SOLAR AND HEAT PUMP SYSTEMS

Status of IEA SHC Task 44 & HPP Annex 38

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Synopsis

Over the past few years, systems that combine solar thermal technology and heat pumps have been marketed to heat houses and produce domestic hot water. This new combination of technologies is a welcome advancement, but standards and norms are still required for its long term successful commercialization.

At this time, most of the manufacturers are developing systems without a clear framework of what could be the best combinations of the two worlds and customers are lacking comparative approaches. The result is that systems reaching today the market are far from being optimized and sometimes simple enough to guarantee a lifetime problem free and efficient operation both technically and economically.

What is needed is a systematic analysis of the different possible systems and their potential for application in different climates and under different boundary conditions. To begin to tackle this, the SHC Programme has launched Task 44, Systems using solar thermal energy in combination with heat pumps (HP+Solar), a joint effort with the Heat Pump Programme under the name Annex 38.

The scope of this new Task, which has begun in 2010 and will end in 2013, is on the following items:

- Small-scale residential heating and hot water systems that use heat pumps and any type of solar thermal collectors as the main components.
- Systems offered as one product from a system supplier/manufacturer.
- Electrically driven heat pumps, but during the development of performance assessment methods thermally driven heat pumps will not be excluded.
- Market available solutions and advanced solutions (produced during the course of the Task).

Task is divided into four Subtasks:

- Overview of solutions (existing, new) and generic systems
- Performance figures and performance assessment
- Modeling and simulation
- Dissemination and market supporting measures

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

Background

The solar thermal market is expanding since 2000 due to two factors: the near cost effectiveness of solar hot water preparation and the incentives and promotions in place in many European countries. However reaching 100% solar is still a cost challenge. A good passive house in mid Europe can be almost 100% solar with about 30 m2 of collectors and 10 to 20 m3 of storage. The initial cost can reach 60 to 70’000 € for such a solution and it also deserves some space inside the house. In most cases an auxiliary heating system will be needed.

It has become very popular to heat a house with a heat pump solution due to the promotion undertaken by electrical utilities since a few years and the willingness of consumers not to dependant upon fossil fuels. In some countries electricity is however produced by fossil fuels. More and more customers are thus attracted by a heat pump solution combined with a solar installation at least for domestic hot water preparation.

Manufacturers have started to offer since a couple of years solution combining a heat pump and solar not only for hot water but also for heating purposes. Of course such combinations are more complex and need more control strategies and electronics. Therefore the optimisation of the combination is more complex and the cost effectiveness of the combination is not obvious.

Types of heat pumps can be all kinds but the market is clearly oriented towards brine to water in ground coupled heat pumps and comes slowly more and more to air to water heat pumps since their performance, reliability, frost and noise protection have improved over past years.

IEA Solar Heating and Cooling

The International Energy Agency has started the Solar Heating and Cooling programme in 1977. It has followed or lead the development of solar thermal market through a number of cooperative tasks that have confronted many new ideas within international groups of experts. The SHC programme started its 44th Task by the beginning of 2010. The task is called “Solar and heat pump systems”.

IEA Heat pump programme

The IEA Heat pump programme has decided to jointly initiate the Task with the SHC programme under the name “Annex 38”. This gives the Task 44 group a great opportunity to share solar knowledge with Heat pump experts and vice versa. The nickname of the activity is therefore T44A38.

IEA T44A38 scope

The scope of this new Task, which has begun in 2010, is on the following items:

- Small-scale residential heating and hot water systems that use heat pumps and any type of solar thermal collectors as the main components.
- Systems offered as one product from a system supplier/manufacturer.
- Electrically driven heat pumps, but during the development of performance assessment methods thermally driven heat pumps will not be excluded but are seldom proposed yet.
- Market available solutions and advanced solutions (produced during the course of the Task).

To better focus on the current market demand which is on one family solutions, large scale systems i.e. systems using any type of district network or systems for large buildings are not directly included, nor is the comfort cooling of buildings. However a heat pump can also be used for cooling, and the performance assessment methodology of T44A38 will not forget this "optional" feature.

Companion technologies?

Solar and heat pump technologies share some common points:

- Both solar collectors and heat pumps use electricity to make „free" energy available for hot water and space heat.
- In both cases, the „free" resource varies with the seasons in terms of exergy (quality).
- Both have decreasing efficiency with increasing supply temperature.
- Both have relatively high capital costs and lower running costs compared to conventional heating systems.
- Both use thermal storage in systems.

The optimisation of one technology will therefore often help the other one and it makes much sense to look at both in a consistent and global way. On top of that, they have "complementary disadvantages" such as:

- Collectors cannot easily supply 100% of load: solar systems need auxiliary heater unless big storage volumes are possible.
- Heat pumps use a significant amount of primary energy: improving COP (coefficient of performance), SCOP (seasonal COP) or SPF (Seasonal Performance Factor) by the use of solar can thus be an environmental advantage for HPs.

They are however two "mature" technologies and the combination will not be easy to tackle for this reason.

Solar companies and research institutes are busy on:

- Increasing solar fraction for heating and hot water with less material and less complexity in systems if possible to increase the system or components MTBF (mean time before failure).
- Finding alternative to concepts using very large heat storage to reach high renewable fraction.
- Looking for overall solar fraction larger than 50 %.
- Trying to keep the investment cost in limits where the cost of heat is 1 to 2 to the most of that of more historical heating solutions (fossil, direct heating).
- Trying to provide affordable solutions for thermal solar cooling.

Heat pump companies and research institutes are busy on:

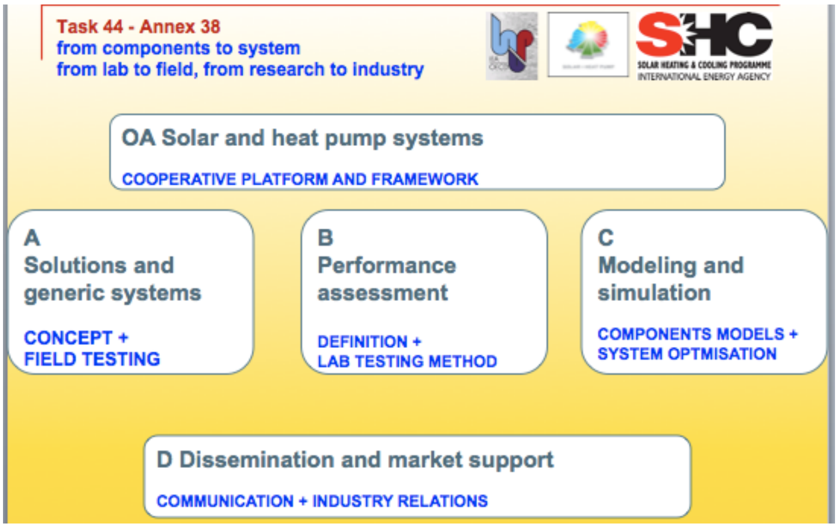
- Increasing annual COP or SPF (above 5 is the target).
- Possibly making direct use of solar energy for hot water or heating if produced temperature is sufficient.
- Avoiding any or significant temperature decrease of the ground over many heating seasons in the case of a ground coupled heat pump.
- Making reversible machines for additional summer cooling at marginal cost.

IEA Task 44 organisation

Task 44 is divided into four Subtasks:

- Subtask A: Overview of solutions (existing, new) and generic systems, lead by Sebastian Herkel from Fraunhofer ISE of Stuttgart, Germany
- Subtask B: Performance assessment, lead by Ivan Malenkovic from the Austrian institute of technology (AIT)
- Subtask C: Modeling and simulation, lead by Michel Haller from the SPF in Rapperswil, Switzerland
- Subtask D: Dissemination and market support, lead by Wolfram Sparber form the EURAC research center in Bolzano, Italy.

Like all IEA SHC Tasks, Task 44 – Annex 38 (T44A38) meets twice a year during two days where experts report the status and progress of their work and discuss new methods or tools for assessing and optimizing combinations of solar and heat pump. The task has been organized by the Operating Agent so as to separate important activities with clear boundaries and the minimum of overlapping.



Participants

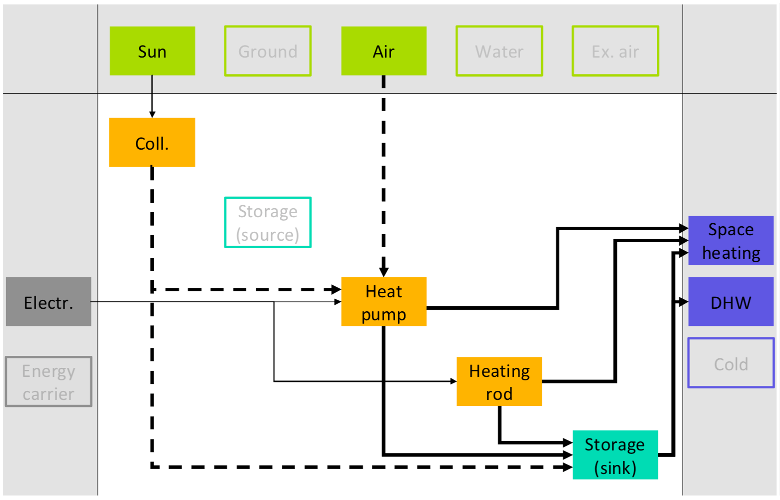
The following countries are participating: Austria, Belgium. Canada, Denmark, Finland, France, Germany, Italy, Spain, Sweden, Switzerland, UK, USA. However funding is often a problem and all countries are unfortunately not devoting the same level effort to the common work. As of April 2011, there are 13 countries and 55 to 70 persons participating, with a stronger representation form Austria, Germany and Switzerland.

In Switzerland we have managed to have five institutions participating (SPF, HES Yverdon, Uni Fribourg, Uni Geneva, HES Muttenz) and 2 companies (ESSA, 3S) in line with the strategy of our BFE research programmes “Solar Waerme” on one side and “Heat pump” on the other side, that both are investigating with a strategical focus the combinations of solar and heat pump since swiss customers tend to buy both technologies.

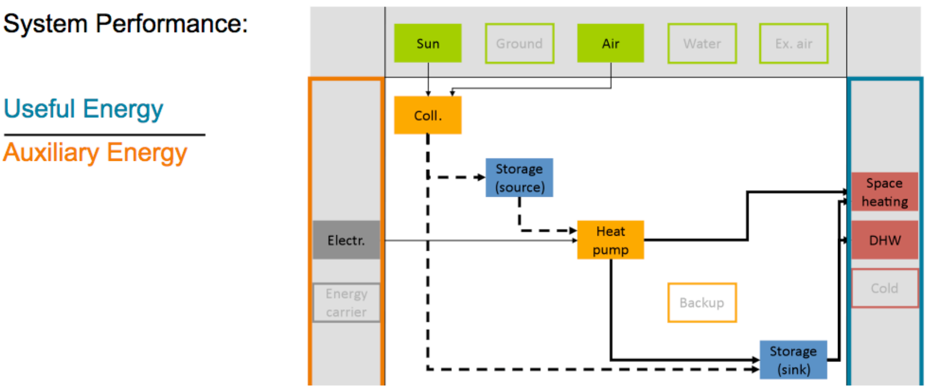
Subtask A: analysis of existing systems

Subtask A is a collaborative work to compare the results of existing systems combining solar and heat pumps that are monitored. A list of 55 systems has been collected, 22 from AT, 15 DE, 3 CH, 3 CAN, 8 DK, 1 SE and 1 SP. Not all are monitored at the same level but we can expect to have a common description of at least 20 of them. Following the recommendations of subtask B, it is proposed to use the SPF definitions developed in subtask B for analyzing the subtask A demonstration projects. This could help to prove both, the analysis concept and the measurement concept.

The "square view" of a system was developed in subtask A as the common tool to describe graphically every system. Almost all participants had prepared the square view of their system allowing a rapid understanding of any type of systems.



Example of a square view depicting the system functions



Using the square view to show one definition of the system performance (blue rectangle = the output divided by orange rectangle = the non local energy input

$${}^{Sol,\ Air}_{srS,\ skS}SHP^{srS}_{skS,\ SH}$$

S	*solar collector*	*Air*	*air*	*srS*	*source storage (usually cold)*
HP	*heat pump*	*G*	*ground*	*skS*	*sink storage (usually hot)*
Sol	*solar irradiation*	*W*	*ground water*	*SH*	*space heat (directly)*

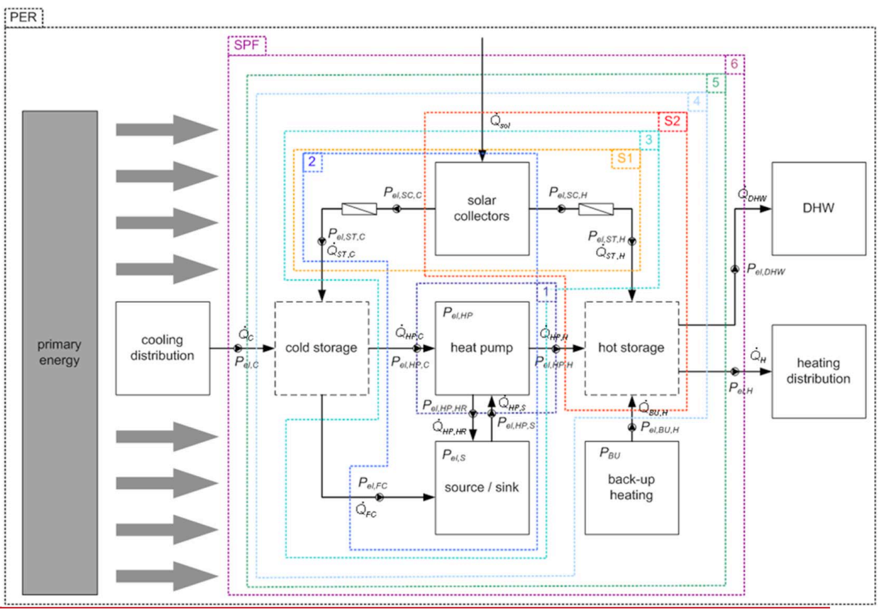
Conventional naming of a system as proposed by T44A38. The method is useful to describe in short both the sources and the sinks of a solar+heat pump system.

A collection of marketed available systems compiled by Fraunhofer ISE is available on the Task web site and a common reporting format will be soon available for the reader to understand rapidly every system. All presentations of field test results already available have shown, that valuable results from demonstration projects are already available and show that :

- Some achieved the expected system performance,
- Some give hints regarding potential improvements. In most systems, the storage and its temperature management seems to be the critical component.
- New systems are coming with combination of solar and a heat pump and a PV array trying to reach an annual net 100% renewable fraction. T44A38 can handle these cases too, since the PV system can be considered totally independently of the heating system, entering only in the primary energy ratio performance.

Subtask B: Performance assessment

Participants are discussing a proposal for the system boundaries at all levels from components to subsystems, and for the definition of performance figures. The question is not simple: what to or not to include into the definition of COP or a SPF ? It is foreseen to use the same "square view" as the subtask A does for reporting cases to define a SPF and its limits. Figure below from Subtask B leader I. Malenkovic, shows the definitions of all possible SPFs, including all auxiliary inputs present in solar and heat pump system.



The vision of a system and all possible définitions of performance indicators from S1 to S6, SPF and PER Primary Energy Ratio (Subtask B)

Subtask B is defining test conditions for laboratory testing of solar and heat pump systems in a way analog to what is available for solar combisystems and was derived from IEA SHC Task 26 work. T44A38 is therefore in discussion with CEN TC113 and TC320 to reach some common views and hopefully a normative environment. This will be based on the 5 research institutes who have installed a test bench for at least one configuration of a solar and heat pump system.

Subtask C: Modelling and simulation

The T44A38 Reference Framework has been thoroughly worked out by Subtask C leader. Climate, heating and cooling loads and all characteristics defining a common reference case for simulations have been defined and made available in a Trnsys deck.

A review of component models has been done. Lacks have been identified for the purpose of our Task in heat pump modelling (transient finishing aspects), solar collector models (condensation, frosting, etc..), ground heat storage (dynamic behaviour of single boreholes). Subtask C is working on providing these three component models.

Started by a team for uncovered collectors, some system simulations for collector heat use for the evaporator of a heat pump has been done, but not with T44/A38 boundary conditions and reference framework yet. The priority is still on the definition of the reference framework before detailed system simulations will be carried out by what we think will be at least 10 different teams providing the Task with enough results for good comparisons.

Subtask D: Dissemination and market support

The website of the Task is updated frequently. Educational material will be uploaded after Meeting 3. It will be slides of existing systems described in the "square view". This material comes from Subtask A.

The Task brochure has been issued in March 2011 (enclosed). It is a 2 pages leaflet. It was decided not to print it for a wide distribution but use pdf only. For international events the OA might print some copies to distribute on the IEA booth.

The first newsletter is late and rediscussed at meeting 3. It should be available and distribute during June 2011. Content is not yet new material from Subtasks, but more a description of intentions still. It is too early for guidelines.

Conclusions: Task expectations

- The combination of a heat pump and solar will represent a large market share in future decades. In some regions, systems are already installed in 80% of new homes ! T44A38 will contribute to select best solutions mainly in terms of SPF and reliability.
- The T44A38 pre normative work will produce materials to define a SCOP or SPF factor and to assess performances of combined systems. Such common international definition is currently lacking.
- An IEA framework provides a unique opportunity to meet and share with the experts from universities and industries working on thermal solar and heat pumps to exchange new ideas and to test them.
- Models to simulate such any type of combination of solar and heat pumps will be available in a TRNSYS framework and the most common ones will probably appear in common design tools like Polysun.
- Future systems will be sketched and new ideas will emerge from the exchange of practice, knowledge and experience, as past IEA SHC Tasks did.

References

[1] Hadorn J.-C.(2009). IEA SHC Task 44, Definition and workplan, www.iea-shc.org

[2] Hadorn J.-C. editor, Thermal energy storage for solar and low energy houses, June 2005, IEA SHC Task 32 book, 170 pages, orders: jchadorn@baseconsultants.com

[3] Hadorn J.-C.(2010). SOLAIRE ET POMPE A CHALEUR - Tâche 44 de l'AIE SHC & HPP, 16. Wärmepumpentagung vom 9. Juni 2010, BFE-Forschungsprogramm «Wärmepumpen, Wärme-Kraft-Kopplung, Kälte», Burgdorf

[4] Bales C. (2010). Solar Thermal and Heat Pumps – a Promising Technology, Intersolar 2010, Münich, June 2010

[5] Haller Michel et al., Systematische Gliederung der Systemkombination von solarthermischen Anlagen und Wärmepumpen, SPF Rapperswil, OTTI, 20. Symposium Thermische Solarenergie, May 2010, Klosters

[6] Herkel S et al., Task 44 Subtask A projects, Industry workshop, Bolzano April 2010, www.iea-shc.org/task44

[7] Miara M. (2009). Systems using solar thermal energy in combination with heat pumps – overview, Fraunhofer Institute for Solar Energy Systems ISE, Task Definition Workshop, April 23-24 2009, Freiburg, Germany