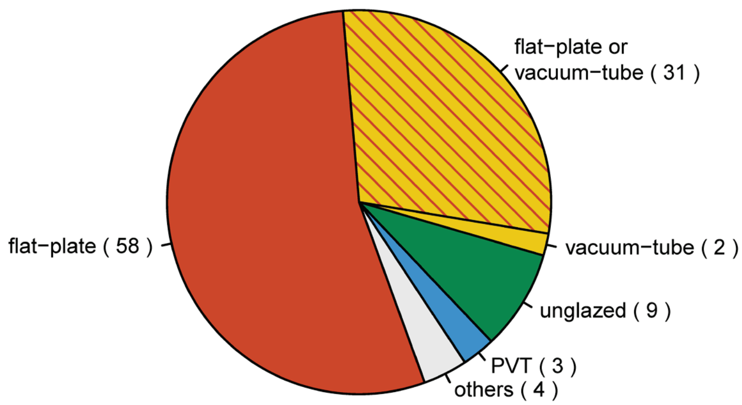

Figure 5: Surveyed systems by collector type

Flat-plate collectors are found in most systems, vacuum-tube collectors are essential only in fewest cases. Instead, the choice between these two types is frequently left open, i.e. affected by the conditions at site as well as the preferences of client and installer. Uncovered or unglazed collectors are found repeatedly, mainly in specific applications as source for the heat pump (see below). Recently developed photovoltaic-thermal (PVT) collectors are found only in few market-available SHP systems, for the first time in 2011.

3.4 System Concepts

In this paper, the system concepts are defined by the way of interaction between heat pump and solar collector. Typically (cf. [7] or [8]), the following distinction is made:

- Collector and heat pump independently supply useful energy (space heating and/or DHW), usually via one or more storages. This configuration is often denoted as “parallel”.
- The collector acts as a source of the heat pump, either as exclusive or as additional source, and either directly or via a buffer storage. This configuration is often denoted as “serial”.

Thirdly, a “regenerative” concept shall be used here, i.e. the usage of solar energy to enhance the actual source of the heat pump, in these cases usually ground. The regenerative approach could possibly be regarded as subset of the serial concept. However, there are operational differences: Regenerative operation usually occurs in summer, when the DHW storage is heated and no heating demand exists, i.e., when the heat pump is off. The intention differs as well because regenerative operation is usually applied to avoid the deterioration of the ground source on long time scale (or merely to prevent solar collector stagnation). And indeed, systems were found on the market featuring regenerative modes explicitly, though no (intended) serial mode. The obvious objection that the publications cited above do not present the regenerative concept can be replied to with the fact that only non-regenerable air-source heat pump systems were examined then.

Yet, it was realised in the publications cited above that such concepts can be combined within one system, or in other words, that "parallel" and "serial" arrangements do not exclude each other. The counting of all possible combinations of the three options proposed here – while ignoring permutations, redundancies and the trivial case of "none" – results therefore in 7 concepts (cf. Figure 6). It has to be accepted that possible cooling functions of SHP systems are not represented by this approach, though they might provide regenerative effects as well.

Applied to the surveyed systems, this approach results in a fragmentation that is shown in Figure 6. The "parallel only" concept, which is simple in design, installation and control, clearly dominates. SHP systems with "serial only" concept are rare, and "regenerative only" even non-existent. There are, however, manifold "versatile" or "combined" concepts. All in all, more than 40 systems with serial and/or regenerative character are presented.

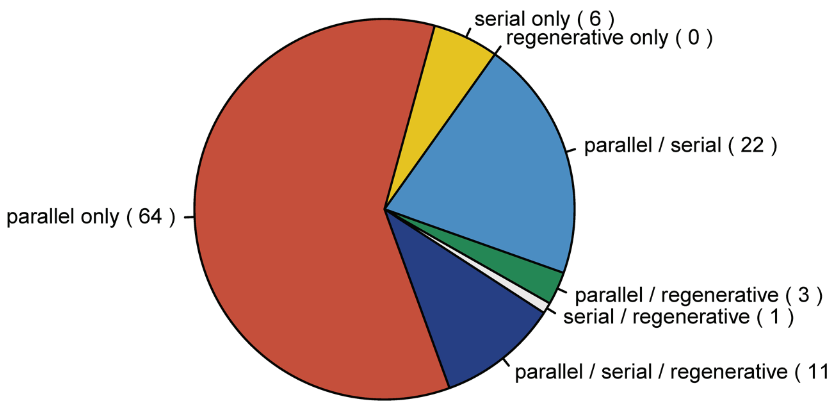

Figure 6: Surveyed systems by system concept

4. Conclusion and Outlook

In this paper, it was shown that solar thermal heat pump (SHP) systems are widely available on the European market. Most companies offer "traditional" systems with flat-plate collectors in parallel arrangement for both space heating and preparation of DHW. Still, manifold alternative configurations were found, utilising for example unglazed collectors or provide DHW only.

As main result of this survey, the need for flexible performance figures and testing methods becomes visible. It was, for example, shown that serial (or more complex) system configurations are widely distributed in Europe, which is ignored by today's standards. In these cases, solar energy is extensively used as source energy for the heat pump though not directly as useful energy. Thus, the solar fraction – generally a popular performance figure for solar heating systems – becomes inapplicable.

The fact that PVT collectors are applied in market-ready systems is a rather young trend. Consequently, assessment methods are required taking account of energy both consumed and fed-in to the grid, similar to cogeneration systems.

Not shown in this paper, but in principle given by the surveyed data, are storage characteristics (medium, volume, number and function), type of (optional) backup and the distinction between active cooling via heat pump and "passive" cooling without heat pump operation. These parameters, as well as cross analyses, will be shown in the official reports of Task 44 / Annex 38. The trend shown in Figure 2 suggests that further companies will enter the market of SHP systems. These dynamics should be kept in mind, even after an extended and updated report is published.

Acknowledgements

The authors would like to thank the participants of IEA SHC Task 44 / HPP Annex 38. The evaluated data basis originates from their commitment. In particular, acknowledgements are expressed towards[e] Matteo D'Antoni (EURAC research), Walter Becke, Alexander Thür, Martin Vukits (all three AEE intec), Simon Braungardt, Qiaoqiao Hou (both Fraunhofer ISE), Sara Eicher (HEIG-VD), Klaus Ellehauge (Ekolab), Hilbert Focke (ASiC – Austria Solar Innovation Center), Robert Haberl, Michel Haller and Daniel Philippen (SPF Institut für Solartechnik), Ivan Katić (Danish Technological Institute), Anja Loose (ITW, University of Stuttgart), Ivan Malenković (AIT Austrian Institute of Technology), Peter Pärisch (Institut für Solarenergieforschung GmbH).

All representatives of the surveyed companies deserve our thanks for their cooperation.

Funding of the Federal Ministry of Economics and Technology (BMWi) for the project "EnOB: Kompetenzzentrum Wärmetransformation – QTrafo" (03ET1028A) allows Fraunhofer ISE to participate in Task 44 / Annex 38. This support is gratefully acknowledged.

The main author's research work is kindly supported by the Evangelisches Studienwerk Villigst e.V.

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[e] in alphabetical order