SHC 2012

IEA SOLAR AND HEAT PUMP SYSTEMS

SOLAR HEATING AND COOLING TASK 44 & HEAT PUMP PROGRAMME ANNEX 38

Jean-Christophe Hadorn, BASE consultants SA, Switzerland
Operating Agent of T44A38 for the Swiss Federal Office of Energy

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Summary

The objective of Task 44 of the Solar Heating and Cooling program of the IEA is to assess performances and relevance of combined systems using solar thermal and heat pumps, to provide a common definition of performances of such systems, and to contribute to successful market penetration of these new promising combinations of renewable technologies. The Task is also Annex 38 of the Heat pump program and thus called T44A38. It gathers 12 countries and 55 participants.
This paper presents the mid term results of the activity, which started in January 2010 and will last until December 2013.

Keyword: solar, heat pump, collectors, air, ground, PV/T, hybrid systems, IEA, seasonal performance factor, models, vaalidation

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1. Scope of T44A38

SHC Task 44 / HPP Annex 38 started in January 2010. Its The scope considers solar thermal systems in combination with heat pumps, for the supply of domestic hot water and heating in family houses. The main target market is small systems in the range of 5 to 20 kW. Any type of solar collector can be 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 can be considered: air, water or ground source. The main focus is on heat pumps driven by electricity as the market is so oriented. However thermally driven heat pumps would be welcome but no such project has yet been presented by a participant.

To limit the scope, comfort cooling of buildings is not directly addressed in the Task common work, although it is not forbidden for a heat pump to be used in reverse mode for cooling purposes besides its main heating objective. The Task covers market available solutions as well as advanced solutions, which may be still in a laboratory stage or still will be developed during the course of the Task.

The Task is a joint effort of the Solar Heating and Cooling Programme (SHC) and the Heat Pump Programme (HPP) of the International Energy Agency. It is Task 44 for SHC and Annex 38 for HPP. Participating countries are from HPP: Finland, Germany, Switzerland (Operating Agent), and from SHC: Austria, Belgium, Canada, Denmark, France, Germany, Italy, Spain, Sweden, Switzerland, USA.

2. Task organization

The Task is organized in four Subtasks each lead by an expert:

Subtask A: Solutions and generic systems (Lead Country: Germany, Fraunhofer ISE, Sebastian Herkel)
The objective of Subtask A is 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 deals mainly with manufactured systems and systems installed and monitored.

Subtask B: Performance assessment (Lead Country: Austria, AIT, Ivan Malenkovic)

The objective of this subtask is to reach a common definition of the figures of merits of solar + heat pump systems and how to assess them. This work can lead to prenormative definition on how to test and report the performance of a combined solar and heat pump system.

Subtask C: Modeling and simulation (Lead Country: Switzerland, SPF, Michel Haller)

The objective of subtask C is 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 will also be possible using the output of this Subtask, either with the computing tools developed or with general or system specific tables.

Subtask D: Dissemination and market support (Lead Country: Italy, EURAC, Wolfram Sparber).

The objective of this subtask is to provide information to the external world during the course of T44A38 so that value added created by the participants can be transferred as fast as possible to a growing market. A second objective is to deliver the final book of T44A38 aimed as a reference document in the field of solar heat and heat pumps.

3. Solutions installed and monitored (Subtask A)

3.1. Existing systems in operation

More than 100 systems from participating countries were surveyed during 2010 and 2011. A classification into few generic systems turned out to be difficult and the seven basic configurations sketched in 2010 end up to be many more.

Subtask A therefore decided to classify all systems in four new categories: the parallel concept, the serial, regenerative and the complex concept. A special tool call the “square view” was developed in order to describe all systems in a consistent way.

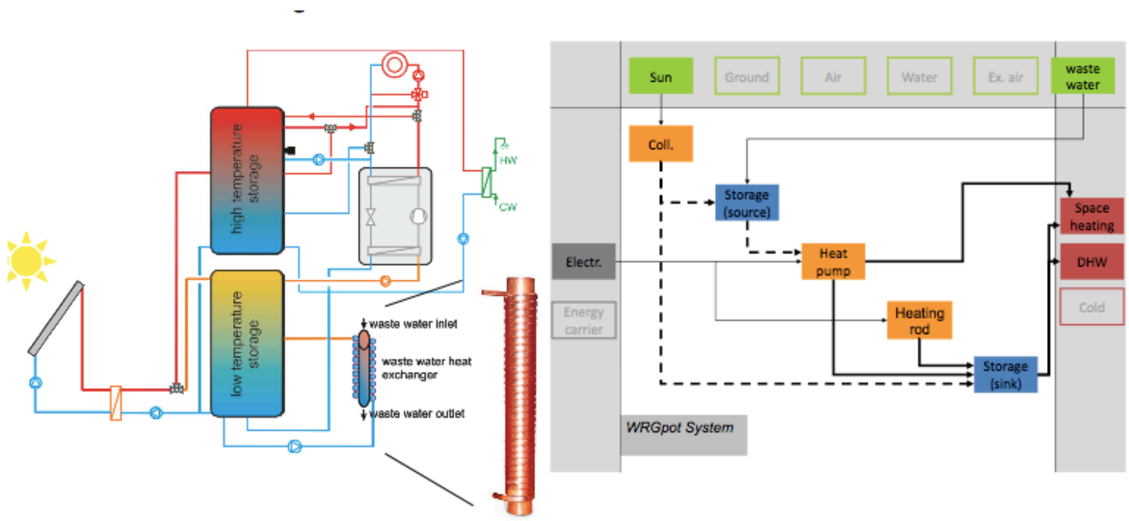


Fig. 1. The square view describes all fluxes in a S+HP systems in a more simple way than the classical hydraulics scheme

The results of the survey showed that 70% of systems were found to be parallel solutions, 7% serial system, 21% complex and very few regenerative solutions. Air and ground heat source were about in the same numbers and some systems were operated only with solar collectors as a source of heat for the evaporator and many in several modes of operation (i.e. “multi sources”).

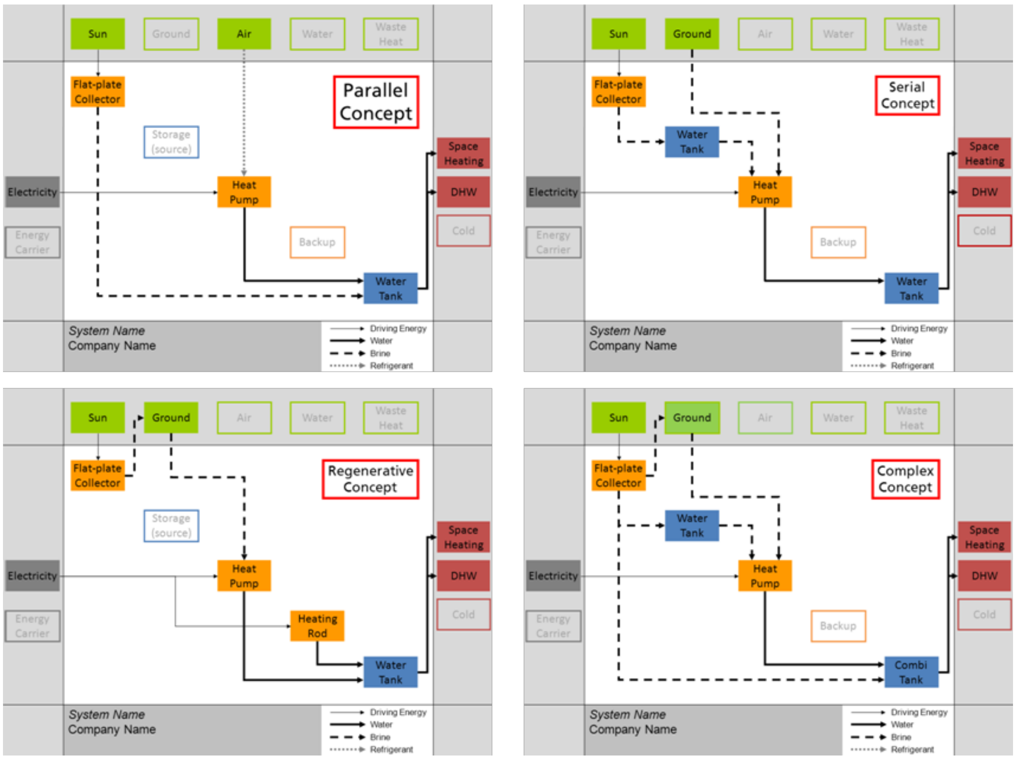


Fig. 2: The square views of the four categories of systems which describe all combinations of S+HP.

In order to compare all the demonstration projects it is proposed to use the Seasonal Performance Factor (SPF) definitions developed primarily for testing systems on test rigs in laboratory in Subtask B. This will help to rapidly benchmark both the concept and its monitored results.

Overall Subtask A has succeeded to describe in a similar way different S+HP concepts from different manufacturers and designed for different local conditions.

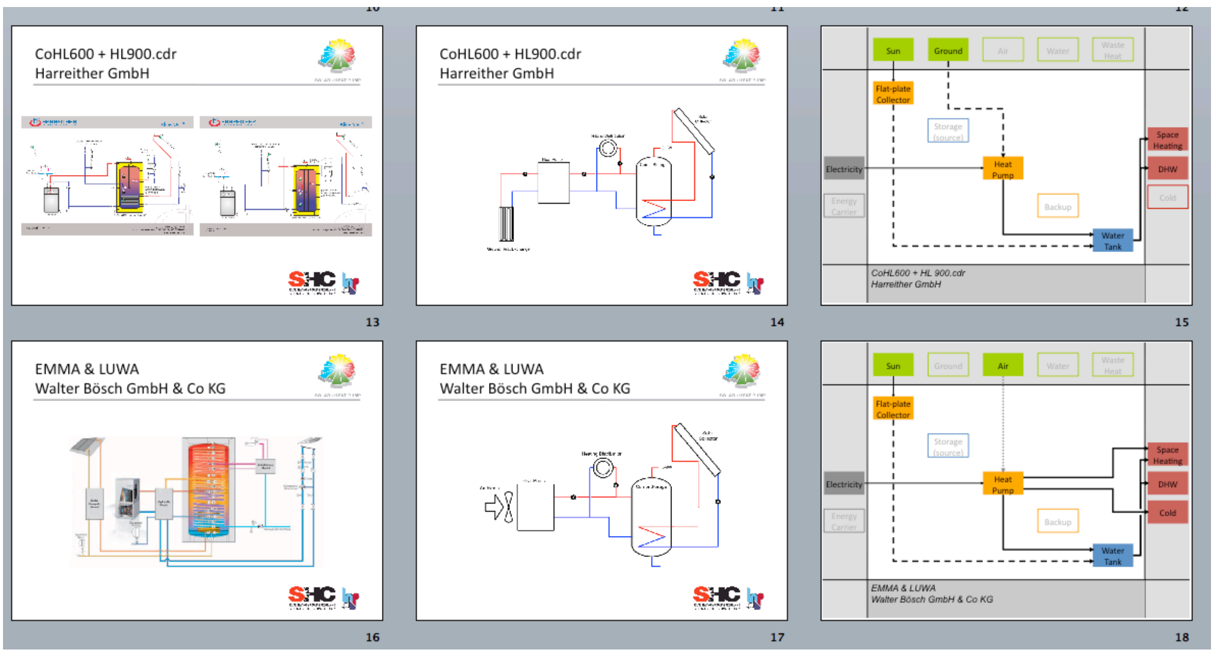
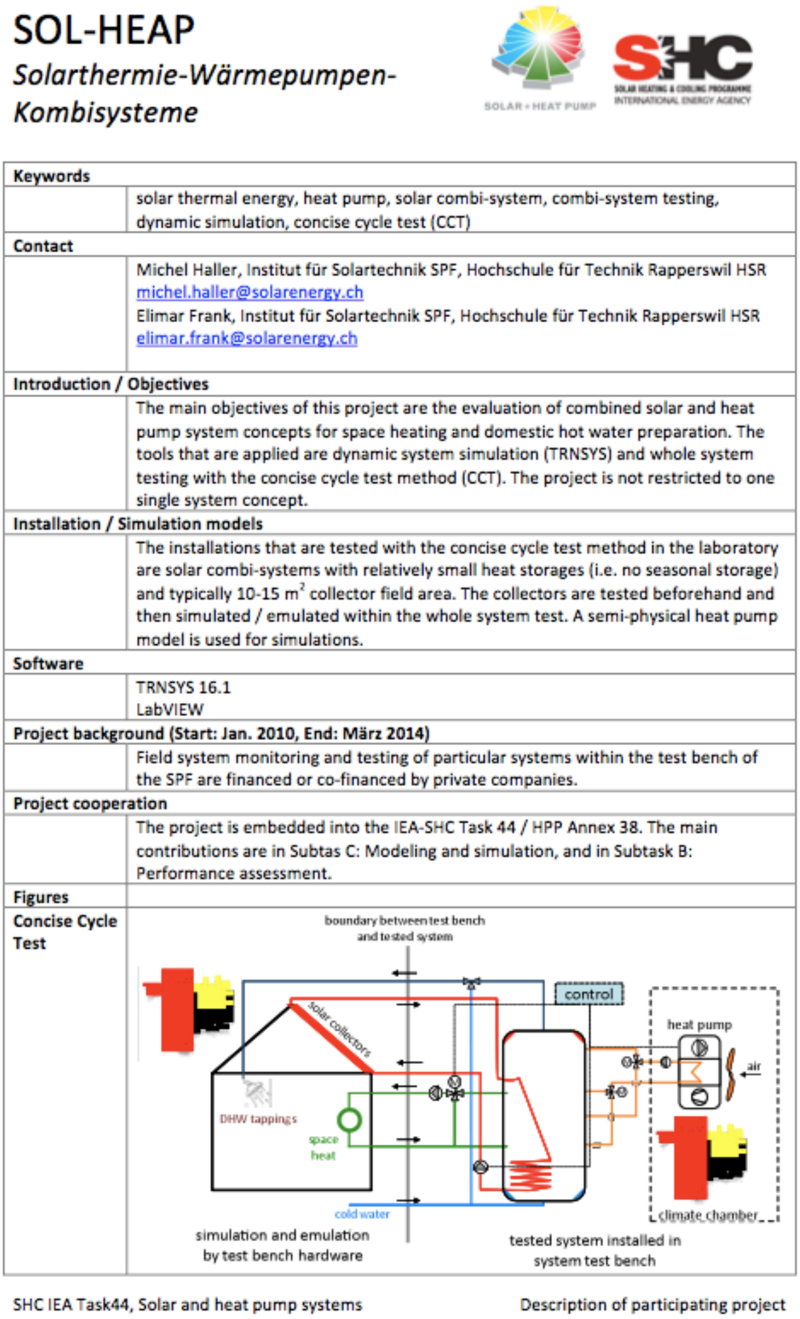


Fig. 3: More than 80 systems available on the market have been described in a first document by Subtask A, here an example of 2 [1]

3.2. Field test results reporting format

Participants in T44A38 have reported thirty built projects in a common way. Some of these projects are already monitored and results are available. Monitoring data from projects will produce interesting material for simulation and models validation in Subtask C. A common reporting format has been defined for this purpose.



SOL-HEAP

Solarthermie-Wärmepumpen-Kombisysteme

Keywords	
	solar thermal energy, heat pump, solar combi-system, combi-system testing, dynamic simulation, concise cycle test (CCT)
Contact	
	Michel Haller, Institut für Solartechnik SPF, Hochschule für Technik Rapperswil HSR michel.haller@solarenergy.ch Elimar Frank, Institut für Solartechnik SPF, Hochschule für Technik Rapperswil HSR elimar.frank@solarenergy.ch
Introduction / Objectives	
	The main objectives of this project are the evaluation of combined solar and heat pump system concepts for space heating and domestic hot water preparation. The tools that are applied are dynamic system simulation (TRNSYS) and whole system testing with the concise cycle test method (CCT). The project is not restricted to one single system concept.
Installation / Simulation models	
	The installations that are tested with the concise cycle test method in the laboratory are solar combi-systems with relatively small heat storages (i.e. no seasonal storage) and typically 10-15 m^2 collector field area. The collectors are tested beforehand and then simulated / emulated within the whole system test. A semi-physical heat pump model is used for simulations.
Software	
	TRNSYS 16.1 LabVIEW
Project background (Start: Jan. 2010, End: März 2014)	
	Field system monitoring and testing of particular systems within the test bench of the SPF are financed or co-financed by private companies.
Project cooperation	
	The project is embedded into the IEA-SHC Task 44 / HPP Annex 38. The main contributions are in Subtas C: Modeling and simulation, and in Subtask B: Performance assessment.
Figures	
Concise Cycle Test	

SHC IEA Task44, Solar and heat pump systems | Description of participating project

Fig. 4: Example of reporting results from systems in field or in laboratory

4. Performance assessment. Subtask B

4.1. Definition of performance indicators

A proposal for performance indicators was issued during 2011. It proved to be much more time consuming that anticipated to come to a consensus among participants on performance indicators. Several indicators such as system and component efficiency, primary energy, CO2 emissions or savings, have been defined. This step is important for a future comparison of systems to be achieved.

One important question when dealing with hybrid systems such as S+HP systems is how to calculate the benefit of the combination "solar and heat pump". Is a benefit to be calculated against other alternative solutions like solar and wood or solar and gas, or against "solar only" or "HP only" solutions? Working on examples from Subtask A will bring more light on this matter in the future.

Criteria	Indicator 1	Indicator 2
Energy performances	Seasonal Performance factor	Primary Energy ratio
Grid impact	Max electrical power asked from grid	Summer / Winter ratio
Renewable energy performances	Renewable energy fraction	Solar savings fraction
CO2 emissions	Annual emissions g/kWh	On site / Globally
Climate performance	Productivity of solar kWh/m2 or kWh/kW	Heating / Cooling
Cost performances	Investment/kW	Cost/kWh

Fig. 5: criteria and performance indicators considered in T44A38 to evaluate S+HP combinations

4.2. Defining testing on stands procedures

A number of institutes participating in T44A38 are already testing S+HP total systems or at least system components on stands. A common procedure of testing is however still being discussed since no standards exist.

A short overview of relevant standards dealing either from Solar Thermal or Heat Pump has been reported in a draft report. Applicability to S+HP systems and recommendations for revision is however still to be worked out. But prior to derive a generic vision, the various methods developed by all the participants will have to be described in technical reports. The question "can T44A38 propose one test method to cover all system configurations and applications?" still holds. The EU project "Qaist" also lead by our Subtask B leader advances in parallel with our work and has a similar the goal to reach standardized definitions and procedures for testing S+HP systems. We therefore join forces in international collaboration.

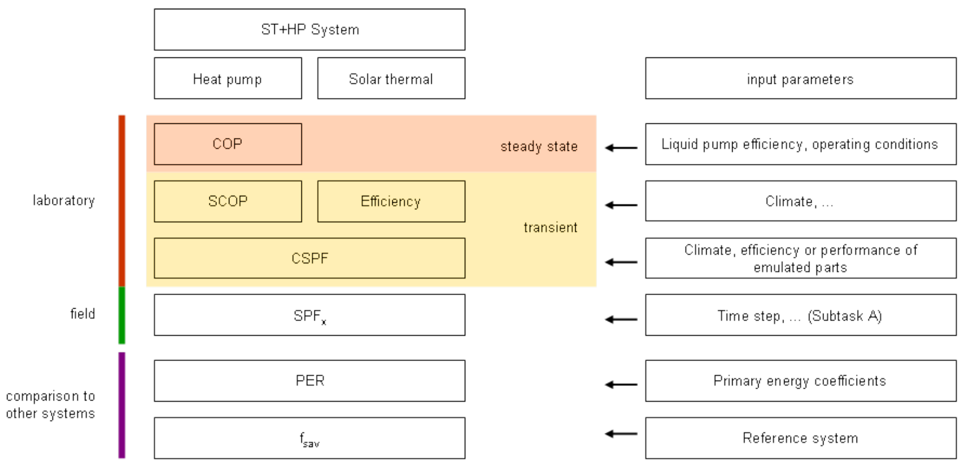


Fig. 6: understanding the various definitions of performance indicators is key to be able to compare combined systems with and without solar (source: AIT, Subtask B, 2011)

5. Modeling and simulation. Subtask C

5.1. A reference framework

In order to compare systems it is necessary to simulate them on the same "case". A common framework has to be derived with all necessary inputs defined. Such a framework is usual in IEA activities. The T44A38 framework for "Solar and Heat Pump" simulations has been issued in 2011. A reference building has also been defined with its heating and cooling load. The final report is completed and available through our web site [Haller, 2012]. Our common boundary conditions will be implemented on different simulation platforms since not all participants want to use TRNSYS, and the implementations will be shared with other participants. This is a common effort not possible without our international collaboration.

5.2. Models of components

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, each led by an expert in the field have been actively set up. Investigations on existing models have been carried out to identify gaps in dynamic modelling of components. A new Heat Pump Model (Type 877) for TRNSYS has been presented by one Austrian team. Its validation is in progress before it can be used for optimisation purposes.

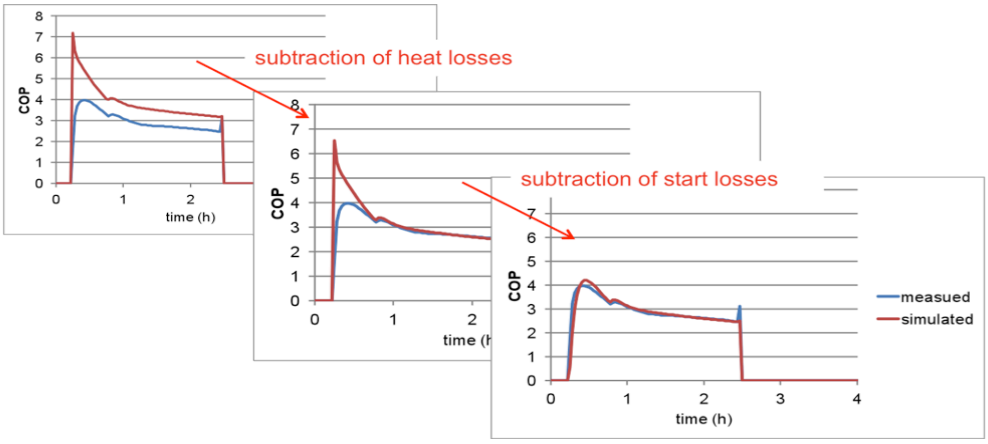


Fig. 7: a dynamic model of a heat pump can be improved by taking into account transient heat losses (Source : SPF 2011)

Modeling the frost conditions and water condensation heat exchange on solar absorbers for night operating conditions is also well advanced thanks to prior work of our Swedish experts. The model has been tested on laboratory results in Switzerland and proved to be adequate. Condensation however is not very important in the annual balance of heat supplied. Solar radiation and air exchange dominate.

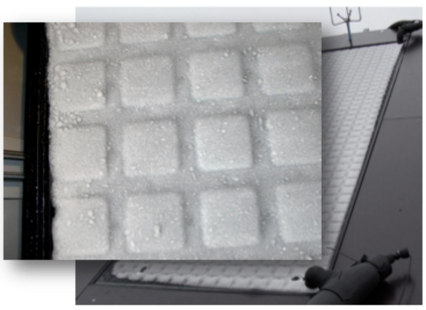


Fig. 8: frost on a selective uncovered collector when used below the dew point (source SPF, 2011)

5.3. Models of systems

Several systems are under investigations by different teams but no completed result yet is available for comparison purposes. Some show however good correlations with monitored data for some important S+HP configurations. Comparison of solutions (serial, parallel, or others) and optimisation will happen during 2012 and 2013. Ways to report annual results have been proposed by Switzerland (fig. 9 as an example).

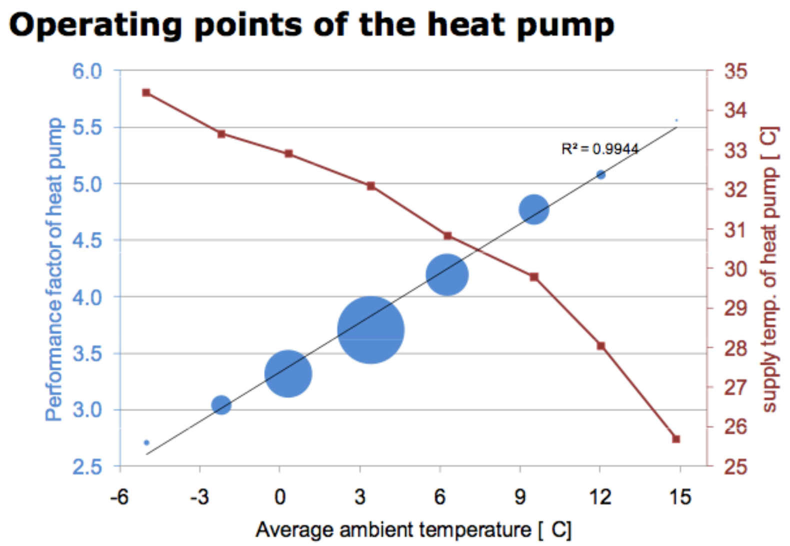


Fig. 9: annual system simulation of air-water heat pump system with solar shows the ambient temperature ranges of supply vs the performance factor of the heat pump together with the delivery temperature asked by the distribution to the floor heating system (source SPF 2011)

6. Market support. Subtask D

6.1. Dissemination of information tools

The website of T44A38 is continuously adapted and enriched. Some teaching material for S+HP combinations is already available. A list of publications dealing with our topic from participants in conferences and journals is maintained on the site. The first newsletter was issued end of October 2011 and is available on our web site.

6.2. Final handbook

The T44A38 final handbook due end of 2013 will reflect the work in all aspects of S+HP: practical experience, performance indicators definition, standard testing, component modelling, system simulations, comparison and guidelines for planning good systems. Until this outcome, many papers at conferences will be available directly from participants. Presentation can be recognized with the T44A38 logo they should show.

SOLAR + HEAT PUMP

Fig. 10: T44A38 logo

6.3. List of foreseen deliverables from T44A38 – end of 2013

1. Technical reports on existing and monitored systems from national experts
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 – pre normative work
5. Technical reports on systems tested in laboratory with this procedure from national experts
6. New reference framework for simulating solar and heat pumps systems: already available [4]
7. New components models or compiled existing ones
8. Website with all major reports and papers: in place [1]
9. Educational material on the website
10. Support to national workshops about the topic "solar and heat pump"
11. Papers at international conferences [3], see also [1] under menu: publications
12. Newsletters along the T44A38 duration, 2011 is available on [1]
13. Final handbook with all methods developed and results found
14. A recommended policy paper for S+HP development [2]

Acknowledgements

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References

[1] Task web site: www.iea-shc.org/task44

[2] Hadorn et al., Solar and heat pumps position paper, Internal document of the IEA SHC programme, Nov. 2011, to be released in public domain during 2012

[3] Hadorn J.-C., 2010, Solar and heat pump systems, OTTI Seminar 2010, Bad Stafelstein

[4] Haller M., 2012 , The Reference Framework for System Simulations of the IEA SHC Task 44 / HPP Annex 38

A final report of subtask C + Reference Buildings Description of the IEA SHC Task 44 / HPP Annex 38