IEA Heat Pump Programme

Annex 38

Solar and Heat Pump Systems

Final Report

Operating Agent: Switzerland

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Preface
This project was carried out within the Heat Pump Programme, HPP which is an Implementing agreement within the International Energy Agency, IEA.

The IEA
The IEA was established in 1974 within the framework of the Organization for Economic Cooperation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster cooperation among the IEA participating countries to increase energy security through energy conservation, development of alternative energy sources, new energy technology and research and development (R&D). This is achieved, in part, through a programme of energy technology and R&D collaboration, currently within the framework of over 40 Implementing Agreements.

The IEA Heat Pump Programme
The Implementing Agreement for a Programme of Research, Development, Demonstration and Promotion of Heat Pumping Technologies (IA) forms the legal basis for the IEA Heat Pump Programme. Signatories of the IA are either governments or organizations designated by their respective governments to conduct programmes in the field of energy conservation.

Under the IA collaborative tasks or “Annexes” in the field of heat pumps are undertaken. These tasks are conducted on a cost-sharing and/or task-sharing basis by the participating countries. An Annex is in general coordinated by one country which acts as the Operating Agent (manager). Annexes have specific topics and work plans and operate for a specified period, usually several years. The objectives vary from information exchange to the development and implementation of technology. This report presents the results of one Annex. The Programme is governed by an Executive Committee, which monitors existing projects and identifies new areas where collaborative effort may be beneficial.

The IEA Heat Pump Centre
A central role within the IEA Heat Pump Programme is played by the IEA Heat Pump Centre (HPC). Consistent with the overall objective of the IA the HPC seeks to advance and disseminate knowledge about heat pumps, and promote their use wherever appropriate. Activities of the HPC include the production of a quarterly newsletter and the webpage, the organization of workshops, an inquiry service and a promotion programme. The HPC also publishes selected results from other Annexes, and this publication is one result of this activity.

For further information about the IEA Heat Pump Programme and for inquiries on heat pump issues in general contact the IEA Heat Pump Centre at the following address:

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SOLAR AND HEAT PUMP SYSTEMS

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SOLAR + HEAT PUMP

Abstract

Annex 38 was concerned with solar and heat pump system for space heating and domestic hot water. A total of 55 experts from eleven countries attended some or all of its eight meetings over the period 2010 – 2013.

The main results are as follows:

- A survey of the market in 2010 was responded to by more than 80 companies.
- Four generic categories of SHP systems have been proposed and used throughout the Annex period, and taken over by several other teams in research projects.
- An energy flow chart solution was developed and used by all 32 Annex projects.
- Definitions of all performance indicators (from COP to SPF+) are now available and form a basis for a future EU standard.
- A simulation framework was developed from previous IEA work and proved to be a great tool for comparing SHP systems
- Laboratory testing procedures for any SHP system have been developed and used and described.
- 32 systems in the field were monitored by several teams, and 20 have been reported with a common reporting format.
- Not surprisingly, a high variance of SPFs was observed and the reasons why explained. The management of the store is one of the important ones, together with the overall control strategy and the temperatures of heat distribution systems.
- Validated models are now available for many SHP configurations.
- A comparison of different configurations with the same framework was produced and shows what solar heating can contribute (or not) to heat pump systems
- The final report from the project, in the form of a handbook, is of high scientific and technical quality and will soon be sent to the publisher. Publication date is planned for autumn 2014.
- An economic analysis model to enable systems to be compared has been developed, and will be included in the handbook as Chapter 8.
- S + HP systems are now considered as “standard technologies”, although there is still some work to be done to arrive at optimum high performing solutions.
    - All categories of systems can deliver SPFs of 5.0 or more if solar energy is also used, provided that careful designs and control strategies are applied.

FOREWORD

The operating agent would like to thanks the EXCOs involved,

the supporting institutions from all countries that have financed the work,

the Annex participants and

the four subtask leaders.

TABLE OF CONTENTS

1 INTRODUCTION

1.1 Background

Scope of Annex 38

SHC Task 44 / HPP Annex 38 started in January 2010 and ended in December 2013.

Its scope considered solar thermal collectors and storage in combination with heat pumps, for the supply of domestic hot water and heating in family houses.
The main target market was small systems in the range of 5 to 20 kW.

Any type of solar collector was considered: using a liquid heat transfer fluid, air, hybrid collectors, or even hybrid thermal and photovoltaic or "PV/T" collectors, glazed or unglazed.

Any type of source of heat for the heat pump was considered: air, water or ground source.

The Annex was a joint effort of the Solar Heating and Cooling Programme (SHC) and the Heat Pump Programme (HPP) of the International Energy Agency.

It was called Task 44 for SHC and Annex 38 for HPP therefore abbreviated T44A38.

Participating countries are

from HPP: Finland, Germany, Switzerland (Operating Agent),

and from SHC: Austria, Belgium, Canada, Denmark, France, Germany, Italy, Spain, Sweden, Switzerland (Operating Agent), USA.

1.2 Purpose

The purpose of Annex 38 is to better understand the combinations of solar collectors and heat pump for one family houses.

1.3 Delimitations

All heat pumps reviewed are electrically driven.

2 FRAME OF REFERENCE

Before 2010 an increasing number of systems for house heating and/or domestic hot water production has been developed which use a combination of solar thermal systems and heat pumps. Active promotion of ground coupled heat pumps and efficient modern air heat pumps have led to a growing market penetration of electrical heat pumps.

The market was driven by ecological consideration as well as in some regions by obligation of using solar for preheating of domestic hot water.

The heat pump industry on one hand and the solar industry on the other hand have been presenting at major trade fairs first commercial systems of a combination of solar and heat pump solution. Some manufactures of both worlds have started tight collaboration around a common combined system. Claims of reaching 100% renewable in such combination are made, although there is of course still some electricity needed which has a primary source not necessarily renewable.

In this new market segment most manufacturers exhibit a background in one of the two main involved technologies. However this does not guarantee that the combination leads to an optimal system for the following observations can be made:

- Main system components are just placed one beside the other and do not always interact in phase. Solar energy is mainly used to reduce the electricity demand for hot water preparation and thus heat pump manufacturers tend to put systems side by side with no interaction. Is it the optimum?

- In other systems, the main purpose of the heat pump is understood as a method to increase the energy gain of the solar collector system. The heat pump allows using solar energy even if the temperature of the gained heat has a temperature level below the required temperature of the demand side (heating system, hot water). This was already on the market 30 years ago with the solar roof concept with various unglazed collector types. It is now regaining some attention from the market in situation where ground or air heat source might not be optimal sources.

- We see developments of overall system concepts where solar heat is used as the main source for a heat pump either directly or indirectly, i.e. where the two producers are uncoupled through one rather large heat storage. The storage may be sensible or latent (PCM, ice) and a short term or a long term type (e.g. ground). How big should that storage be? Where shoult it be placed into the system? Is it worth increasing the interaction of the solar and heat pump?

Although recent publications are dealing with some coupling of the two technologies, no systematic analysis of the different systems and their application potentials in different sectors and under different boundary conditions has been undertaken around the world. This was clearly a statement of the international experts during the preparatory meetings in the course of 2009.

Moreover standards sometimes precede the boom of a technology and keep it into quality frameworks that the market need. The systems we are discussing and the way to test and qualify them are not yet described in norms or standards opening the door to non-scientifically commercial claims and future disillusions.

Four main components interact in a combined solar and heat pump system:

- The solar collectors which can be of any type glazed, evacuated or unglazed.
- The heat pump which can be air source, water source or ground source type.
- A storage which can be a water tank, a PCM tank, the structure of the building or the ground, or any other future new type.
- The control strategy which determines how the other components interact.

The increasing number of offered systems using a combination of these three components and the high expectations about their contribution to energy efficient heating, hot water (and possibly cooling) of buildings give background to our proposed systematic investigations.

A systemic comparison of existing systems was needed both from an economical and environmental point of view. In addition, it might be highly advisable to adjust various systems to their specific boundary conditions, such as buildings standards or climate zones.

We know from the past IEA works, that the best approach is a systematic approach, including the modeling, simulations and field-testing of the joint use of solar thermal energy and heat pumps. This method allows optimization and further development of the relevant systems,

After all only a high quality of systems on the market will ensure a sustainable development of this type of combinations of solar and heat pumps. The high quality means competition and comparison. Competition is present in both sectors solar and heat pumps. Fair and independent comparison makes it necessary to have a common agreed approach for system characterization, performance definition, benchmarking reports and standard compliance. If not we will see installations with poor results and unsatisfied users that will affect the “new” market for combined systems (solar thermal + heat pumps) but also the more established markets for heat pumps and solar thermal.

The Annex has emphasized system description and reporting, system monitoring, and performance assessment methods to enable comparison of various systems on few criteria.

Participants included scientists, HVAC engineers, solar and storage components manufacturers, heat pump manufacturers, complete heating solutions providers and industry representatives.

Coordination with other Tasks of the IEA Solar Heating and Cooling Programme, IEA Building and Community Systems and IEA Energy Storage as well as the Heat Pump Programme of the Heat Pump IEA Annex has taken place as appropriate.

3 THE PROCESS

The Annex was organized in four Subtasks each lead by an expert and the choice of topics for each subtask proved to be adequate:

Subtask A: Solutions and generic systems (Lead Country: Germany, Fraunhofer ISE, Sebastian Herkel). The objective of Subtask A was to collect, create and disseminate information about the current and future solutions for combining solar thermal and heat pump to meet heat requirements of a one family house. Subtask A dealt with pre-manufactured systems and systems installed and monitored during 1 or 2 years.

Subtask B: Performance assessment (Lead Country: Austria, AIT, Ivan Malenkovic 2010-2012 and Michael Hartl in 2013). The objective of this subtask was to reach a common definition of the figures of merits of solar + heat pump systems and how to assess them. This work lead to prenormative definition on how to test and report the performance of a combined solar and heat pump systems.

Subtask C: Modeling and simulation (Lead Country: Switzerland, SPF, Michel Haller). The objective was here to provide modeling tools of all generic solar and heat pump systems and to report sensitivity analysis on most of the systems such as being able to pinpoint important features and marginal ones in a given system configuration. Sizing of systems and optimizing their control are also possible using the output of this Subtask, with the computing tools and the framework developed.

*Subtask D: Dissemination and market support (Lead Country: Italy, EURAC, Wolfram Sparber).*The objective was to provide information to the external world during the course of T44A38 so that value added created by the participants could be transferred as fast as possible to a growing market. A second objective was to deliver the final book of T44A38 aimed as a reference document in the field of solar heat and heat pumps.

4 RESULTS

Subtask A : Solutions and generic systems - the main results

- In a survey organized by Subtask A leader, more than eighty manufacturers from eleven countries provided information on their SHP systems available on the market during the period 2010-2012. It was a surprise to see the number of marketed systems in a technical and standardization environment that was not at all established. Performances were announced without clear definition and without any reliable benchmark and on top without any standard for the definition of a SHP hybrid system performance.

- The survey showed that the idea of combining solar collectors and a heat pump (SHP) was a followed idea in the HVAC industry. A clear market objective of the industry for one family house is to deliver complete pre-fabricated systems rather than components that installers should assemble reducing the chance of wrong installation and misconnection. And the SHP combination can deliver both heating and domestic hot water all year long with a high renewable fraction performance. A criteria that the market can value! Not all the market but a segment of environmentally concerned buyers.

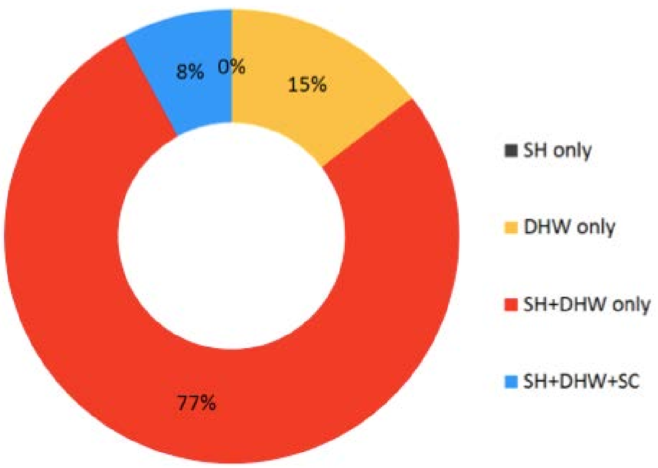


Figure 1: Survey output: SHP system classification according to the supplied building load (the combisystem is the vast majority of SHP systems on the market) (source: Fraunhofer ISE)

- A great variety of combinations of solar collectors and heat pump was found on the market. The industry has not yet clarified the best options for a given application. As always in hybridization of systems, real installations and behaviour proved to be more complex than just the juxtaposition of components. Annex 38 showed some best practice examples in this direction.

- The work of Annex 38 has brought some order and clarification into the systems by establishing a clear classification of solutions, as follows:

  - The parallel system where solar delivers heat mainly to the domestic hot water (DHW) tanks and heat pump does the heating and the backup of the DHW. There is no connection between the collectors and the evaporator of the heat pump. Often chosen with air/water heat pump this combination is the big market share. This is by far the simplest system idea. It deserves however careful design especially when the heat storage is shared between the two producers: the solar collectors and the heat pump.

- The serial concept where solar heat can be used by the evaporator of the heat pump enhancing the temperature of evaporation and thus the heat pump coefficient of performance (COP). Often unglazed collectors are used to avoid problems with condensation in glazed collectors operating below the dew point of the collector atmosphere or the outdoor air.

- The regenerative concept for ground source heat pump, where the solar collectors can regenerate the heat into the borehole when there is excess of solar energy collected. Most of the time the basic system is a serial system in this case and the collectors are often unglazed collectors. The gain of the regeneration is not always decisive as Annex 38 showed in simulations.

- More Complex systems where all systems components can be linked together in different arrangement, with 3-way valves and dedicated controller, but at the price of a more complex installation and sometimes a delicate control strategy. Those systems are found in bigger installations and where various users (heating and cooling) at different levels of temperature have to be supplied.

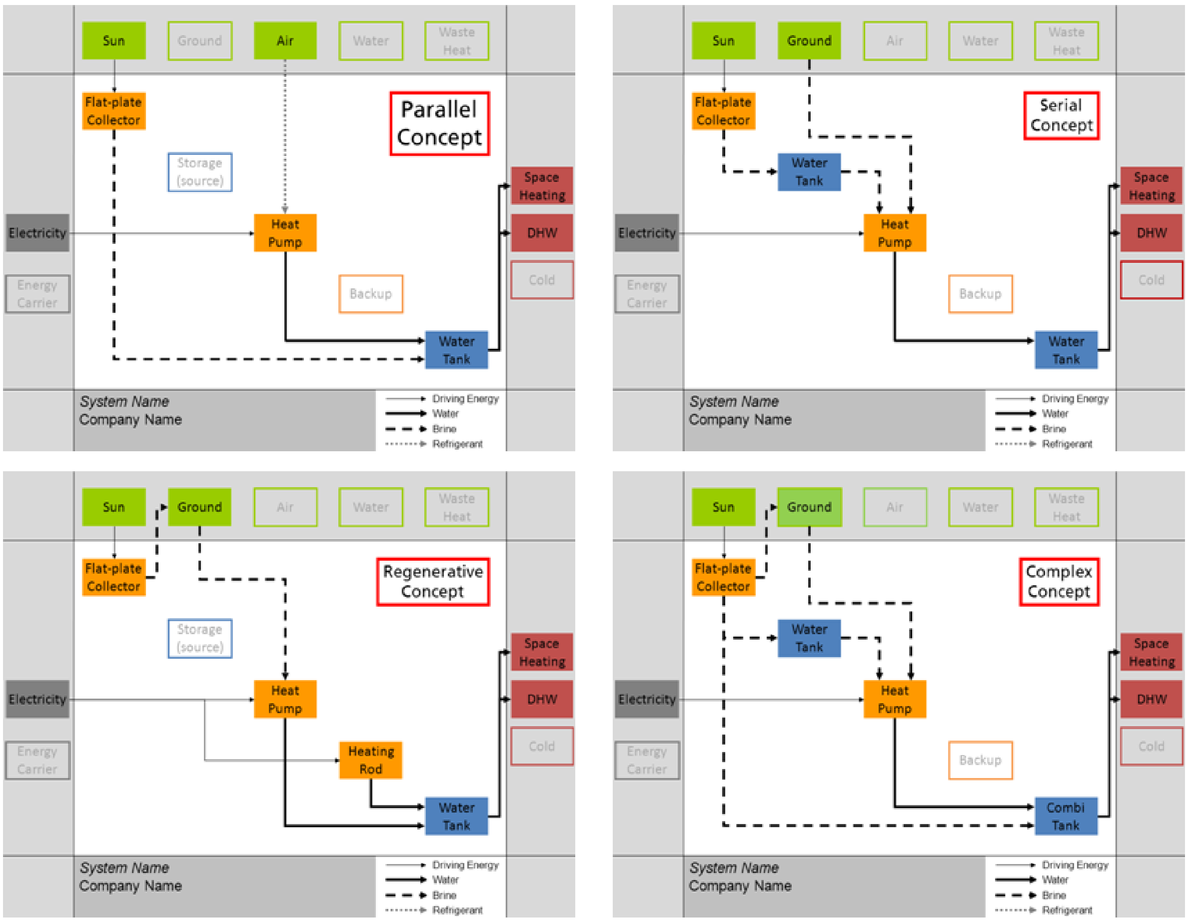


Figure 2: the four generic SHP systems according to Annex 38 depicted with the "energy flow chart" designed by Annex 38 (source: Fraunhofer ISE)

- Annex 38 has established a way to represent any combination of solar and heat pump system and more generally any energy system in a systematic “energy flow chart” diagram that simplifies the rapid understanding of a system configuration and the energy flows, without losing information compared to a classical hydraulic scheme. This chart is available as a simple Excel tool from the task web site. As an example figure 2 shows all basic concepts of SHP with such a chart.

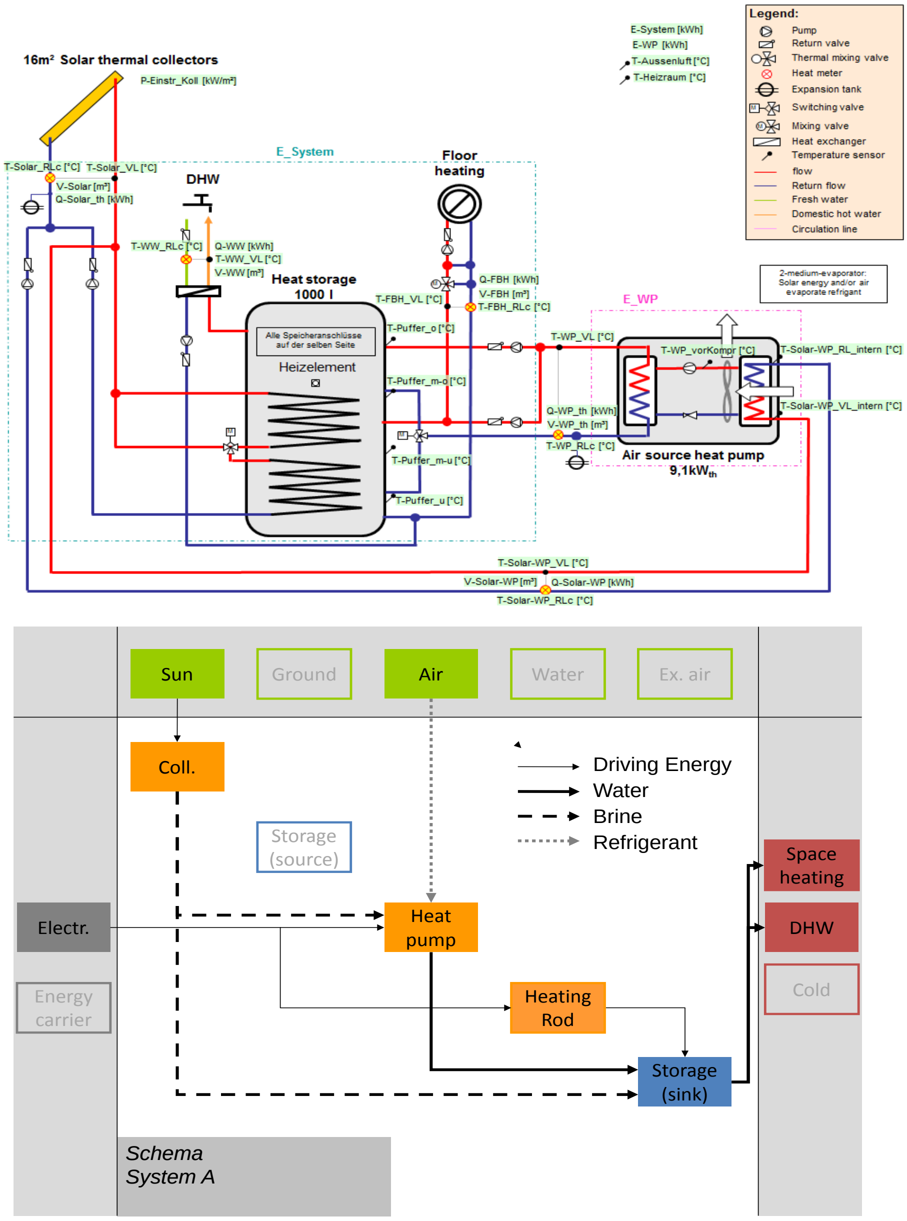


Figure 3: A parallel system described with the hydraulic scheme and with the Annex 38 energy flow chart (source: Austria)

- The survey made by Subtask A showed also that there was a need for test methods and performance factor definitions, since a combination of solar heating and heat pumps was still to be considered as a complex system and no standard was existing at golbal level even at national level.

Systems monitored in-situ

- Participants in the Task have provided 1 to 2 years of monitored results from 50 different systems in seven countries, covering not only the variety of systems on the market but also prototype systems. The variance of performances was however found to be large. Seasonal performance factors (SPF) from as low as 1.5 to a very good 6 were measured.

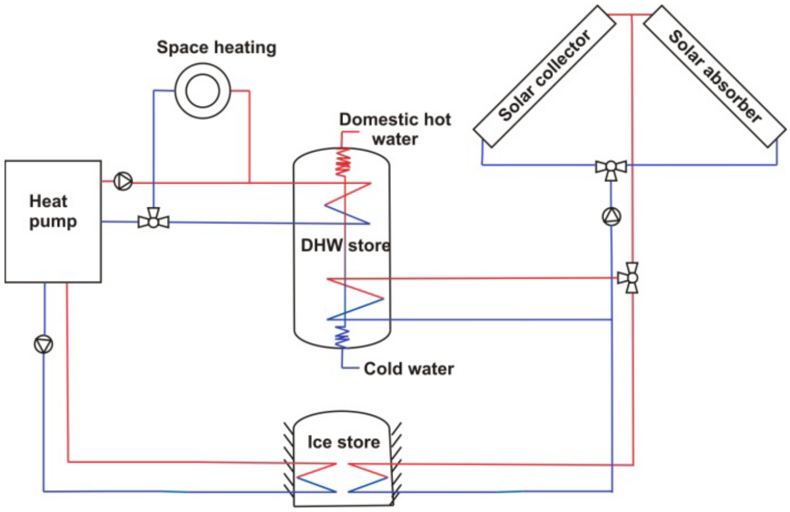


Figure 4: a SHP concept with an ice storage (Source: ITW, Germany)

- Reasons for the variety of results have been analyzed and are explained in the Subtask A reports as well as in the handbook that will appear in June 2014.

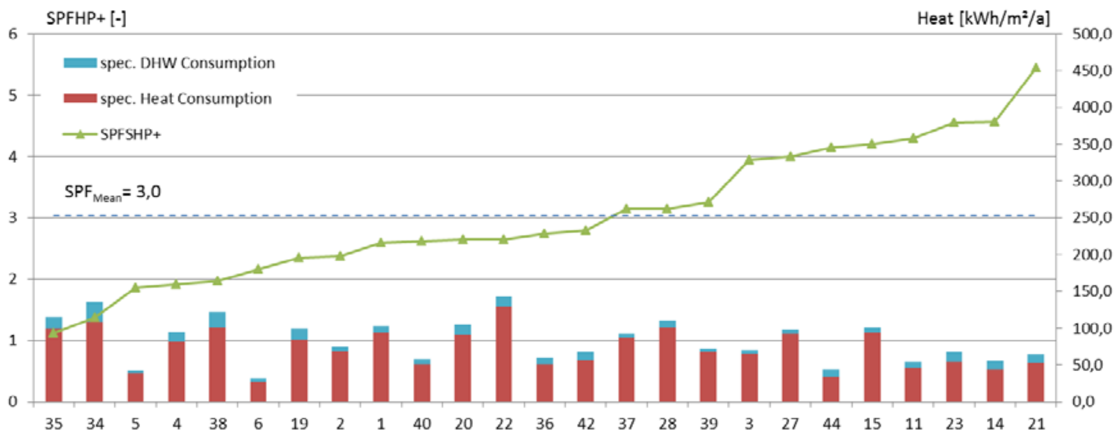


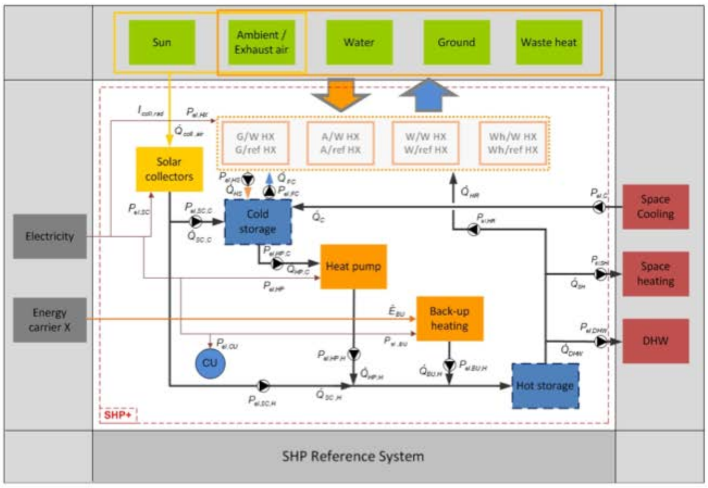
Figure 5: Monitored results on 25 SHP systems. The SPF can range from bad systems to excellent ones (copyright: Fraunhofer ISE)

- Although parallel systems are the most common and the simplest to operate, well-performing systems were found in all four identified categories (P/S/R/C), and good integration of all components was shown to be possible. Some best practice examples have been reported and will appear in the handbook.

Subtask B Performance assessment – Main outcomes

Performance assessment

- In terms of reporting performance of a SHP installation, Annex 38 showed that there is a need for different performance figures for different purposes. Those can be: energy evaluation, environmental analysis or economic aspects. Those various performance factors have been derived in a Subtask B report where all equations and system boundaries are given.



$$SPF_{SHP+} = \frac{\int \left(\dot{Q}_{SH} + \dot{Q}_{DHW} + \dot{Q}_{C} \right) dt}{\int \left(\sum P_{el,H,SHP+} \right) dt}$$

$$\sum P_{el,SHP+} = P_{el,SC} + P_{el,SC,C} + P_{el,SC,H} + P_{el,HP} + P_{el,HP,C} + P_{el,HP,H} + P_{el,HS} + P_{el,BU} + P_{el,BU,H} + P_{el,SH} + P_{el,DHW} + P_{el,C} + P_{el,FC} + P_{el,HR} + P_{el,HX} + P_{CU}$$

Figure 6: The definition of SPF_{SHP+} according to Annex 38

- There is also a necessity to take all components into account in any performance calculation. The auxiliary components such as pumps, controllers, displays, fans, valves, sensors,… must be accounted for since this can make the difference between a good system and an unacceptable one, i.e. with too low a seasonal performance factor (SPF) when auxiliary electricity is considered. And auxiliary electricity should be considered in all cases for a fair comparison between different heating technologies.

- System boundaries have been clearly defined in order to calculate all relevant performance indicators. The method to fix the boundaries uses the energy flow diagram describing all flows in a system and can be applied to any kind of energy system (solar cooling for instance), and not only to solar and heat pump systems.

- Subtask C has derived the correct definitions for System Performance Factors (SPF) that take the overall system into account. Engineers and manufacturers can refer to this work to specify the SPF within common boundaries: this is a necessary basis for any system comparison.

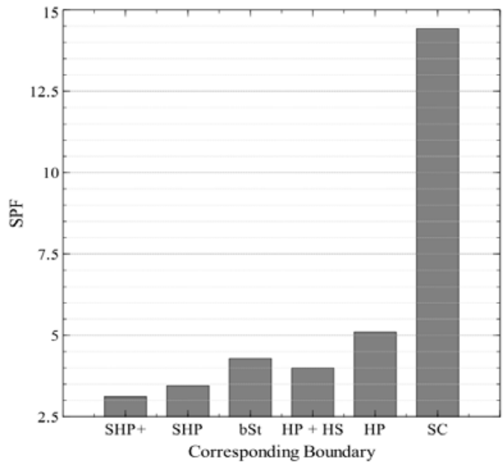


Figure 7: SPF depends strongly on the boundary considered (for definitions of boundaries in this figure refer to Subtask B reports)

Laboratory testing

- Laboratory testing is important, since SHP combinations are complex systems with dynamic interactions. Solar energy is intermittent and highly variable during a day and provides dynamical situation in a solar based system. Testing the whole system is thus fundamental to the process of developing SHP systems and can provide relevant information for performances, failures, default behaviour etc. in a rather short period of time. Those lab tests should therefore be encouraged my authorities.

- Test sequences over twelve days with variable meteorological conditions have been used to test several types of SHP systems in several European solar laboratories. The methodology used by Annex 38 proved to be accurate and reliable.

- There are different methods of testing SHP in laboratory over this predefined sequence of twelve days. Subtask B has described the main methods that are in use in the participating laboratories. Pros and Cons of each method are analyzed in a technical report.

Subtask C: Modeling and simulation – some of the findings

- Annex 38 has shown that basic models for simulating components in solar and heat pump systems are available. Features of the most relevant models for solar collector, heat pump, heat storage, borehole, have been analyzed and reported. Recommendations for choosing an adequate model have been formulated in Subtask C reports. The best ones have been integrated into the Trnsys framework of the Annex 38.

  Simulation models of components are essential in order to be able to simulate systems. Four working groups on solar collector, ground heat exchanger, heat pump, and heat storage, have surveyed on existing models. A new Heat Pump Model (Type 877) for TRNSYS has been developed. Its validation is in progress before it can be used for optimisation purposes.

  Modeling the frost conditions and water condensation heat exchange on solar absorbers for night operating conditions was also done. The model has been tested on laboratory results and proved to be adequate. However it was found in the Task that heat gain from the condensation on the surface of the solar collectors is not very important in the annual balance of heat supplied. Solar radiation and air exchange dominate.

- Simulations and also field monitoring have shown the great importance of the storage component in a combined system. Also the storage stratification is very important to ensure better performance.

- Annex 38 also showed that there is a need of monitored data for modeling variable-capacity or variable-speed heat pumps, and special heat pumps based on advanced concepts. Models are not available at present for those complex machines and this reduces the capacity of researchers to find optimal combinations.

- There is also a lack of simulation models for complex hydrothermal effects that was shown to appear in water storage tanks. Namely, the mixing of heated water and the loss of exergy due to high velocities of incoming flow or due to a poorly design introduction geometry. Current CFD (Computational Fluid Dynamics) 3D software can be used for design purposes but they are massive and slow and not adapted for system optimization where computation time is critical.

Annex 38 has developed a range of tools to simulate all kind of solar and heat pump combinations. National teams have used these tools and the task framework to optimize several aspects of a solar and heat pump combination. One of this aspect concerns the heat storage which is shared by the solar collectors and the heat pump in the most common parallel arrangement.

As an example, recommendations derived from many simulations have been formulated:
1. The position of the DHW sensor for boiler charging control must be placed at a safe distance from the space heating zone of the storage
2. The return from the storage to the heat in DHW mode must be placed above the space heating zone of the storage
3. It can be advantageous to bypass the storage when the heat pump runs in the space heating mode.

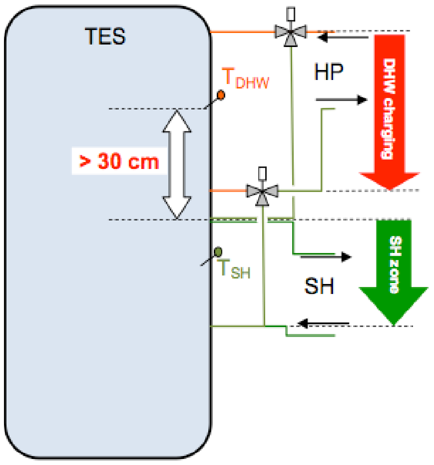


Figure 8: The DHW charging zone in the upper part of a tank must be respected in a combistore (copyright: SPF Switzerland)

- Annex 38 has devoted the first year of the Task to set up a framework for simulating SHP systems in different climates and for different loads. The framework is an international collaborative work and proved to be very useful for national work as well. All relevant documents for this framework are available on the Task web site.

- Participants in Annex 38 simulated more than 20 different system concepts using the common tools. Several simulation platforms were used and the framework was adapted to each platform.

- Simulation results show that the solar benefit contribution to an SHP system can be substantial when optimal arrangement and a good control strategy are considered. Figure 9 shows the increase of SPF that installing collectors can bring in a parallel system with an air/water heat pump. Installing 8 m^2 of collectors on a one family house, can bring the SPF_{SHP+} to 3.5 from a usual 2.8 for a non-solar air heat pump. Combisystems (having a single storage for DHW and heating) can also benefit from adding solar collectors in a system. The SPF can reach 4.0 with 15 m^2 of collectors from the 2.8 reference case.

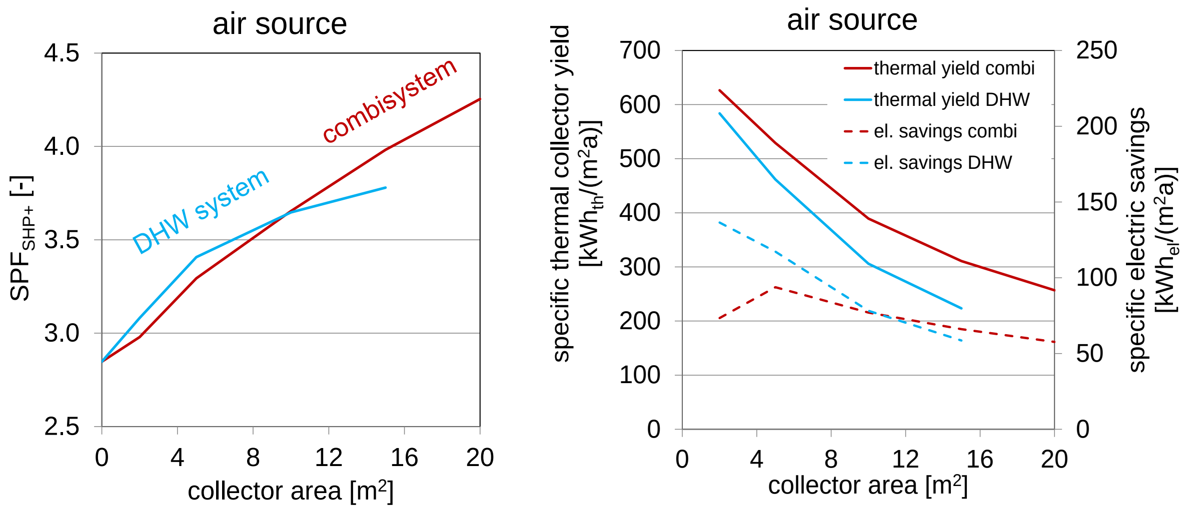


Figure 9: What does solar heating add to the whole? Performance of air-source solar and heat pump systems, where solar heating is used for DHW only (DHW) or for a combined system with combined storage (combi). (Simulations of SPF in reference conditions.) For more results refer to the final book to appear in 2014.

- Simulations of different system configurations have been made by several teams participating in the Task with the same boundary conditions and in the same climate. This was a great common effort. Figure 10 shows the overall results in terms of SPF achieved by each system concept in the same conditions.

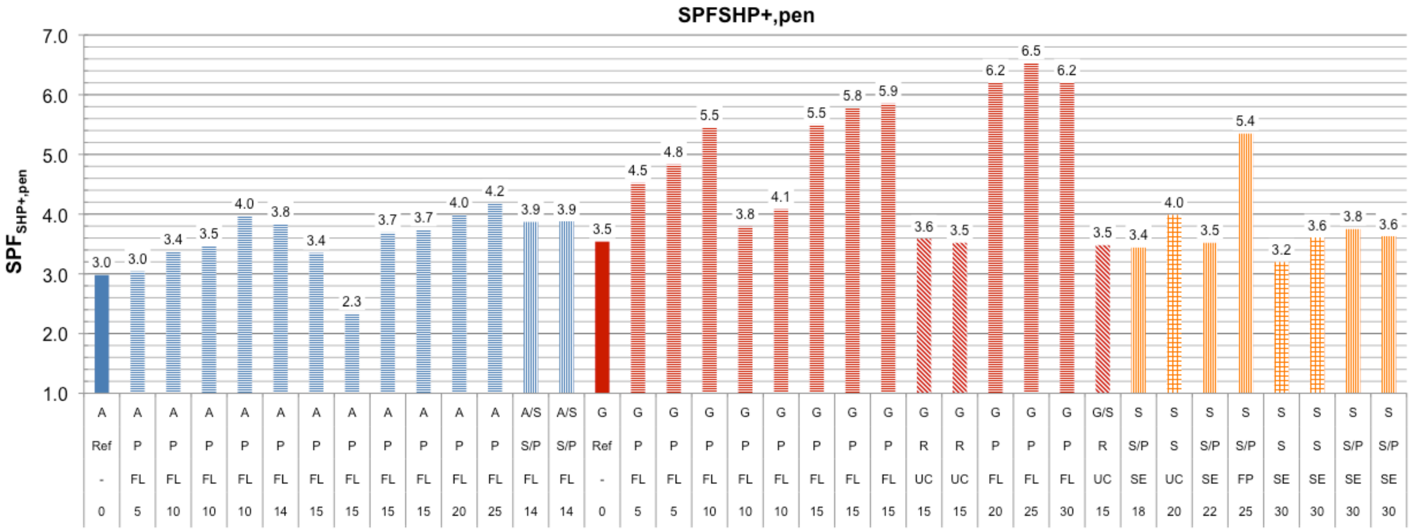


Figure 10: The results for all systems simulated with the same boundary conditions are compared in Chapter 7 of the final handbook.

Subtask D: Dissemination – the main steps

Subtask D had the mission to disseminate the added value created by the other subtasks. It did so by:

- issuing 3 newsletter (2011, 2012, 2013) largely distributed by mail and through our web site,
- by opening a Wikipedia page "solar and heat pump systems",
- by preparing in 2010 a document regrouping some teaching material on solar and heat pumps
- by organizing several industry workshops held locally in conjunction with the Task meeting where industry experts could exchange their vision with our Task R&D experts.

The T44A38 final handbook due in June 2014 will reflect the work in all aspects of SHP: practical experience, performance indicators definition, standard testing, component modelling, system simulations, comparison and guidelines for planning good systems.

Deliverables from T44A38 will be found on the web site (some with limited access to the participating members):

1. Technical reports on monitored systems
2. Map of generic systems with pros and cons
3. New set of performance indicators
4. Procedure to test combined solar and heat pump systems
5. Technical reports on systems tested in laboratory
6. New reference framework for simulating solar and heat pumps systems
7. New components models or compiled existing ones
8. Website with all major reports and papers
9. Educational material on the website
11. Papers at international conferences
12. Three Newsletters along the T44A38 duration

and:

13. Final handbook (about 200 pages) with all methods developed and all results will be available in June 2015

5 DISCUSSION AND CONCLUSIONS

5.1 Discussion

The combination S+HP can lead to high renewable fractions by either improving the heat pump seasonal performance factor or improving the productivity of each m^2 of collector or doing both.

There is a great potential in new housing mainly for detached houses. Renovation of one family houses could also become a segment of choice for solar and heat pump combination when a building owner wants to reduce its CO_2 exposure or fossil fuel dependency.

Up to 80 % to 90 % of the heating and DHW needs could be done “locally” i.e. in the house, with S+HP systems. If the source of electricity is 100 % renewable, such as wind energy or hydropower or PV, 100 % of the heating and cooling needs could be done by renewable.

A good potential exists for improving solar and heat pump combinations both for the classical parallel systems where solar and heat pump are working side by side, as well as for systems where solar thermal collectors are connected to the evaporator of the heat pump.

Some of the improvements that are currently in the focus of R&D and deserve national and international research support are:

- High efficiency heat pumps with variable evaporating temperatures
- Storage integration of heat pump circuits to produce highly prefabricated compact systems that are easy and fail-proof to install and use little space.
- Highly stratifying thermal stores and hydraulic integration with the heat pump such as to limit the condensation temperatures of the heat pump process to the lowest possible value.
- De-superheater heat exchangers in the heat pump circuit that may – in combination with the solar thermal heat in summer – lead to almost no need to run the heat pump at condensation temperature needed for DHW (60 to 65 °C).
- Control strategies for using heat from solar thermal collectors for the evaporator of the heat pump or for a “direct to load” supply.
- Storage solutions for the cold side of the heat pump in order to store solar heat from the collectors before using it for the heat pump, for instance ice storages.
- Solar thermal collectors that can use ambient air as well as solar irradiation as a heat source.
- Solar thermal collectors that can be operated below the dew point without destruction of selective surfaces or insulation or even the roof underneath.
- Solar thermal collectors combined with photovoltaic (PV/T collectors).
- Smart control of the overall system including automatic fault detection and possibly also using demand and weather forecast.

5.2 Conclusions.

In conclusion, Annex 38 has delivered much information on the assessment, the design and the performance of combined solar and heat pump systems. Participants have developed tools to simulate any type of system combination, as well as performance indicators that should be calculated for fair comparisons between systems. Comprehensively monitored systems have shown that high SPF values can be delivered if design and commissioning are carefully carried out.

Solar heating can be a good heat source for heat pumps as an alternative or a complement to air and ground sources and “solar only” solutions emerging with ice storage as a heat source!

6 RECOMMENDATIONS AND FUTURE WORK

6.1 Recommendations

Solar and heat pump systems (S+HP) is a combined technology that can take a market share in the segment of building heating and cooling since it carries some advantages: high renewable energy share, lower electricity demand, lower primary energy demand, lower CO_2 emission depending on the electricity mix feeding the heat pump.
Market share of S+HP systems could reach 100 % of new houses in many countries where heat pump technology is well implanted and solar is mandatory for domestic hot water.
In the long term, S+HP could take a significant market share in all IEA countries if electricity is produced CO_2 free and available. Solutions including solar PV could develop and expand for net zero houses and positive energy houses.

The components are mature; the combination of solar and heat pump needs however international R&D work to better understand the optimal configurations under several criteria.
Solar and heat pump systems can be deployed for both small and large systems. There is no limitation of size in such a combination.
Solar and heat pump combination offers many advantages for the developing market, such as:

- It can cover all needs of a building: heating, DHW, cooling, dehumidification;
- Specific combinations can be suited for different applications, climates, etc.
- It offers cooling (active or passive, if ground-coupled);
- It gives a capability of energy storing and supply-demand unbundling;
- Ventilation can also be integrated in compact air units;
- Solar and gas-driven heat pump can be suitable for high-temperature distribution systems as boiler-replacement;
- Part of the locally produced electricity (PV, wind) can be stored on site as thermal energy without stressing the grid.

A supporting policy is needed for:

- Technological development
- Quality assessment of products
- Partnership between R&D teams and HVAC industries
- Sharing of knowledge among countries
- Communication to large audiences and customers
- Clean electricity production that would make S+HP solutions 100 % renewables
- Thermal heat pump development
- Material and system testing platforms

It is anticipated that an obligation of a renewable share (for instance 70 % or more over the years for the Primary Energy Ratio as asked by the RHC platform for EU) in national policies will help a lot to develop S+HP systems, which exhibit a high renewable energy fraction in regions where the electricity is produced by renewable. A CO_2 index could also be used to favour clean solutions and S+HP systems would certainly benefit from such a supporting scheme.

6.2 Future work

New ideas for future annexes have also been proposed as a result of experience from Annex 38:

- Optimisation of control strategies of a hybrid system
- PVT solution for ice storage heat pumps
- Bigger systems than 100 kW
- Thermally driven heat pumps
- Heating systems that can also provide cooling during the hot season.

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Annex reports

A1	A Review of Market-Available solar heat pump systems	March 2013	Web
A2	Field test monitoring of SHP systems	March 2014	Web
A3	Dissemination Activities of Subtask A of the IEA SHC Task 44 / HPP Annex 38	March 2014	Web
B1	Definition of main system boundaries and performance figures for Reporting on SHP Systems	December 2013	Web
B2	Testing solar and heat pump systems in laboratory	Dec 2013	Web
B3	Definition of a standard test for SHP systems	March 2014	Web
B4	Dissemination activities of Subtask B	March 2014	Web

	of the IEA SHC Task 44 / HPP Annex 38		
C1	The reference framework for system simulations of the IEA SHC Task 44 / HPP Annex 38 Part A: General simulation boundary conditions Part B: Buildings and space heat load	March 2013	Web
C2	Models of sub-components and validation for the IEA SHC Task 44 / HPP Annex 38 Part A: Summary Part B: Collector models Part C: Heat pump models Part D: Ground heat exchangers Part E: Storage models	March 2013	Web
C3	System Simulation Reports for the IEA SHC Task 44 / HPP Annex 38	March 2014	Web
C4	Synthesis of system simulation results for the IEA SHC Task 44 / HPP Annex 38	March 2014	Web
C5	Dissemination activities of Subtask C of the IEA SHC Task 44 / HPP Annex 38	March 2014	Web
D1	Presentation of system performance calculation Educational material	Oct. 2013	Web
D2	Newsletters issued by IEA Task 44 / Annex 38 from 2010 to 2013	Oct. 2013	Web
D3	T44A38 presentations in conferences	March 2014	Web
D4	*Cancelled - information is included in C4*		
D5	Solar and heat pump systems – A handbook	June 2015	Print

All publicly available reports and articles can be downloaded from: http://task44.iea-shc.org

The final book will be available through Wiley-VCH in June 2015.

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