Newsletters issued by IEA Task 44 / Annex 38 from 2010 to 2013

A technical report of subtask D – Report D2

Date: 21.10.2013

By Matteo D'Antoni

[1] Eurac Research, Institute for Renewable Energy

Viale Druso 1

I - 39100 Bolzano

Phone: +39 0471 055614

Fax: +39 0471 055699

e-mail: matteo.dantoni@eurac.edu

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA Solar Heating and Cooling Programme

The Solar Heating and Cooling Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency. Its mission is *"to enhance collective knowledge and application of solar heating and cooling through international collaboration to reach the goal set in the vision of solar thermal energy meeting 50% of low temperature heating and cooling demand by 2050.*

The member countries of the Programme collaborate on projects (referred to as "Tasks") in the field of research, development, demonstration (RD&D), and test methods for solar thermal energy and solar buildings.

A total of 52 such projects have been initiated to-date, 39 of which have been completed. Research topics include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44)
- Solar Cooling (Tasks 25, 38, 48)
- Solar Heat or Industrial or Agricultural Processes (Tasks 29, 33, 49)
- Solar District Heating (Tasks 7, 45)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52)
- Solar Thermal & PV (Tasks 16, 35)
- Daylighting/Lighting (Tasks 21, 31, 50)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46)
- Storage of Solar Heat (Tasks 7, 32, 42)

In addition to the project work, there are special activities:

- SHC International Conference on Solar Heating and Cooling for Buildings and Industry
- Solar Heat Worldwide – annual statistics publication
- Memorandum of Understanding with solar thermal trade organizations
- Workshops and conferences

Country Members

Australia	Germany	Portugal
Austria	Finland	Singapore
Belgium	France	South Africa
China	Italy	Spain
Canada	Mexico	Sweden
Denmark	Netherlands	Switzerland
European Commission	Norway	United States

Sponsor Members

ECI	ECREEE	RCREEE

Further information:

For up to date information on the IEA SHC work, including many free publications, please visit www.iea-shc.org.

Current Tasks & Working Group:

Task 36	*Solar Resource Knowledge Management*
Task 39	*Polymeric Materials for Solar Thermal Applications*
Task 40	*Towards Net Zero Energy Solar Buildings*
Task 41	*Solar Energy and Architecture*
Task 42	*Compact Thermal Energy Storage*
Task 43	*Solar Rating and Certification Procedures*
Task 44	*Solar and Heat Pump Systems*
Task 45	*Large Systems: Solar Heating/Cooling Systems, Seasonal Storages, Heat Pumps*
Task 46	*Solar Resource Assessment and Forecasting*
Task 47	*Renovation of Non-Residential Buildings Towards Sustainable Standards*
Task 48	*Quality Assurance and Support Measures for Solar Cooling*
Task 49	*Solar Process Heat for Production and Advanced Applications*

Completed Tasks:

Task 1	*Investigation of the Performance of Solar Heating and Cooling Systems*
Task 2	*Coordination of Solar Heating and Cooling R&D*
Task 3	*Performance Testing of Solar Collectors*
Task 4	*Development of an Insolation Handbook and Instrument Package*
Task 5	*Use of Existing Meteorological Information for Solar Energy Application*
Task 6	*Performance of Solar Systems Using Evacuated Collectors*
Task 7	*Central Solar Heating Plants with Seasonal Storage*
Task 8	*Passive and Hybrid Solar Low Energy Buildings*
Task 9	*Solar Radiation and Pyranometry Studies*
Task 10	*Solar Materials R&D*
Task 11	*Passive and Hybrid Solar Commercial Buildings*
Task 12	*Building Energy Analysis and Design Tools for Solar Applications*
Task 13	*Advanced Solar Low Energy Buildings*
Task 14	*Advanced Active Solar Energy Systems*
Task 16	*Photovoltaics in Buildings*
Task 17	*Measuring and Modeling Spectral Radiation*
Task 18	*Advanced Glazing and Associated Materials for Solar and Building Applications*
Task 19	*Solar Air Systems*
Task 20	*Solar Energy in Building Renovation*
Task 21	*Daylight in Buildings*
Task 22	*Building Energy Analysis Tools*
Task 23	*Optimization of Solar Energy Use in Large Buildings*
Task 24	*Solar Procurement*
Task 25	*Solar Assisted Air Conditioning of Buildings*
Task 26	*Solar Combisystems*
Task 27	*Performance of Solar Facade Components*
Task 28	*Solar Sustainable Housing*
Task 29	*Solar Crop Drying*
Task 31	*Daylighting Buildings in the 21st Century*
Task 32	*Advanced Storage Concepts for Solar and Low Energy Buildings*
Task 33	*Solar Heat for Industrial Processes*
Task 34	*Testing and Validation of Building Energy Simulation Tools*
Task 35	*PV/Thermal Solar Systems*
Task 37	*Advanced Housing Renovation with Solar & Conservation*
Task 38	*Solar Thermal Cooling and Air Conditioning*

Completed Working Groups:

CSHPSS; ISOLDE; Materials in Solar Thermal Collectors; Evaluation of Task 13 Houses; Daylight Research

IEA Heat Pump Programme

This project was carried out within the Solar Heating and Cooling Programme and also within the *Heat Pump Programme*, HPP which is an Implementing agreement within the International Energy Agency, IEA. This project is called Task 44 in the *Solar Heating and Cooling Programme* and Annex 38 in the *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:

IEA Heat Pump Centre
Box 857
SE-501 15 BORÅS
Sweden
Phone: +46 10 16 55 12
Fax: +46 33 13 19 79

Visit the Heat Pump Programme website - **http://www.heatpumpcentre.org/** - to find more publications and to learn about the HPP Programme.

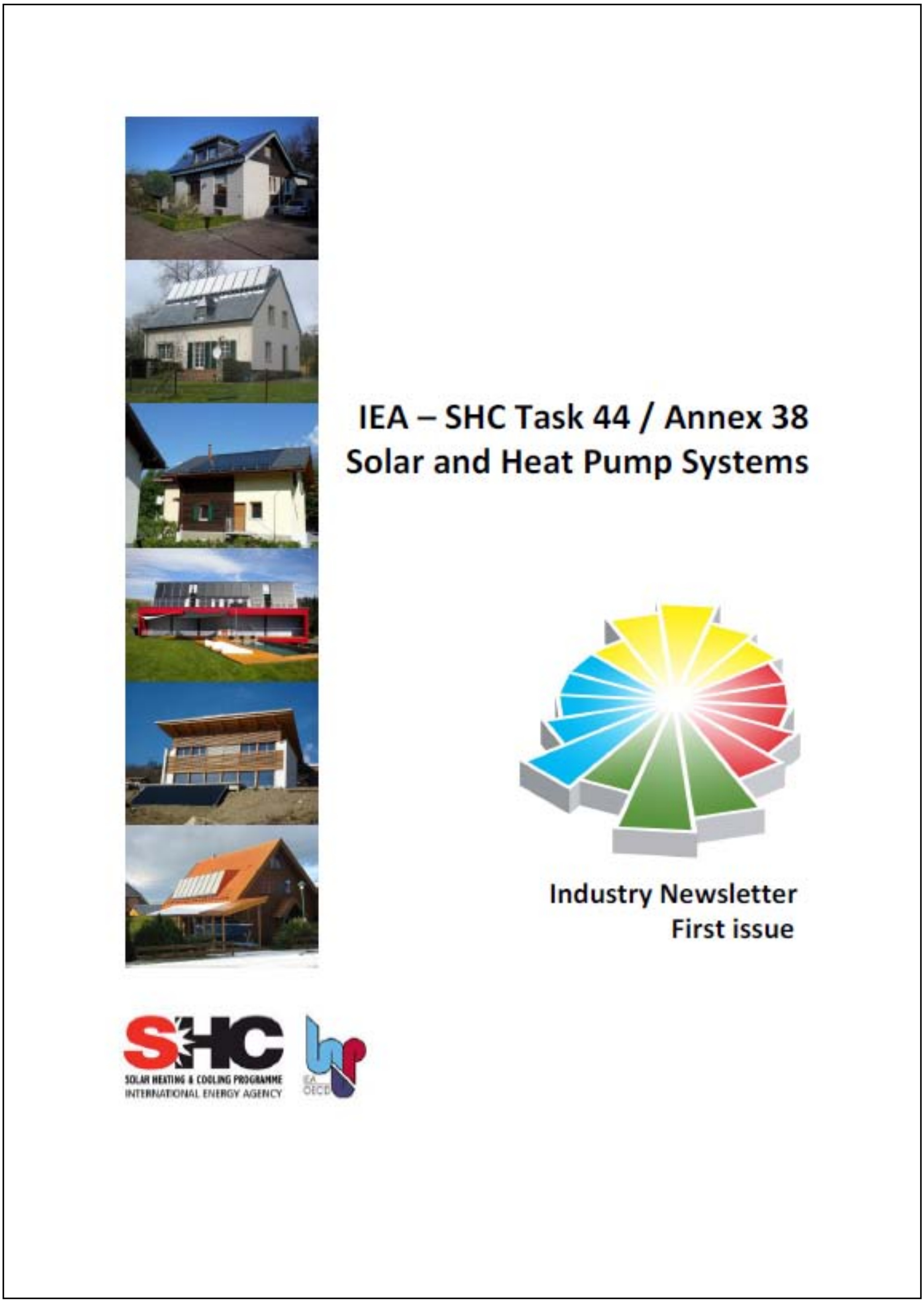
Contents

1 Introduction

This deliverable collects all newsletter issues produced by Subtask D within IEA Task 44 / Annex 38 (T44A38). The motivation of these newsletters is to communicate to the industry and the research community important developments and findings achieved within T44A38. The first issue has aimed to present the objectives, the structure and the activities, as well as the participants of the project. The second issue has focused on the classification of Solar plus Heat Pump (SHP) systems according different criteria (e.g. heat pump evaporator sources, building load covered, …) and the presentation of a unified energy flow chart for the analysis of SHP systems. The third newsletter has presented monitoring results of different SHP concepts under different boundary conditions (location and building loads).

The newsletters have been posted in project webpage (http://task44.iea-shc.org), distributed in fairs and events on solar thermal and heat pump topics and linked to the project Wikipedia page.

2 First newsletter


IEA – SHC Task 44 / Annex 38
Solar and Heat Pump Systems

Industry Newsletter
First issue

Industry newsletter

First issue, 10-2011

IEA – SHC Task 44 / Annex 38

Solar and Heat Pump Systems

Elaborated by:

M. D'Antoni, W. Sparber

EURAC Research

This newsletter presents the status of the work of the SHC Task 44 / HPP Annex 38 or T44A38 work. The solar industry and the heat pump industry are the primary targets. The content reflects the activities along the course of the work and not necessarily the final conclusions that will be published in all deliverables at the end of the work duration (December 2013).

Task 44 / Annex 38

Solar and Heat Pump Systems

Background

Operating Agent:
Jean Christophe Hadorn
BASE Consultants SA
8 rue du Nant, 1207 Geneva
Switzerland
email: jchadorn@baseconsultants.com

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. Such combinations are complex and need more control strategies and electronics than separate configurations. Therefore the optimisation of the combination is more complex and the cost effectiveness of the combination is not obvious.

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 dependent 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. Market for S+HP in countries like Switzerland, Austria, Germany are booming due to several favourable conditions like CO_2 reduction promotion programs, direct electrical heating substitution encouragement, obligation of a minimum of 30% renewable for domestic hot water production, high electricity peak cost and incentives.

Task 44 / Annex 38 – "Solar and Heat Pump Systems"

International collaboration through an IEA activity is an efficient way to share knowledge and new ideas on comparison and standardisation of such complex systems. Moreover the Task 44 of Solar heating and cooling called "Solar and heat pump systems" is also Annex 38 of the Heat Pump Programme, thus gathering experts from both technologies.

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.

Task Objectives

The objective of this Task is the assessment of performances and relevance of combined systems using solar thermal and heat pumps, to provide common definition of performances of such systems and to contribute to successful market penetration of these new systems.

Other objectives are needed to reach the main one where international collaboration is definitively needed to make it possible within a 4 years framework, mainly:

- surveying the possible generic combinations;
- defining performance figures of a combined solar and heat pump solution;
- defining assessment and test methods of such systems;
- analysing monitored data on such systems;
- developing component models or integrating existing ones into a system model;
- simulating various systems under common conditions;
- providing guidelines of good practice to the market and stakeholder;
- providing authorities with relevant information on the interest of such systems;
- staying close to the market and bringing independent information and knowledge to the actors on this market along the duration of the Task.

The scope of the Task considers solar thermal systems in combination with heat pumps, applied for the supply of domestic hot water and heating in family houses.

Duration of Task 44 / Annex 38

Task 44 / Annex 38 started in January 2010 and will end in December 2013. A number of deliverables will be available from time to time on the T44/A38 web site:

http://www.iea-shc.org/task44/.

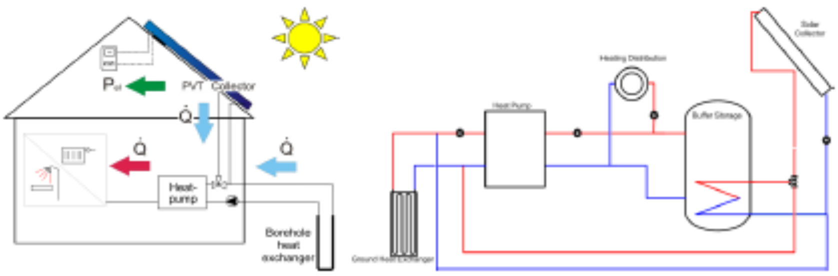
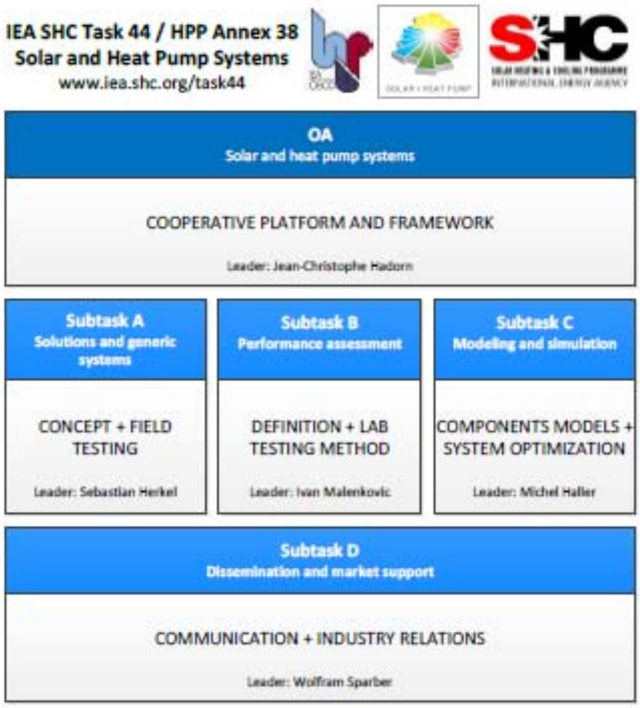


Figure 1 and 2: S+HP system: Example of a system including PV-T collectors and ground heat exchanger coupled with a water-to-water heat pump (source: ISFH and Fraunhofer ISE).

Subtasks

The work in this T44A38 is divided into four Subtasks:

- Subtask A: Overview of solutions (existing, new) and generic systems, led by Sebastian Herkel from Fraunhofer ISE of Stuttgart, Germany;
- Subtask B: Performance assessment, led by Ivan Malenkovic from the Austrian Institute of Technology (AIT);
- Subtask C: Modelling and simulation, led by Michel Haller from the SPF in Rapperswil, Switzerland;
- Subtask D: Dissemination and market support, led by Wolfram Sparber form the EURAC Research centre in Bolzano, Italy.



Subtask A:

Solutions and generic systems

Subtask Leader:
Sebastian Herkel
Fraunhofer ISE, Hiedenhofstrasse 2, 79110 Freiburg
GERMANY
email: sebastian.herkel@ise.fraunhofer.de

The objective of Subtask A is to collect, create and disseminate information about the current and future solutions for combining solar heat pump systems. Both heat pumps and solar thermal collectors gained high popularity in the European market, as it can be seen in Figure 3. The similarity of these trends is striking, though unfortunately, it remains unknown to what extent the components were installed in combined systems.

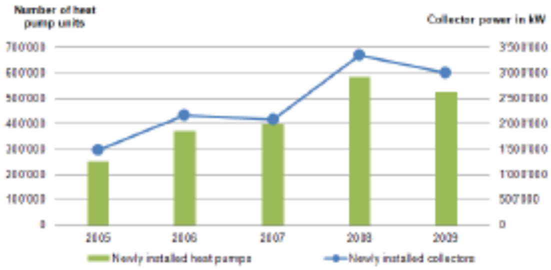


Figure 3: Market development of solar collectors (EU27+CH, data from ESTIF) and heat pumps (AT, CH, DE, FI, FR, IT, NO, SE, UK, data from EHPA) (elaborated by Fraunhofer ISE).

A review of market-available systems was started within Subtask A in 2010. The aim is to provide a more detailed description for each system, including specifications of the main components, hydraulic schemes and market availability. Until today, 75 distinguishable products were found. By far most of them are offered by German or Austrian manufacturers, numerous systems also by Danish, French, Swiss and Swedish companies. Structured by the source of the heat pump used within these systems, the result appears as follows:

- 34 air;
- 34 ground;
- 2 water;
- 5 waste heat.

To visualize and to analyze even the most different concepts, a flow diagram has been developed. Exemplary applications can be seen in Figure 4. Here, all system components are shown against white background, namely energy-storing (blue) and energy-transforming (orange) objects. From above, environmental energy (green) enters the system, from left (grey) final energy or "energy to be purchased". On the right, useful energy is recorded. The whole visualization remains on a qualitative level, i.e. neither losses nor component sizes nor efficiencies are shown. It is also important to know that all possible operational modes of the systems are shown within one single visualization scheme.

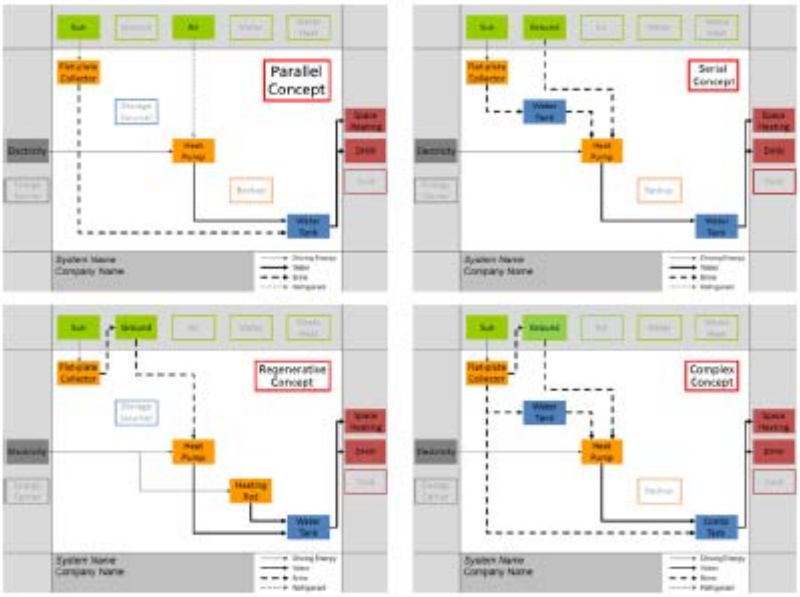


Figure 4: Visualization schemes for typical solar heat pump systems (source: Fraunhofer ISE).

Subtask B:

Performance assessment

Subtask Leader:
Ivan Malenkovic
AIT Austrian Institute of Technology, Giefinggasse 2, 1210 Vienna
AUSTRIA
email: ivan.malenkovic@ait.ac.at

The objective of this subtask is to reach a common definition on performance figures for solar heat pump systems and define procedures for their assessment. This is an important goal since this technology presently lacks standardised quality assurance methods – a fact that can have a negative impact on the future market development. The results of the subtask should finally lead to a pre-normative definition of performance assessment methods for solar heat pump systems. The work is coordinated with a number of on-going activities concerning other, both heat pump and solar thermal applications and should provide a transparent basis for technology comparisons both on the economic and ecological levels.

The output of the subtask should be used by the industry to communicate the performance of the systems they promote. To facilitate this, the first step was to propose a systematic approach regarding the definition of performance figures, Figure 5.

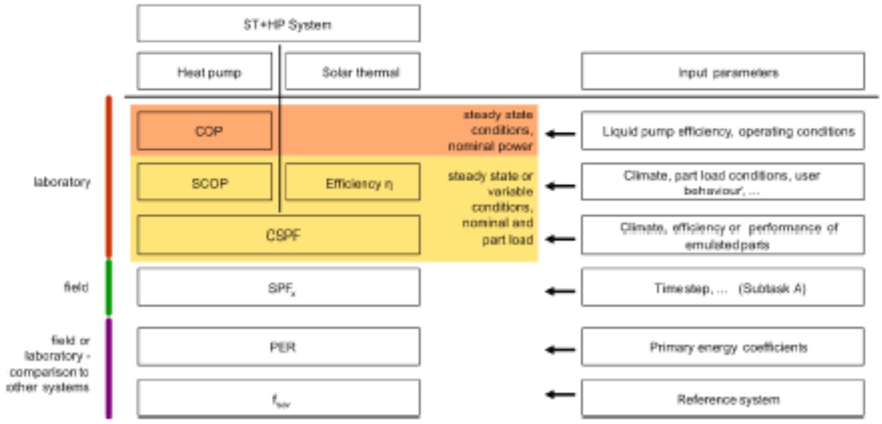


Figure 5: Proposal for a systematic approach to the definition of performance figures for solar heat pump systems (source: AIT).

Based on an analysis of currently available standards for solar thermal and heat pump technologies, proposed approach includes clear nomenclature, definition of system boundaries and type of boundary conditions for the most important performance figures.

A survey of existing solar heat pump systems yielded a variety of different configurations. It is therefore necessary for a widely applicable definition of performance figures to create a generic system which covers all available system configurations.

In Figure 4, the elaborated generic system with an example of three system boundaries for the performance assessment of solar heat pump systems and their subsystems is shown. When choosing the boundaries and defining the performance figures, the following aims were considered:

- Analysis of the system performance for development and optimisation;
- Comparison of systems within the solar heat pump technology for quality assurance;
- Comparison of solar heat pump systems with other technologies regarding economic and ecological aspects.

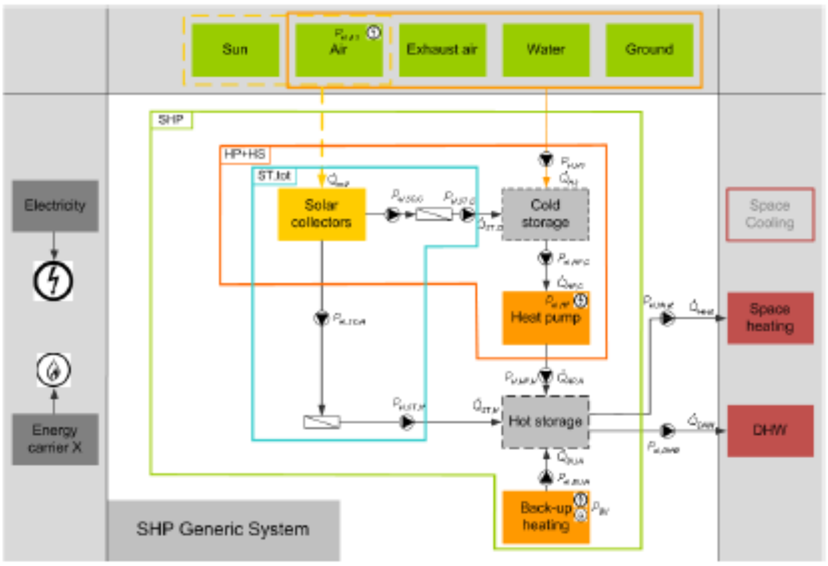


Figure 6: Proposal for a systematic approach to the definition of performance figures for solar heat pump systems (source: AIT)

Following the definition of performance figures, test methods as a basis for future quality assurance tools will be developed. Technical reports on measurement results from laboratory tests on different systems will be a part of the subtask output.

Finally, the requirements for a quality label, comparable to existing marketing tools for solar thermal or heat pump technologies, will be discussed and work on needed standards initiated within respective standardisation committees (e.g. CEN or ISO).

Subtask C:

Modeling and simulation

Subtask Leader:
Michel Haller
Institut für Solartechnik SPF, University of Applied Science Rapperswil HSR
Oberseestrasse 10, 8640 Rapperswil
SWITZERLAND
email: michel.haller@solarenergy.ch

For the evaluation and optimization of systems, detailed component and system models are needed. In Subtask C, those modeling tools for components and complete generic systems are compiled, used and compared. Different partners are carrying out simulations and sensitivity analysis on systems which are then used to identify important and less important features for different system configurations. Furthermore, the thermodynamics of heat pump processes that involve more than one heat source are analyzed. Based on the results of this subtask, accurate performance simulation and sizing of systems will be possible.

A comparison of energy performance simulation results for different systems is only possible if the same boundary conditions for the domestic hot water demand and the building heat load were applied. Therefore, common boundary conditions have been defined and implemented on three different simulation platforms that are used within T44A38 (TRNSYS, Matlab-Simulink and IDA-ICE).

A collection and documentation of state of the art simulation models for the different components in solar & heat pump systems has been elaborated. These collections include models for solar thermal collectors (flat plate, vacuum tube and uncovered), heat pumps (air-source, ground source / brine source), ground heat exchange (vertical boreholes as well as horizontal collectors) and heat storage (sensible and latent).

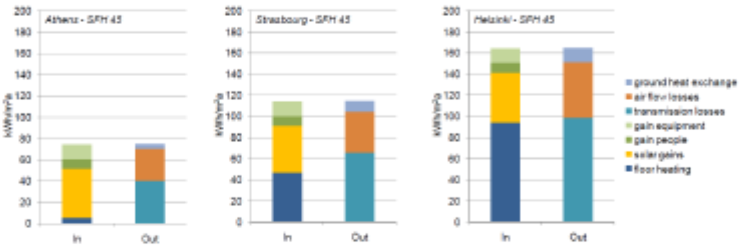


Figure 7: Building energy balances of a Single Family building with an annual heating demand of 45 kWh/(m²year) for Strasbourg climate - SFH 45 - at three different reference location.

Figure 8: Frost on an uncovered solar collector operated below the dew point (source: Institut für Solartechnik SPF).

Thermodynamic analysis of a heat pump that can use either heat from a solar thermal collector or heat from a different heat source (e.g. the air or the ground) has led to new knowledge that will influence the control algorithms of these systems in the field and lead to better energetic efficiency.

The next steps in Subtask C will be to perform and compare simulations using the common boundary conditions, to validate component models and elaborate recommendations on which models to use for which simulation task, and to carry on with thermodynamic analysis of solar and heat pump systems. Finally, based on these simulations and analysis, sizing tools will be elaborated.

Subtask D:

Dissemination and market support

Subtask Leader:
Wolfram Sparber
EURAC Research, Viale Druso 1, 39100 Bolzano
ITALY
email: wolfram.sparber@eurac.edu

The objective of this subtask is to provide information on on-going R&D activities to the scientific community, industrial actors and to the public during the course of the Task so that the value added created by the participants can be transferred as fast as possible to a growing market.

The communication of the running activities is organized via different communication channels. An important channel is the homepage of T44A38 where all main information and results are collected. Within the homepage it has been decided to collect not only material strictly from the task, but as well on topics which are related to the task. Therefore there are included the links to research and industry actors working in the field as well as links to other R&D projects researching within the topic. Furthermore within the download area scientific publications are listed which Task participants have published on international scientific conferences on solar and heat pump systems.

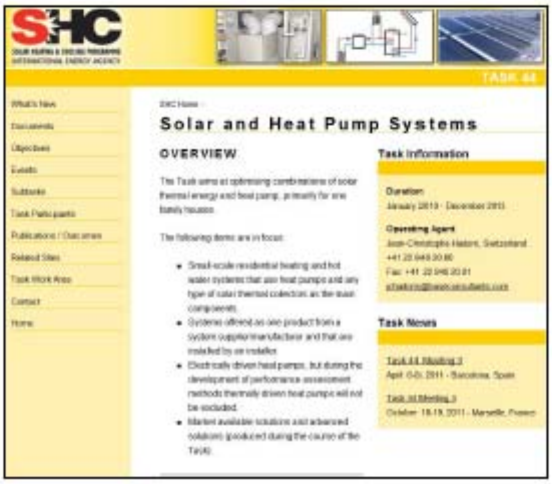


Figure 9: view of the Task 44 / Annex 38 web page (www.iea-shc.org/task44)

In order to meet and discuss face to face the results and critical aspects industry workshops are organized in parallel to many of the half yearly Task meetings. These are usually organized within the language of the country in order to be of easy access as well to the local industry actors.

At the end of the Task, next to the single technical reports there will be delivered two main documents. This in on the one hand a "Policy paper" where an overview of the development of the technology, the market entry and possible evolution, and the needed actions are presented in order to allow a market development based on high quality systems.

On the other hand a technical handbook will be elaborated, including all main results of the task activities and experiences. This handbook will be distributed globally and is aimed as a reference document in the field of solar heat and heat pump systems.

Furthermore Subtask D includes the following deliverables:

- guidelines for planers and other target audiences: installation, commissioning, operation, with to do's and not to do's;
- assessment of existing norms, regulations;
- transfer new performance assessment methodologies to the target audiences;
- education schemes and education material
- newsletters;
- participation in workshops and international conferences

Recent publications on the topic:

[1] Bertram, E., Stegmann, M., Kundmüller, K. & Rosinski, C., 2011, "Wärmepumpensysteme mit unabgedeckten photovoltaisch- termischen Kollektoren", *OTTI Solarthermie PVT*, Ulm, Germany.

[2] Bertram, E., Glembin, J., Scheuren, J. & Rockendorf, G., 2010, "Condensation heat gains on unglazed solar collectors in heat pump systems". *Eurosun Conference*, Graz, Austria.

[3] Bertram, E., Stegmann, M., Scheuren, J., Rosinski, C. & Kundmüller, K., 2010, "Unglazed photovoltaic thermal collectors in heat pump systems". *Eurosun Conference*, Graz, Austria.

[4] Bertram, E., Glembin, J., Scheuren, J., Rockendorf, G. & Zienterra, G., 2008, "Unglazed solar collectors in heat pumps systems: measurement, simulation and dimensioning". *Eurosun Conference*, Lisbon, Portugal.

[5] Bertram, E. Glembin, J., Scheuren, J. & Zienterra, G., 2009, "Soil regeneration by unglazed solar collectors in heat pump systems". *ISES Solar World Congress*, Johannesburg, South Africa.

[6] Bettoni, M., D'Antoni, M. & Fedrizzi, R., 2011. "Progettazione e analisi numerica di un quadro di controllo standardizzato per applicazione Solar Combi+ di piccola taglia". *48° Convegno Internazionale AiCARR*, Baveno, Italy.

[7] Carbonell, D., Cadafalch, J. & Consul, R., 2011. "A transient model for radiant heating and cooling terminal heat exchangers applied to radiant floors and ceiling panels". *ISES Solar World Congress*, Kassel, Germany.

[8] Citherlet, S., Bony, J. & Nguyen, B., 2008, *Sol-Pac. Analyse des performances du couplage d'une pompe à chaleur avec une installation solaire thermique pour la renovation*. Heute Ecole d'Ingénierie et de Gestion du Canton de Vaud (HEIG-VD), Yverdon-les-Bains, Switzerland.

[9] D'Antoni, M., Bettoni, D., Fedrizzi, R. & Sparber, W., 2011, "Parametric analysis of a novel Solar Combi+ configuration for commercialization". *4th International Conference Solar Air-Conditioning*, Larnaka, Cyprus.

[10] Frank, E., Haller, M.Y., Herkel, S. & Ruschenburg, J., 2010, "Systematic classification of combined solar thermal and heat pump systems". *Eurosun Conference*, Graz, Austria.

[11] Haller, M.Y. & Frank, E., 2011, "Steigert die Nutzung von Solarkollektoren als Wärmequelle für Wärmepumpen die System-Arbeitzahl?" *21. Symposium Thermische Solarenergie*, Bad Staffelstein, Germany.

[12] Haller, M.Y., Frank, E., Trinkl, C. & Zörner, W., 2010, "Systematische Gliederung der Systemkombination von solarthermischen Anlagen mit Wärmepumpen". *20. Symposium Thermische Solarenergie*, Bad Staffelstein, Germany.

[13] Haller, M.Y. & Frank, E., 2011, "On the Potential of using heat from solar thermal collectors for heat pump evaporators". *ISES Solar World Congress*, Kassel, Germany, 2011

[14] Haller, M.Y., 2011, "Entwicklung von Prüfverfahren für Anlagen mit Kombination aus Wärmepumpen und Solarthermie". *VDI-Fachkonferenz Wärmepumpen - Umweltwärme effizient nutzen*, Frankfurt, Germany,.

[15] Henning, H.M. & Miara, M., 2009, "Kombination Solarthermie und Wärmepumpe – Lösungsansätze, Chancen und Grenzen". *19. Symposium Thermische Solarenergie*, Bad Staffelstein, Germany.

[16] Kjellsson, E., Hellström, G. & Perers, B., 2010, "Optimization of systems with the combination of ground-source heat pump and solar collector in dwellings". *Energy*, vol. 35, pp. 2667-2673.

[17] Kurmann P. & Ursenbacher T., 2011, "Optimierung der Einbindung eines 28 m^3 – Wasserspeichers in die Beheizung und die WW-Versorgung mit WP und Solartermik". *17. Wärmepumpentagung BFE-Forschungsprogramm „Wärmepumpen, Wärme-Kraft-Kopplung, Kälte"*, Burgdorf, Switzerland.

[18] Leibfried, U., 2011, "Integrierte Systemlösungen für Bestand und Neubau als Weg zum Erreichen der Klimaziele". *21. Symposium Thermische Solarenergie*, Bad Staffelstein, Germany.

[19] Lerch, W., Heinz, A., Fink, C., Breidler, J. & Wagner W., 2011, "Kombination Solarthermie / Wärmepumpe inkl. Abwasser-Wärmerückgewinnung (AWR)". *21. Symposium Thermische Solarenergie*, Bad Staffelstein, Germany.

[20] Loose, A., Drück, H., Hanke, N. & Thole, F., 2011, "Field test for performance monitoring of combined solar thermal and heat pump system". *ISES Solar World Congress*, Kassel, Germany.

[21] Loose, A., Mette, B., Bonk, S. & Drück, H., 2011, "Development of performance test methods for combined solar thermal and heat pump systems". *5th European Solar Thermal Energy Conference ESTEC*, Marseille, France.

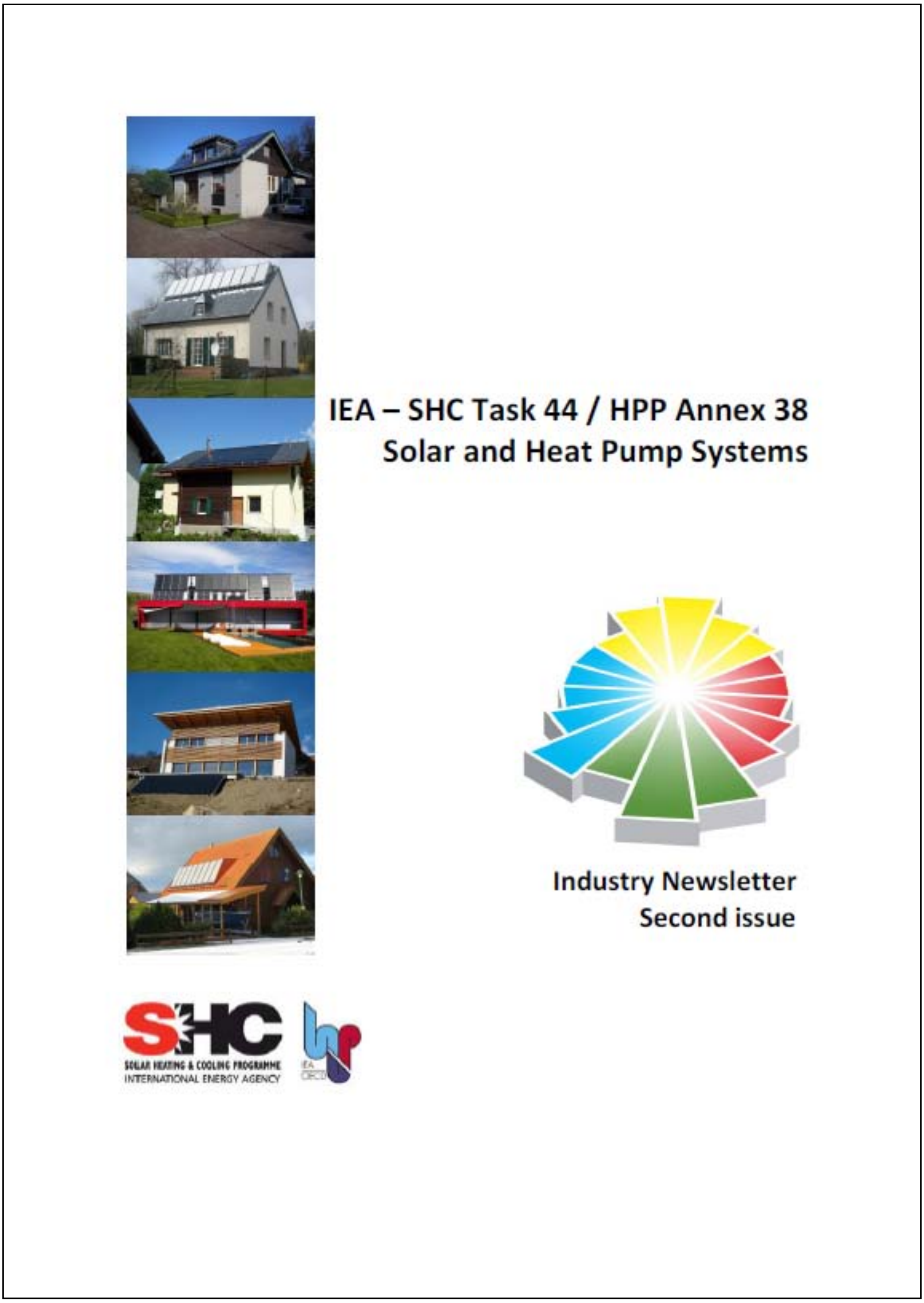
[22] Malenkovic I., 2011, "Current work on performance evaluation of solar thermal and heat pump hybrid systems within IEA SHC Task 44 / HPP Annex 38 and IEE QAiST Project". *5th European Solar Thermal Energy Conference ESTEC*, Marseille, France.

[23] Mette, B., Drück, H., Bachmann, S. & Müller-Steinhagen, H., 2009, "Performance testing of solar thermal systems combined with heat pumps". *ISES Solar World Congress*, Johannesburg, South Africa.

[24] Pärisch, P., Kirchner, M., Wetzel, W., Voß, S. & Tepe, R., 2011, "Test system for the investigation of the synergy potential of solar collectors and borehole heat exchangers in heat pump systems". *ISES Solar World Congress*, Kassel, Germany.

[25] Philippen, D., Haller, M.Y. & Frank, E., 2011, "Einfluss der Neigung auf den äusseren konvektiven Wärmeübergang unabgedeckter Absorber". *21. Symposium Thermische Solarenergie*, Bad Staffelstein, Germany.

3 Second newsletter



IEA – SHC Task 44 / HPP Annex 38
Solar and Heat Pump Systems

Industry Newsletter
Second issue

Industry newsletter

Second issue, 6-2012

IEA – SHC Task 44 / HPP Annex 38

Solar and Heat Pump Systems

Elaborated by:

M. D'Antoni, R. Fedrizzi, W. Sparber

EURAC Research

This newsletter presents the effort made in classifying Solar and Heat Pumps systems made by Task 44 / Annex 38. A uniform SHP system representation has been presented and a guide line in developing it is shown. This energy flow chart can be applied to any other space heating or DHW generation systems and a direct comparison can be derived. Finally, the framework for the performance figure calculation is presented.

Task 44 / Annex 38

Solar and Heat Pump Systems

Background

Operating Agent:
Jean Christophe Hadorn
BASE Consultants SA
8 rue du Nant, 1207 Geneva
Switzerland
email: jchadorn@baseconsultants.com

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. Such combinations are complex and need more control strategies and electronics than separate configurations. Therefore the optimisation of the combination is more complex and the cost effectiveness of the combination is not obvious.

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 dependent 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. Market for S+HP in countries like Switzerland, Austria, Germany are booming due to several favourable conditions like CO_2 reduction promotion programs, direct electrical heating substitution encouragement, obligation of a minimum of 30% renewable for domestic hot water production, high electricity peak cost and incentives.

Task 44 / Annex 38 – "Solar and Heat Pump Systems"

International collaboration through an IEA activity is an efficient way to share knowledge and new ideas on comparison and standardisation of such complex systems. Moreover the Task 44 of Solar heating and cooling called "Solar and heat pump systems" is also Annex 38 of the Heat Pump Programme, thus gathering experts from both technologies.

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.

Task Objectives

The objective of this Task is the assessment of performances and relevance of combined systems using solar thermal and heat pumps, to provide common definition of performances of such systems and to contribute to successful market penetration of these new systems.

Other objectives are needed to reach the main one where international collaboration is definitively needed to make it possible within a 4 years framework, mainly:

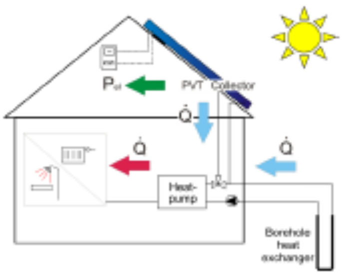
- surveying the possible generic combinations;
- defining performance figures of a combined solar and heat pump solution;
- defining assessment and test methods of such systems;
- analysing monitored data on such systems;
- developing component models or integrating existing ones into a system model;
- simulating various systems under common conditions;
- providing guidelines of good practice to the market and stakeholder;
- providing authorities with relevant information on the interest of such systems;
- staying close to the market and bringing independent information and knowledge to the actors on this market along the duration of the Task.

The scope of the Task considers solar thermal systems in combination with heat pumps, applied for the supply of domestic hot water and heating in family houses.

Duration of Task 44 / Annex 38

Task 44 / Annex 38 started in January 2010 and will end in December 2013. A number of deliverables will be available from time to time on the T44/A38 web site:

http://www.iea-shc.org/task44/.



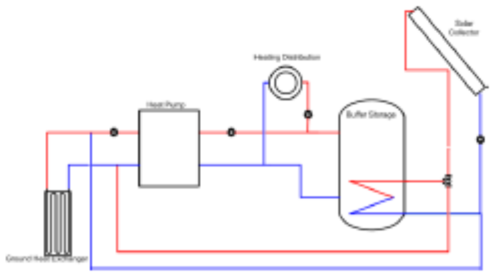
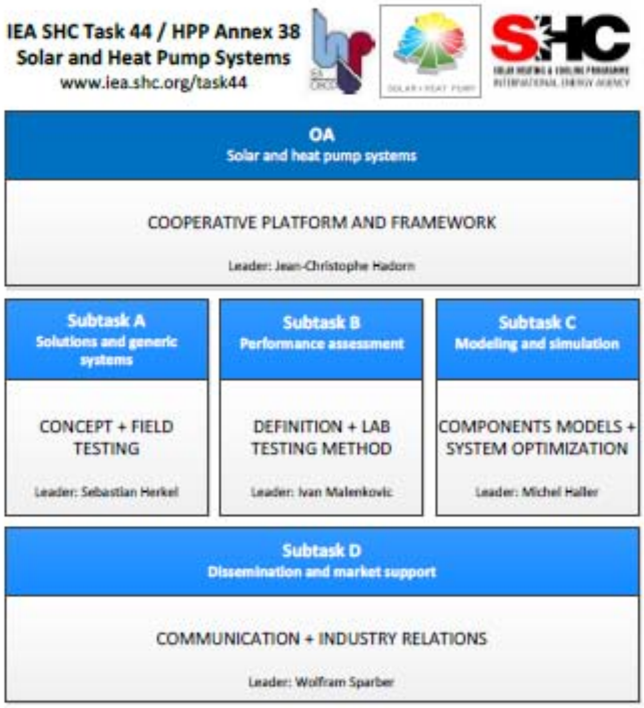


Figure 1 and 2: S+HP system: Example of a system including PV-T collectors and ground heat exchanger coupled with a water-to-water heat pump (source: ISFH and Fraunhofer ISE).

Subtasks

The work in this T44A38 is divided into four Subtasks:

- Subtask A: Overview of solutions (existing, new) and generic systems, led by Sebastian Herkel from Fraunhofer ISE of Stuttgart, Germany;
- Subtask B: Performance assessment, led by Ivan Malenkovic from the Austrian Institute of Technology (AIT);
- Subtask C: Modelling and simulation, led by Michel Haller from the SPF in Rapperswil, Switzerland;
- Subtask D: Dissemination and market support, led by Wolfram Sparber form the EURAC Research centre in Bolzano, Italy.



Classification of Solar and Heat Pump systems

An overview of the S+HP systems available on the European market have been carried out Within the activities of Subtask A. This has permitted to gather information regarding the major characteristics of these systems, with the aim of deriving a uniform classification.

From this investigation, several classification criteria became evident and among these have been selected:

- building load covered;
- heat pump's source;
- system layout.

The commercial S+HP systems identified on the EU market are 89. These are adopted for covering one or more building loads as depicted in Figure 2. The vast majority of S+HP systems covers Domestic Hot Water (DHW) and Space Heating (SH) loads (69 systems) of residential buildings, while 13 systems is devoted exclusively to DHW preparation. A number of systems (7) fulfils DHW, SH and Space Cooling (SC) loads.

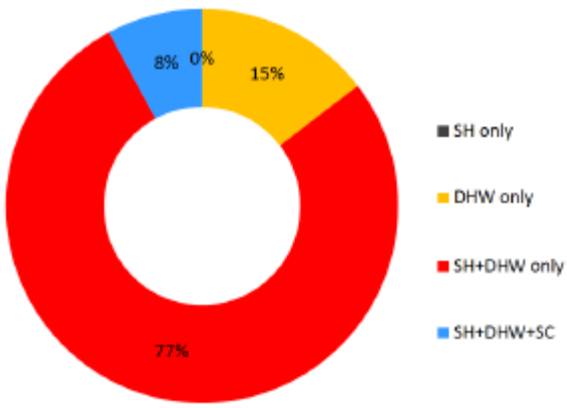


Figure 2: S+HP system classification accordingly to the covered building load.

The heat sources of the heat pump can be the ambient air, solar energy, ground, well water or waster heat. These can be exploited singularly, simultaneously or alternatively, in accordance to the energy concept adopted by the manufacturer.

Looking at the mutual position of solar-thermal field and heat pump with respect to the building load (DHW or heating), S+HP systems can be further classified in pure parallel, pure series or hybrid systems. In a parallel system (Figure 3), the solar-thermal field covers a first fraction of the load, while the heat pump provides the remaining required energy: thus here, solar energy has no influence of heat pump operation condition. The solar-thermal collector feeds the heat pump's evaporator in a series system (Figure 4): this can be guaranteed directly or indirectly through the adoption of a cold storage.

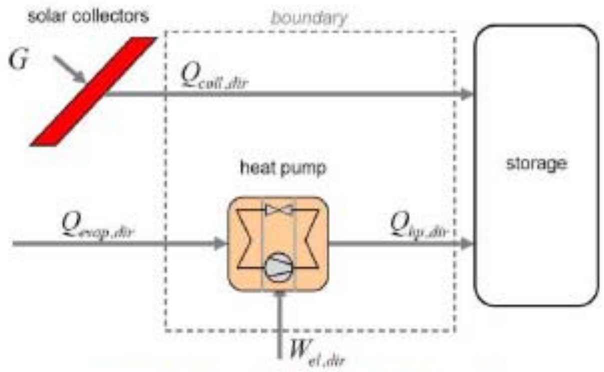


Figure 3: S+HP parallel system (Haller & Frank 2011).

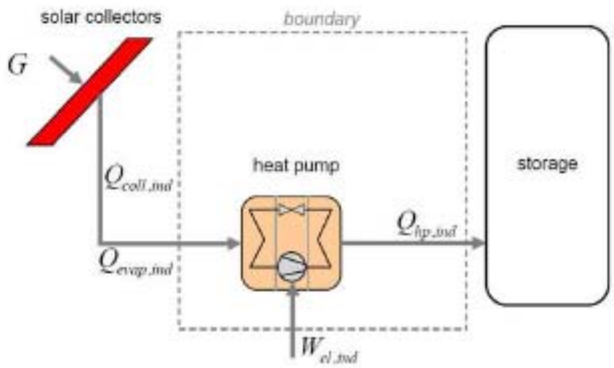


Figure 4: S+HP series system (Haller & Frank 2011).

Finally, in hybrid systems, both parallel and series configurations can be present and the operation mode is regulated by the control strategy. As can be recognized in Figure 5, almost 60% of the investigated systems work in parallel mode, 30% are hybrid systems, while the remaining 10% is due to the pure series systems.

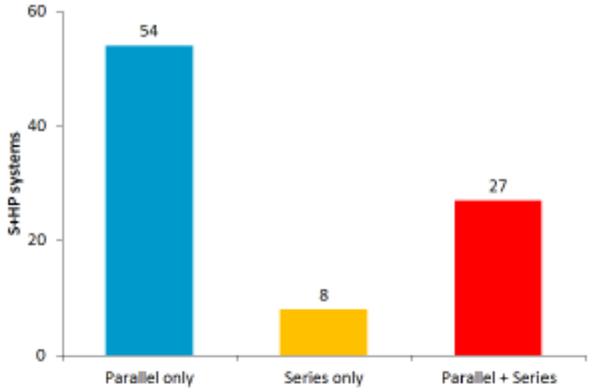


Figure 5: S+HP system classified accordingly to plant layout.

Grouping together the previous two criteria, the graph of Figure 6 can be derived. In the parallel systems, heat pump operates always as a monovalent system, adopting one single source among ambient air, ground, well water or waste heat. In pure serial systems, solar energy is most of the time used as a unique source (monovalent system), while in very limited cases ambient air or ground are used alternatively. In hybrid parallel/series systems a great variety of plant layouts have been recognized. Here the combination of ground and solar energy showed to be the widest adoption.

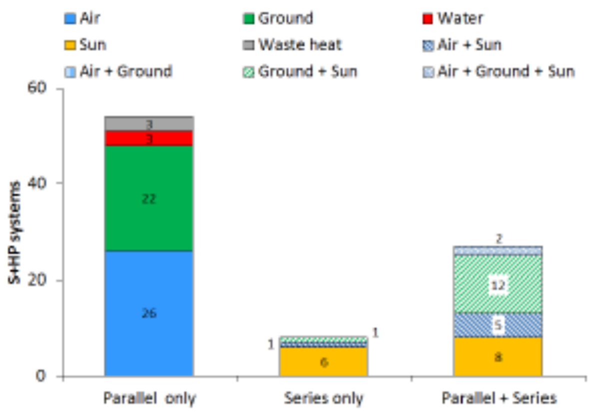


Figure 6: S+HP systems classified accordingly to the plant layout and heat pump source.

Energy flow chart

In order to effectively describe S+HP systems, an energy flow chart has been created (Figure 7). This diagram has been developed accordingly to a source-sink approach, in which any component can virtually supply any other (source) with thermal or electric energy, or behaves as a sink of energy from any other. The clear benefit of this approach is the degree of freedom left to the description of the connections. All system components, as well mutual connections, are shown against a white background and the following convention have been established:

- in grey **traded energy** input/output to/from the system are accounted for: (Electricity)
  - electricity;
  - any other energy carrier fossil or renewable: gas, oil, wood, district heating circuit;
- in dark green **free available renewable energy sources** (RES) are reported: (Air)
  - sun;
  - ground;
  - air;
  - water;
  - waste heat;
- in light green the **heat exchangers** between the RES and the systems are shown: (Solar Collector)
  - solar collectors;
  - ground probes;
  - air/water, air/vapour heat exchangers;
- in dark blue the **storages** are set: (Hot Storage)
  - cold storage, as heat source for the heat pump:
  - hot storage, the one that could fulfil building loads (e.g. DHW storage, combi storage) and can be charged by solar energy or any heat generator system;
- in orange **compression heat pumps** and eventually the **auxiliary heating system** (e.g. heating rod); (HP)
- in dark red the **building loads.** (DHW Distrib.)

Heat and electricity fluxes are represented with arrows among elements (from the source to the sink) accordingly to the source-sink approach. Electricity fluxes are represented in grey, thermal energy is displayed in dark red. All arrows are also identified correspondingly to the source-sink approach.

Since electricity fluxes to pumps and fans would pack the diagram in case of complex systems, those components are shown as blue dots to be displaced on the diagram onto the respective energy fluxes: themselves represent the respective electricity consumption.

A second clear advantage of this approach is that boundaries of the system and subsystems can be represented on the diagram and input/output energy fluxes can be detected, justifying the performance figures calculation and the meters needed for the acquisition of the needed data. In Figure 7, one exemplary boundary around the entire system have been sketched. Entering and leaving fluxes are clearly different and so are the meters to be used to describe the system and the performance figures computed.

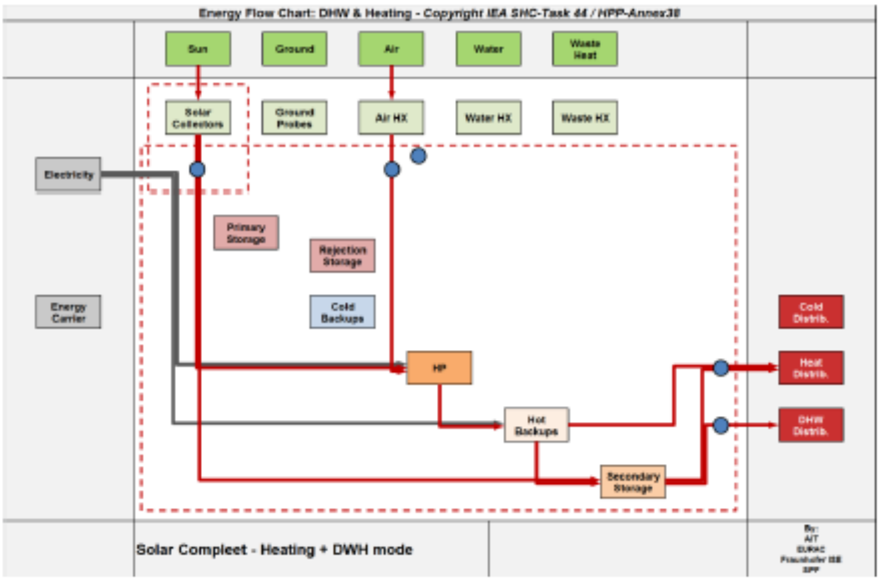


Figure 7: energy flow chart of S+HP system.

Source-sink generic table

To easily manage the great variety of the connections, an Excel-based table has been elaborated where the first column shows all possible elements of the system, treated as sources, and the first row reports the same elements regarded as sinks (see Figure 8).

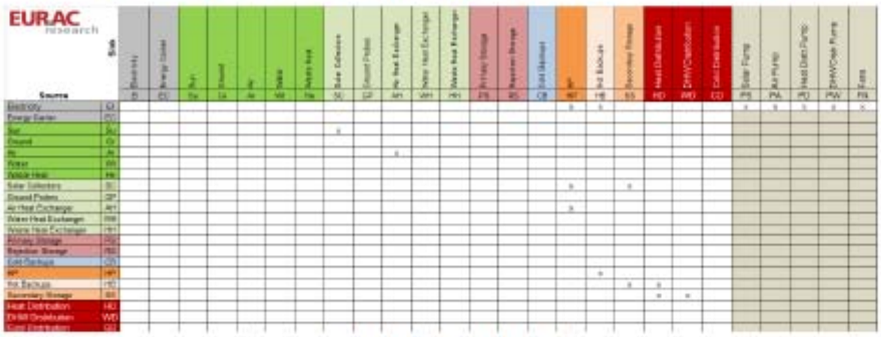


Figure 8: Source-sink table.

The elements are grouped together with different colours, accordingly to the nomenclature given above. Any element is fully identified by an two-letter code: first two letters of the name (Sun = Su) or first letter of a composite name (Solar Collector = SC) (see Figure 9). In this way any component is marked with an intuitive abbreviation: this will be then used to identify also all energy fluxes through the system. In particular the flux is named as: "source"."sink".

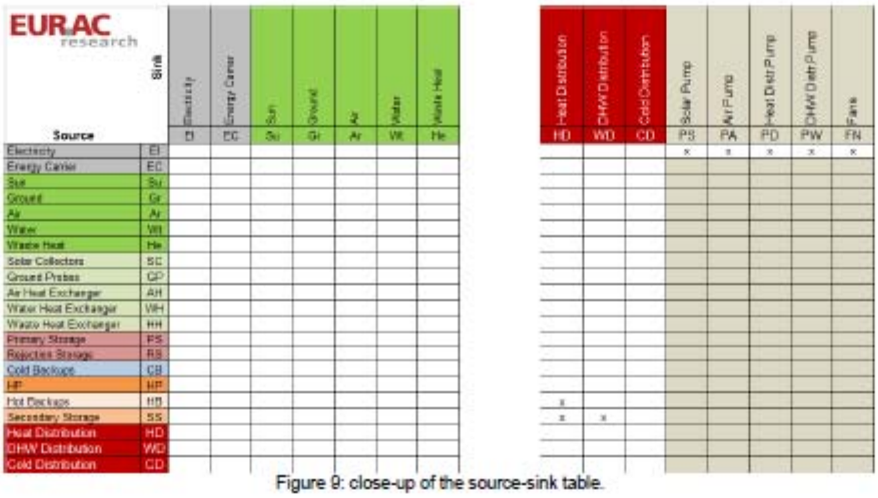


Figure 9: close-up of the source-sink table.

The system is described by marking the cross between the specific sources and sinks: in Figure 9, the fluxes from the HP and hot backups to the heating distribution, and from the secondary storage to the DHW distributions, are shown as example. Obviously the large majority of the cells remain unused. Therefore an automated procedure simplifies the main table and prepares a reduced one that only reports the envisaged fluxes and names them with the specific abbreviations (see Figure 10).

Source	Sink	Solar Collectors	Air Heat Exchanger	HP	Hot Backups	Secondary Storage	Heat Distribution	DHW Distribution	Solar Pump	Air Pump	Heat Distr. Pump	DHW Distr. Pump	Fans
		SC	AH	HP	HB	SS	HD	WD	PS	PA	PD	PW	FN
Electricity	El			El.HP	El.HB				El.PS	El.PA	El.PD	El.PW	El.FN
Sun	Su	Su.SC											
Air	Ar		Ar.AH										
Solar Collectors	SC			SC.HP		SC.SS							
Air Heat Exchanger	AH			AH.HP									
HP	HP				HP.HB								
Hot Backups	HB					HB.SS	HB.HD						
Secondary Storage	SS						SS.HD	SS.WD					

Figure 10: Reduced source-sink table.

Performance figures definition

On the basis of the defined reference system, a set of system boundaries was proposed for the definition of different component and system performance figures. The proposed boundaries were chosen not only to suit SHP systems, but to be applicable to a broad variety of heating systems and technologies in order to enable a transparent comparison between them.

When defining the boundaries, the following goals were pursued:

1. Overall system performance including energy distribution system. Possibility of an energetic, economic and ecological evaluation of the whole system – overall energy balance, purchased energy, free energy, emissions etc. The information is interesting for the user, the policy, statistical evaluation etc.
2. Possibility of an economic and ecological evaluation of the energy producing system, without the energy distribution system, which is different for every application. Interesting for product quality assurance, labelling, manufacturers, planers, installers, comparison between different systems and technologies regarding efficiency, primary energy, emissions etc.
3. Performance of the system without the influence of the storage losses – decoupling of the energy producing part and energy storage part. Interesting e.g. for control analysis (production-demand), dimensioning etc. Mainly interesting for system analysis (manufacturers, R&D etc.).
4. Performance of each "energy transformation unit" (e.g. heat pump), including all parts needed for its proper functioning (e.g. heat sources). Performance of each unit under given circumstances gives information about the efficiency of every subsystem and possible improvements. Interesting for component and subcomponent manufacturers, planners and installers, system analysis etc.
5. Performance of each energy transformation unit for itself, without influence of the "auxiliary" energy (energy sources etc.). This closely corresponds to the energy balance used currently in most quality assurance schemes both for solar thermal collectors and heat pumps (e.g. Solar Keymark, EHPA Quality Label). By comparison with other performance figures, an analysis of the system regarding peripheral energy consumption can be made. Interesting for manufacturers, planers etc.

Starting from these five goals for a comprehensive analysis of an energy producing system, system boundaries for SHP systems can be defined, Figure 11. At this stage, the boundaries have been defined for heating operation and domestic hot water (DHW) production only. The cooling mode will also be considered.

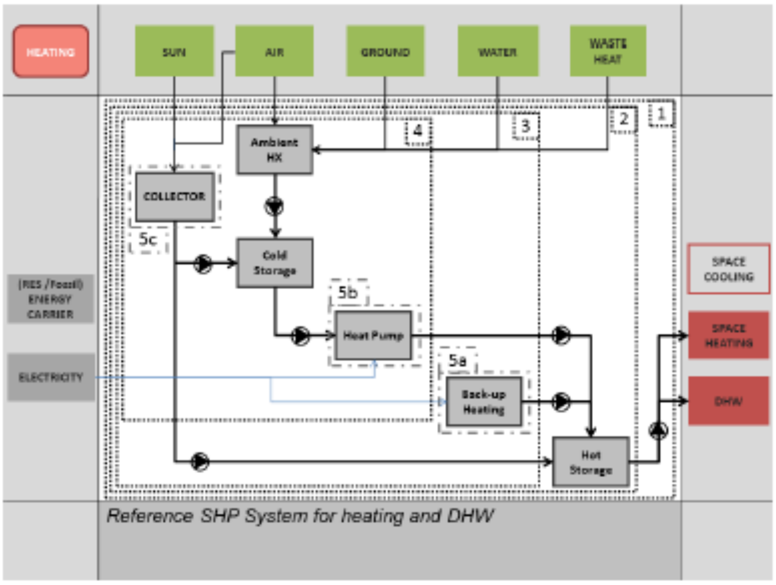


Figure 11: System boundaries for SHP Systems in heating mode

The five boundaries from Figure 11 represent the following subsystems:

1. The whole system including all components up to the purchased energy at the interface (on the left of the diagram), including heat distribution system (on the right).
2. The whole system excluding heat distribution system.
3. SHP System excluding storages, but including possible back-ups (e.g. electric heating element in the storage).
4. The heat pump unit with its sources, which can also include another heat transforming unit, here the solar collector.
5. Energy supplying units: Back-up heating (a) heat pump (b) and solar collector (c).

As the most important performance figure on the system level, the seasonal performance figure (SPF) has been defined. An SPF is defined as the ratio of the "useful" energy output from the considered system to the "purchased" energy input to the system. For every proposed system, an SPF can be determined, if the required data is available. By comparing different SPFs, the potential for system improvement can be evaluated.

However, the data to determine all SPFs proposed is often not available. Therefore, it was agreed to propose the SPF for system boundary 2 as obligatory for reporting (for field tests, laboratory measurements and simulations) within Task 44 / Annex 38, as the most important one. Moreover, this system boundary corresponds to reporting boundaries for other heating systems defined in recent international projects like SEPEMO[1] and HPP Annex 37[2] (electrically driven heat pumps) or HPP Annex 34[3] (thermally driven heat pumps) and is already used in a number of standards, e.g. EN 15316-4-2, EN 16147, EN 12976 etc.

[1] www.sepemo.eu
[2] www.heatpumpcentre.org/en/projects/ongoingprojects/annex37/Sidor/default.aspx
[3] www.annex34.org

Introducing SPF as the key performance indicator, however, does not allow a comparison to other technologies (e.g. gas boilers, direct electricity) regarding the environmental impact, mainly caused by the depletion of primary energy sources and CO_2 emissions. Therefore, two more performance figures were proposed to be used for system reporting: GWP (global warming potential, and CED_{NRE} (non-renewable primary energy). These two figures represent the emissions caused by the operation of the system and the usage of primary, non-renewable energy sources, respectively. CED_{NRE}, as defined in EN 15603:2008 is the ratio of the primary energy consumed by the system to the final energy distributed to the user and GWP is the ration of the emitted amount of CO_2 (in kg) during the system operation to the final energy distributed to the user. Both factors are connected over the primary energy coefficients, which have to be assumed for every type of primary energy. As the acronym GWP is already widely used in the heat pump industry to indicate the global warming potential of the refrigerants, another nomenclature might be proposed to avoid misunderstanding.

In order to fully evaluate the quality of the system, the operating conditions including climate, building category, user behaviour etc. have to be considered. The knowledge of the SPF, measured or calculated, is not enough. Therefore, a proposal defining the minimum required information (including different performance indicators), which should be supplied to different target groups (users, planners and installers, subsidy bodies etc.) is currently being developed within the Task.

Task 44 / Annex 38 – Participants

Aalto University School of Science and Technology Lämpömiehenkuja 2 02150 Espoo FINLAND www.aalto.fi	AEE INTEC Institute for Sustainable Technologies Feldgasse 19 8200 Gleisdorf AUSTRIA www.aee-intec.at	AIGUASOL ENGINYERIA C/ Roger de Llúria, 29 3r 2a 08009 Barcelona SPAIN www.aiguasol.com
AIT Austrian Institute of Technology Giefinggasse 2 1210 Vienna AUSTRIA www.ait.ac.at	ASIC Austria Solar Innovation Center Durisolstraße 7/Top 50 4600 Wels AUSTRIA www.asic.at	Base Consultants SA 8 rue du Nant CP 6268 1211 Geneve SWITZERLAND www.baseconsultants.com
CEA INES Institut National de l'Energie Solaire 50, Avenue du Lac Leman 73377 Le Bourget du Lac France www.liten.fr www.ines-solaire.org	CENERGIA Herlev Hovedgade 195 2730 Herlev DENMARK www.cenergia.dk	Consolar Solare Energiesysteme GmbH Gewerbestrasse 7 79539 Lörrach GERMANY www.consolar.de
DTI Danish Technology Institute Gregersensvej 3 2630 Taastrup DENMARK www.dti.dk	DTU Technical University of Denmark Anker Engelundsvej 1 2800 Kgs. Lyngby DENMARK www.dtu.dk	Ecole d'ingénieurs et d'architectes de Fribourg Bd de Pérolles 80 P.O. Box 32 1705 Fribourg SWITZERLAND www.eia-fr.ch

EDF R&D Département Enerbat Centre des Renardières Avenue des Renardières Ecuelles 77818 Moret-sur-Loing FRANCE www.edf.fr	EHPA European Heat Pump Association Renewable Energy House Rue d'Arlon 63-67 1040 Brussels BELGIUM www.ehpa.org	Ellehauge & Kildemoes Vestergade 48 H,2s.tv. 8000 Århus C. www.elle-kilde.dk
ENERGIE EST lda Zona Industrial de Laúndos, Lote 48 4570-311 Laúndos / Póvoa de Varzim PORTUGAL www.energie.pt	Energie Solaire SA CP 353 Z.I. Ile Falcon 3960 Sierre / Valais SWITZERLAND www.energie-solaire.com	EURAC research European Accademy of Bolzano Institute for Renewable Energy Viale Druso/Drususallee 1 39100 Bolzano/Bozen ITALY www.eurac.edu
FHNW Fachhochschule Nordwestschweiz Institut Energie am Bau Sankt-Jakobs Strasse 84 4132 Muttenz SWITZERLAND www.fhnw.ch/iebau	Fraunhofer-Institute for Solar Energy Systems ISE Heidenhofstraße 2 79110 Freiburg GERMANY www.ise.fraunhofer.de	HEIG-VD School of Business and Engineering Laboratory of Solar Energetics and Building Physics (LESBAT), Route de Cheseaux 1 1400 Yverdon-les-Bains SWITZERLAND www.heig-vd.ch
Hochschule für angewandte Wissenschaften FH Ingolstadt Esplanade 10 85049 Ingolstadt GERMANY www.haw-ingolstadt.de	ISFH Institut für Solarenergieforschung GmbH Hameln/Emmerthal Am Ohrberg 1 31860 Emmerthal GERMANY www.isfh.de	ITW Stuttgart University Institut für Thermodynamik und Wärmetechnik (ITW) Pfaffenwaldring 6 70550 Stuttgart www.itw.uni-stuttgart.de

KTH Royal Institute of Technology Kungl Tekniska Högskolan, SE-100 44 STOCKHOLM SWEDEN www.kth.se	Lessius Mechelen campus De Nayer Zandpoortvest 13 2800 Mechelen BELGIUM www.lessius.eu	LNEG Laboratório Nacional de Energia e Geologia Estrada do Paço do Lumiar, 22 1649-038 Lisboa PORTUGAL www.lneg.pt
Lund University Box 117 221 00 Lund SWEDEN www.lunduniversity.lu.se	Natural Resources Canada Innovation and Energy Technology Sector 580 Booth Street, 13th floor Ottawa, ON K1A 0E4 www.canmetenergy.gc.ca	NREL National Renewable Energy Laboratory 1617 Cole Blvd. Golden, CO 80401-3305 UNITED STATES www.nrel.gov
Politecnico di Milano Dipartimento di Energia Via Lambruschini 4 20156 Milano ITALY www.polimi.it	RDmes Institut Politècnic Campus Terrassa (IPCT), TR21, Sala 16 Crta. Terrassa N-150 Km 14.5 08227 Terrassa Barcelona SPAIN www.rdmes.com	Rheem Manufacturing Company 1100 Abernathy Road, Suite 1400 Atlanta, GA 30328 UNITED STATES www.rheem.com
Sandia National Laboratories PO Box 5800 Alburquerque, NM 87185 UNITED STATES www.sandia.gov	Schüco International KG Karolinenstraße 1-15 33609 Bielefeld GERMANY www.schueco.com	SERC Solar Energy Research Center School of Industrial Technology and Management Högskolan Dalarna 78188 Borlänge www.du.de

Sonnenkraft GmbH Clermont-Ferrand-Allee 34 93049 Regensburg GERMANY www.sonnenkraft.com	SP Technical Research Institute of Sweden Box 857 SE-501 15 Borås SWEDEN	SPF Institut für Solartechnik Hochschule für Technik Rapperswil HSR Oberseestrasse 10 CH-8640 Rapperswil SWITZERLAND www.solarenergy.ch
TU Graz Technische Universität Graz Institut für Wärmetechnik (IWT) Inffeldgasse 25/B 8010 Graz AUSTRIA www.tugraz.at	University of Geneve Bd du Pont-d'Arve 40 1211 GENÈVE SWITZERLAND www.unige.ch	Univerisity of Innsbruck Innrain 52 6020 Innsbruck AUSTRIA www.uibk.ac.at
University of Applied Sciences of Stuttgart Schellingstr.24 70174 Stuttgart www.hft-stuttgart.de	University of Palermo Dept. DREAM Viale delle Scienze 9 90128 Palermo ITALY www.dream.unipa.it	Universitat Politècnica da València Camino de Vera 46022 Valencia SPAIN www.upv.es
Vela Solaris Brahmstraße 21 63768 Hösbach GERMANY www.polysun.ch	Wagner & Co Solartechnik GmbH Zimmermannstr. 12 35091 Cölbe GERMANY www.wagner-solar.com	Western Renewables Group 30012 Aventura, Suite A CA 92688, Rancho Santa Margarita UNITED STATES www.westernrenewables.com

3S Swiss Solar Systems AG
Schachenweg 24
3250 Lyss
SWITZERLAND
www.3s-pv.ch

4 Third newsletter

IEA – SHC Task 44 / HPP Annex 38
Solar and Heat Pump Systems

Industry Newsletter
Third issue

Industry newsletter

Third issue, 2-2013

IEA – SHC Task 44 / HPP Annex 38

Solar and Heat Pump Systems

Elaborated by:

M. D'Antoni, R. Fedrizzi, W. Sparber

EURAC Research

With contributions by:
Michel Haller, SPF Solartechnik (Switzerland)
Martin Vukits, AEE Intec (Austria)
Erik Bertram, Institute for Solar Energy Research Hameln ISFH (Germany)

This newsletter presents three examples of commercially available Solar plus Heat Pumps systems monitored within IEA Task 44 / Annex 38. Here, domestic hot water and space heating demand of existing residential buildings are covered through the combination of a compression heat pump and solar thermal collectors. More detailed information are available in the referenced literature.

Task 44 / Annex 38

Solar and Heat Pump Systems

Background

Operating Agent:
Jean Christophe Hadorn
BASE Consultants SA
8 rue du Nant, 1207 Geneva
Switzerland
email: jchadorn@baseconsultants.com

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. Such combinations are complex and need more control strategies and electronics than separate configurations. Therefore the optimisation of the combination is more complex and the cost effectiveness of the combination is not obvious.

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 dependent 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. Market for S+HP in countries like Switzerland, Austria, Germany are booming due to several favourable conditions like CO_2 reduction promotion programs, direct electrical heating substitution encouragement, obligation of a minimum of 30% renewable for domestic hot water production, high electricity peak cost and incentives.

Task 44 / Annex 38 – "Solar and Heat Pump Systems"

International collaboration through an IEA activity is an efficient way to share knowledge and new ideas on comparison and standardisation of such complex systems. Moreover the Task 44 of Solar heating and cooling called "Solar and heat pump systems" is also Annex 38 of the Heat Pump Programme, thus gathering experts from both technologies.

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.

Task Objectives

The objective of this Task is the assessment of performances and relevance of combined systems using solar thermal and heat pumps, to provide common definition of performances of such systems and to contribute to successful market penetration of these new systems.

Other objectives are needed to reach the main one where international collaboration is definitively needed to make it possible within a 4 years framework, mainly:

- surveying the possible generic combinations;
- defining performance figures of a combined solar and heat pump solution;
- defining assessment and test methods of such systems;
- analysing monitored data on such systems;
- developing component models or integrating existing ones into a system model;
- simulating various systems under common conditions;
- providing guidelines of good practice to the market and stakeholder;
- providing authorities with relevant information on the interest of such systems;
- staying close to the market and bringing independent information and knowledge to the actors on this market along the duration of the Task.

The scope of the Task considers solar thermal systems in combination with heat pumps, applied for the supply of domestic hot water and heating in family houses.

Duration of Task 44 / Annex 38

Task 44 / Annex 38 started in January 2010 and will end in December 2013. A number of deliverables will be available from time to time on the T44/A38 web site:

http://www.iea-shc.org/task44/.

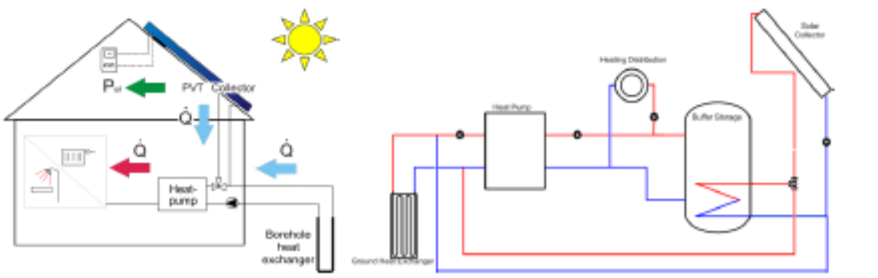
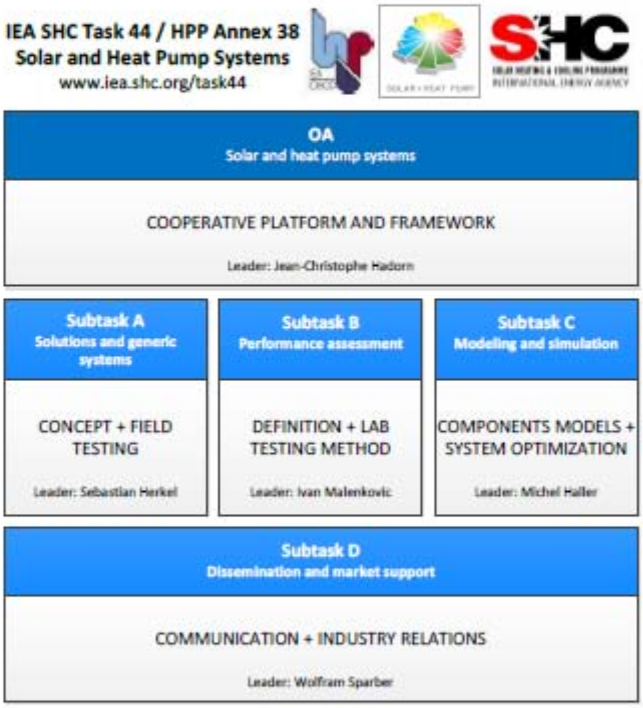


Figure 1 and 2: S+HP system: Example of a system including PV-T collectors and ground heat exchanger coupled with a water-to-water heat pump (source: ISFH and Fraunhofer ISE).

Subtasks

The work in this T44A38 is divided into four Subtasks:

- Subtask A: Overview of solutions (existing, new) and generic systems, led by Sebastian Herkel from Fraunhofer ISE of Stuttgart, Germany;
- Subtask B: Performance assessment, led by Ivan Malenkovic from the Austrian Institute of Technology (AIT);
- Subtask C: Modelling and simulation, led by Michel Haller from the SPF in Rapperswil, Switzerland;
- Subtask D: Dissemination and market support, led by Wolfram Sparber form the EURAC Research centre in Bolzano, Italy.



Introduction

The aim of the 3rd issue of T44A38 newsletter is to focus on monitoring results of Solar and Heat Pump (S+HP) systems. Since a raising number of standardized kits and solutions combining compression heat pumps and solar thermal collector for covering Domestic Hot Water and Space Heating demand are always more available on the market, it is of major interest to understand the actual performance in real operating conditions.

Within the multitude of different solutions combining solar energy with heat pump systems, three examples are here presented. Typical European residential buildings equipped with a S+HP system have been monitored for a year at least. Monitoring data are presented accordingly to IEA SHC Task 44 / HPP Annex 38 approach in calculating system performance figures. This work does not aim to report on the most efficient S+HP systems; it has to be seen as review of some existing systems.

Calculation method

In order to compare different layout scheme of Solar and Heat Pump systems within the IEA SHC Task 44 / Annex 38, a common definition on the performance calculation method has been done. As reported in [1], a series of indexes have been suggested as those which better quantify and represent the influence of solar energy exploitation on heat pump's seasonal performance. Each indicator refers to a system boundary, in order to put in light the behaviour of each system component. However, for sake of brevity, only three indicators have been here presented and in particular the:

- **system boundary SHP+**: this boundary contains all components of the system, including the space heating and DHW distribution system in terms of pumping electrical energy consumption;

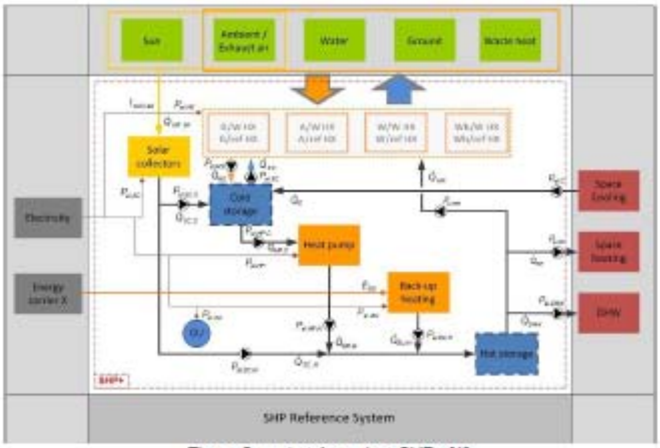


Figure 2: system boundary SHP+ [1].

- **system boundary SHP**: it includes all components of a SHP system, excluding the heating, cooling and DHW distribution systems;

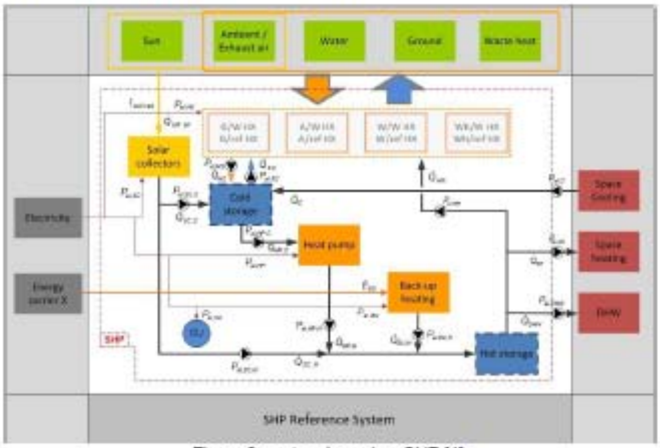


Figure 3: system boundary SHP [1].

- **system boundary HP**: it is used for the performance evaluation of the compression heat pump;

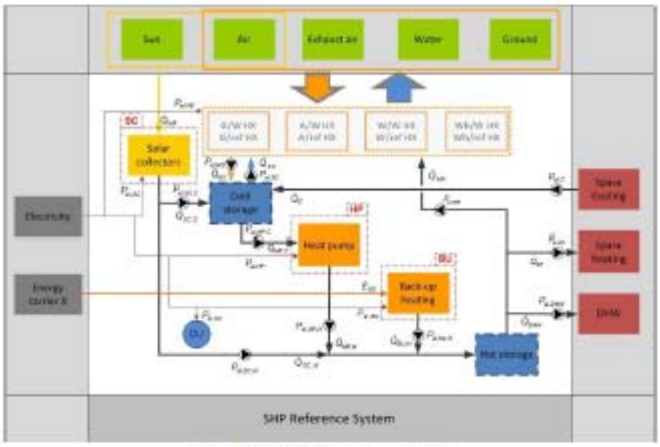


Figure 4: system boundary HP [1].

Solar plus Heat Pump system in Rapperswil-Jona (Switzerland)

System description

A combined air source heat pump and solar thermal heating system has been installed in a single family house in the city of Rapperswil-Jona (Switzerland) in 2009 and monitored from February 2010 to December 2011 [2]. The system provides domestic hot water (1400 kWh/y) for two people and space heating (18700 kWh/y) for 200 m^2 of heated floor area of a house built in 1992. A 15 m^2 covered solar-thermal collector field charges a tank-in-tank solar combi-storage of 1.8 m^3 water volume, which can contribute for space heating and domestic hot water needs. The air-source heat pump has two stages of power (11 kW and 20 kW). It can cover space heating requirements or simultaneously it delivers heat to the combi-storage as secondary heat source to solar energy. The heat pump charges either the upper part or the middle part of the solar combi-storage directly (switching with two three-way valves) and the solar thermal collector field charges the solar combi-storage with internal heat exchangers placed in the top and in the bottom third of the combi-storage, of which the top heat exchanger can be circumvent.

All heat inputs and outputs of the store were monitored as well as the electricity consumption of the heat pump and the solar collector operation including all controllers and pumps with the exception of the space heat distribution pump. For the year 2011, the resulting seasonal performance factor of the system calculated based on all electricity use and the useful heat leaving the store was 4.4.

Technical data

Location	Rapperswil-Jona, Switzerland Coordinates: 47.2° N, 8.8° E Elevation: 409 m
Building	Typology: Single-family house (2 people) Living area: 200 m^2 Space heating demand: 93.5 kWh/(m^2y) Domestic Hot Water demand: 7 kWh/(m^2y)
Heat Pump	Source: ambient air, reversible Heating capacity: 19.7 kW Performance: COP 3.8 (A2/W35 EN 14511)
Solar collectors	Orientation: 20° West Typology: flat-plate solar thermal collectors Thermal efficiency: η_0=0.83, a_1=3.7 W/(m^2K), a_2=0.009 W/(m^2K^2) Absorber area: 15 m^2
Storage	1800 l combi-storage (tank-in-tank type)

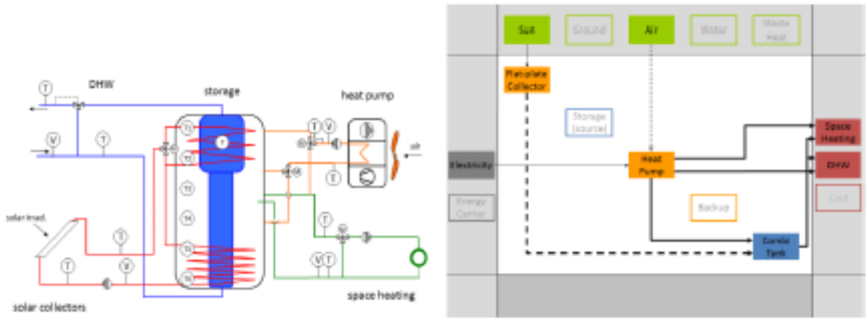


Figure 5: hydraulic scheme (left) and energy flow chart (right) [source: SPF Solartechnik].

Monitoring results

An energy monitoring has been undertaken from February 2010 to December 2011. Measured points included the flow and return temperatures and volume counts of the solar circuit, the heat pump circuit and the space heat circuit as well as cold water and hot water temperatures and tapped volumes. The monitoring used data sampling with 10 sec. intervals, storage was based on thresholds for changes of each single value and the evaluation (including power calculation and uncertainty calculation) was based on a sampling of the recorded data in 1 min. intervals.

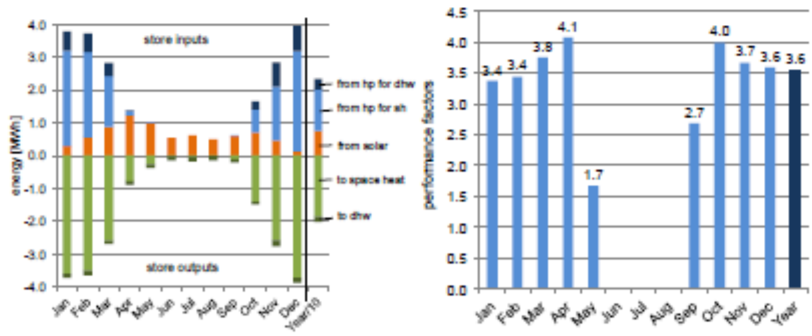


Figure 6: energy balance of the combi-store (left) and performance factor SPF_{HP} (right) [source: SPF Solartechnik].

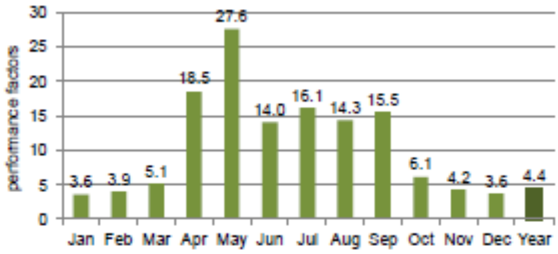


Figure 7: performance factor SPF_{SHP} of the system [source: SPF Solartechnik].

Solar plus Heat Pump system in Trofaiach (Austria)

System description

A combined air source heat pump and solar thermal heating system has been installed into a single family house with a small workshop (electrician) in Trofaiach (Austria) and monitored from October 2010 to February 2012 [3-4]. The system provides domestic hot water (2685.5 kWh/y) for 4 people and space heating (28094.3 kWh/y) for 300 m² heated floor area. The 9.5 kW air source heat pump and the 15 m² flat-plate collectors deliver heat to a combi-storage of 1000 l water volume from where the needs for space heat and domestic hot water are served. The energy from the solar collectors can also support the heat pumps evaporator. All heat inputs and outputs of the storage were monitored as well as the electricity consumption of the heat pump and the rest of the system. For the year 2011, the resulting seasonal performance factor of the system calculated based on all electricity use and the useful heat leaving the storage was 2.59.

Technical data

Location	Trofaiach, Austria Coordinates: 47.4° N, 15.0° E Elevation: 685 m
Building	Typology: Single-family house (4 people) Living area: 300 m² Space heating demand: 93.65 kWh/(m²y) Domestic Hot Water: 8.95 kWh/(m²y)
Heat Pump	Source: ambient air and water (solar energy) Heating capacity: 9.5 kW Performance: COP 3.3 (A2/W35 EN 255)
Solar collectors	Orientation: 35° West Typology: flat-plate solar thermal collectors Thermal efficiency: η_0=0.746, a_1=3.232 W/(m²K), a_2=0.014 W/(m²K²) Aperture area: 15 m²
Storage	1000 l combi-storage with 2 immersed heat exchangers

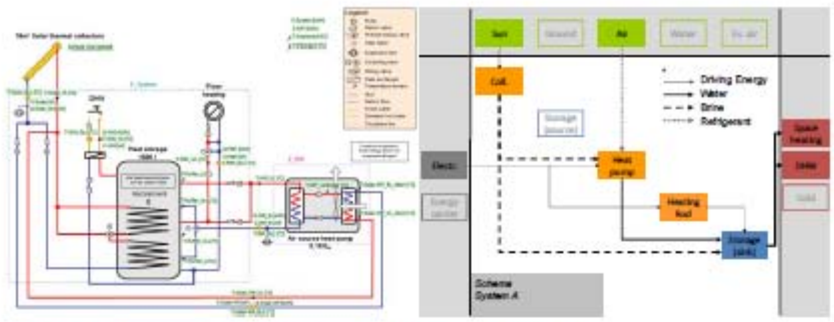


Figure 8: hydraulic scheme (left) and energy flow chart (right) [source: AEE Intec].

Monitoring results

The average ambient temperature during the monitored period was 8.1°C. Space heat demand and domestic hot water demand were 28094 kWh/y and 2685 kWh/y respectively, measured at the outlet of the storage. The solar collectors yielded 487 kWh/(m²y). The total electricity demand of the system including all controllers and pumps was 11868 kWh/y. The system's performance factor was 2.59 based on the useful heat leaving the storage. The performance factor for the heat pump was 2.65 and the storage efficiency reached 82%. The total system losses are about 6700 kWh/y, which equals about 17% of the total produced energy.

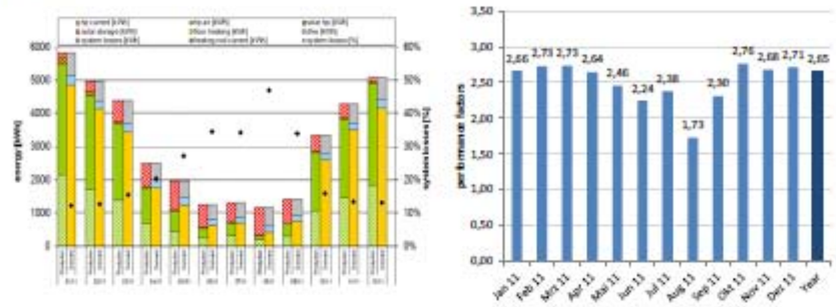


Figure 9: energy balance of the system (left) and performance factor SPF_{HP} (right) [source: AEE Intec].

Figure 10: performance factor SPF_{SHP+} of the system [source: AEE Intec].

Solar plus Heat Pump system in Dreieich (Germany)

System description

A heat pump system with uncovered PVT and ground heat exchanger has been measured over a period of two years starting in March 2009 [5-8]. It consists of a 39 m² PVT-collector field, a 12 kW heat pump and a coaxial borehole heat exchanger with a total length of 225 m. The system provides space heat and domestic hot water for a large single family house.

As the thermal PVT-collector yield's impact on the heat pump performance cannot be measured directly, the measured data has been analyzed using a model of the combined solar and ground heat source in a TRNSYS simulation based on measured data.

Technical data

Location	Dreieich, Germany Coordinates: 50.0° N, 8.7° E Elevation: 140 m
Building	Typology: Single-family house (5 people) Living area: 380 m^2 Space heating demand: 66.4 kWh/(m^2y) Domestic Hot Water: 6.2 kWh/(m^2y)
Heat Pump	Source: brine (PVT collectors + boreholes) Heating capacity: 11.6 kW Performance: COP 4.65 (B0/W35 EN 255)
Solar collectors	Orientation: 24° East Typology: uncovered PVT collectors Thermal efficiency: η_0=0.56, b_1=8.8 W/(m^2K), b_2=0.55 J/(m^3K), b_u=0.08 s/m Electrical efficiency: 14% at STC conditions Aperture area: 39 m^2
Borehole	Typology: coaxial Length: 225 m Depth: 75 m Ground conductivity: 2.75 W/(mK)
Storage	150 l as DHW storage

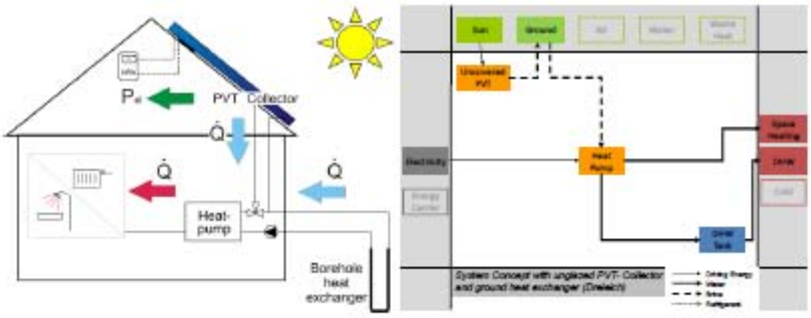


Figure 11: simplified hydraulic scheme (left) and energy flow chart (right) [source: ISFH].

Monitoring results

The planned overall heating demand is 28 MWh/y. However, the measured energy demand is much higher than calculated, presumably caused by high comfort requirements of the user with room temperatures up to 23°C. As a result the heating demand is 25% higher than dimensioned in the first year of operation and 45% higher than in the second year of operation. Nonetheless, the performance and temperature level of the ground heat exchanger is comparatively unchanged, because of the active ground regeneration by the solar thermal PVT- collector. The comparatively good stability of heat source temperatures highlights the robustness of the combined heat source unglazed solar collector and borehole heat exchanger.

Table 1: SPF and temperature levels for the measuring period system [source: ISFH].

Year of operation (April – April)	1st Year 2009-2010	2nd Year 2010-2011
SPF_{SHP+} [1]	3.9	4.0
SPF_{SHP} [1]	4.0	4.2
SPF_{HP} [1]	4.4	4.6
Energy averaged inlet temperature cold heat source side (+ ΔT)	5.9°C (+ 3.5 K)	4.7°C (+ 3.8 K)
Energy averaged outlet temperature hot heat sink side (+ ΔT)	34°C (+ 7.2 K)	35.9°C (+ 8.1 K)

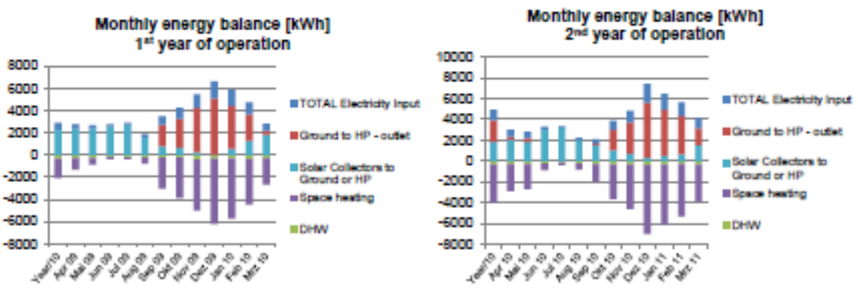


Figure 12: energy balance during the first (left) and second (right) year of operation of the system [source: ISFH].

For the PV yield measurements periods with snow and leaves were not respected. Days with missing or not suitable data were replaced by data from neighboring days, for instance tests of stagnation, blackouts that required MPP-tracker resetting or changing the heat pump in March 2010.

The PVT- collectors have been installed with and without rear side insulation. The measurement was conducted separately for both fields without significant differences for electrical and thermal yields. The Additional PV – yield due to cooling is measured to 4 % independent of rear side insulation.

Literature reference

1. Malenkovic, I., Eicher, S., Bony, J., "IEA SHC Task 44 / HPP Annex 38. Definition of main system boundaries and performance figures for reporting on SHP systems. A technical report of Subtask B. Deliverable B1.1", 2012.
2. Gemperle, S., "Analyse einer solarthermisch unterstützten Luft-Wasser-Wärmepumpenheizung", Bacholararbeit an der Hochschule für Technik Rapperswil HSR, Institut für Solartechnik SPF, 21. Juni 2010, Rapperswil-Jona, Switzerland.
3. Thür A., Vukits M., Becke W., Heinz A., Lerch W. "Ein Jahr Feldmessung von sechs Solar-Kombianlagen mit Wärmepumpen", OTTI - 22. Symposium Thermische Solarenergie, Bad Staffelstein, 2012.
4. Lerch, W., Heinz, A., Thür, A., Vukits, M. "Optimierung von Solar-Wärmepumpen-Kombianlagen anhand von dynamischen Anlagensimulationen", OTTI - 22. Symposium Thermische Solarenergie, Bad Staffelstein, 2012.
5. Bertram, E., Stegmann, M., Scheuren, J., Rosinski, C., Kundmüller, K., "Unglazed Photovoltaic Thermal Collectors in Heat Pump Systems," presented at the EuroSun 2010 International Conference on Solar Heating, Cooling and Buildings, Graz, 2010.
6. Bertram, E., Glembin, J., Rockendorf G., "Unglazed PVT collectors as additional heat source in heat pump systems with borehole heat exchanger," Proceedings of SHC Conference 2012 in San Francisco, published in Energy Procedia, In Press.
7. Bertram, E., Stegmann, M., Rockendorf, G., "Solarthermie 2000plus: Solare Gebäudewärmeversorgung mit unverglasten photovoltaisch-thermischen Kollektoren, Erdsonden und Wärmepumpen für 100% Deckungsanteil", Teilprojekt B: Wissenschaftliche Begleitung. Emmerthal: , 2011. avaiable at http://edok01.tib.uni-hannover.de/edoks/e01fb12/684730588.pdf.
8. Stegmann, M., Bertram, E., Rockendorf G., Janßen, S., "Model of an unglazed photovoltaic thermal collector based on standard test procedures," in Proceedings of ISES Solar World Congress, Kassel, Germany, 2011.

Task 44 / Annex 38 – Participants

Aalto University School of Science and Technology Lämpömiehenkuja 2 02150 Espoo FINLAND www.aalto.fi	AEE INTEC Institute for Sustainable Technologies Feldgasse 19 8200 Gleisdorf AUSTRIA www.aee-intec.at	AIGUASOL ENGINYERIA C/ Roger de Llúria, 29 3r 2a 08009 Barcelona SPAIN www.aiguasol.com
AIT Austrian Institute of Technology Giefinggasse 2 1210 Vienna AUSTRIA www.ait.ac.at	ASIC Austria Solar Innovation Center Durisolstraße 7/Top 50 4600 Wels AUSTRIA www.asic.at	Base Consultants SA 8 rue du Nant CP 6268 1211 Geneve SWITZERLAND www.baseconsultants.com
CEA INES Institut National de l'Energie Solaire 50, Avenue du Lac Leman 73377 Le Bourget du Lac France www.liten.fr www.ines-solaire.org	CENERGIA Herlev Hovedgade 195 2730 Herlev DENMARK www.cenergia.dk	Consolar Solare Energiesysteme GmbH Gewerbestrasse 7 79539 Lörrach GERMANY www.consolar.de
DTI Danish Technology Institute Gregersensvej 3 2630 Taastrup DENMARK www.dti.dk	DTU Technical University of Denmark Anker Engelundsvej 1 2800 Kgs. Lyngby DENMARK www.dtu.dk	Ecole d'ingénieurs et d'architectes de Fribourg Bd de Pérolles 80 P.O. Box 32 1705 Fribourg SWITZERLAND www.eia-fr.ch

EDF R&D Département Enerbat Centre des Renardières Avenue des Renardières Ecuelles 77818 Moret-sur-Loing FRANCE www.edf.fr	EHPA European Heat Pump Association Renewable Energy House Rue d'Arlon 63-67 1040 Brussels BELGIUM www.ehpa.org	Ellehauge & Kildemoes Vestergade 48 H,2s.tv. 8000 Århus C. www.elle-kilde.dk
ENERGIE EST lda Zona Industrial de Laúndos, Lote 48 4570-311 Laúndos / Póvoa de Varzim PORTUGAL www.energie.pt	Energie Solaire SA CP 353 Z.I. Ile Falcon 3960 Sierre / Valais SWITZERLAND www.energie-solaire.com	EURAC research European Accademy of Bolzano Institute for Renewable Energy Viale Druso/Drususallee 1 39100 Bolzano/Bozen ITALY www.eurac.edu
FHNW Fachhochschule Nordwestschweiz Institut Energie am Bau Sankt-Jakobs Strasse 84 4132 Muttenz SWITZERLAND www.fhnw.ch/iebau	Fraunhofer-Institute for Solar Energy Systems ISE Heidenhofstraße 2 79110 Freiburg GERMANY www.ise.fraunhofer.de	HEIG-VD School of Business and Engineering Laboratory of Solar Energetics and Building Physics (LESBAT), Route de Cheseaux 1 1400 Yverdon-les-Bains SWITZERLAND www.heig-vd.ch
Hochschule für angewandte Wissenschaften FH Ingolstadt Esplanade 10 85049 Ingolstadt GERMANY www.haw-ingolstadt.de	ISFH Institut für Solarenergieforschung GmbH Hameln/Emmerthal Am Ohrberg 1 31860 Emmerthal GERMANY www.isfh.de	ITW Stuttgart University Institut für Thermodynamik und Wärmetechnik (ITW) Pfaffenwaldring 6 70550 Stuttgart www.itw.uni-stuttgart.de

KTH Royal Institute of Technology
Kungl Tekniska Högskolan, SE-100 44
STOCKHOLM
SWEDEN
www.kth.se

Lessius Mechelen campus De Nayer
Zandpoortvest 13
2800 Mechelen
BELGIUM
www.lessius.eu

LNEG
Laboratório Nacional de Energia e Geologia
Estrada do Paço do Lumiar, 22
1649-038 Lisboa
PORTUGAL
www.lneg.pt

Lund University
Box 117
221 00 Lund
SWEDEN
www.lunduniversity.lu.se

Natural Resources Canada
Innovation and Energy Technology Sector
580 Booth Street, 13th floor
Ottawa, ON K1A 0E4
www.canmetenergy.gc.ca

NREL
National Renewable Energy Laboratory
1617 Cole Blvd.
Golden, CO 80401-3305
UNITED STATES
www.nrel.gov

Politecnico di Milano
Dipartimento di Energia
Via Lambruschini 4
20156 Milano
ITALY
www.polimi.it

RDmes
Institut Politècnic Campus Terrassa (IPCT), TR21, Sala 16
Crta. Terrassa N-150 Km 14.5
08227 Terrassa
Barcelona
SPAIN
www.rdmes.com

Rheem Manufacturing Company
1100 Abernathy Road, Suite 1400
Atlanta, GA 30328
UNITED STATES
www.rheem.com

Sandia National Laboratories
PO Box 5800
Alburquerque, NM 87185
UNITED STATES
www.sandia.gov

Schüco International KG
Karolinenstraße 1-15
33609 Bielefeld
GERMANY
www.schueco.com

SERC
Solar Energy Research Center
School of Industrial Technology and Management
Högskolan Dalarna
78188 Borlänge
www.du.de

Sonnenkraft GmbH
Clermont-Ferrand-Allee 34
93049 Regensburg
GERMANY
www.sonnenkraft.com

SP
Technical Research Institute of Sweden
Box 857
SE-501 15
Borås
SWEDEN

SPF
Institut für Solartechnik
Hochschule für Technik Rapperswil
HSR
Oberseestrasse 10
CH-8640 Rapperswil
SWITZERLAND
www.solarenergy.ch

TU Graz
Technische Universität Graz
Institut für Wärmetechnik (IWT)
Infeldgasse 25/B
8010 Graz
AUSTRIA
www.tugraz.at

University of Geneve
Bd du Pont-d'Arve 40
1211 GENÈVE
SWITZERLAND
www.unige.ch

Univerisity of Innsbruck
Innrain 52
6020 Innsbruck
AUSTRIA
www.uibk.ac.at

University of Applied Sciences of Stuttgart
Schellingstr.24
70174 Stuttgart
www.hft-stuttgart.de

University of Palermo
Dept. DREAM
Viale delle Scienze 9
90128 Palermo
ITALY
www.dream.unipa.it

Universitat Politècnica da València
Camino de Vera
46022 Valencia
SPAIN
www.upv.es

Vela Solaris
Brahmstraße 21
63768 Hösbach
GERMANY
www.polysun.ch

Wagner & Co Solartechnik GmbH
Zimmermannstr. 12
35091 Cölbe
GERMANY
www.wagner-solar.com

Western Renewables Group
30012 Aventura, Suite A
CA 92688, Rancho Santa Margarita
UNITED STATES
www.westernrenewables.com

3S Swiss Solar Systems AG
Schachenweg 24
3250 Lyss
SWITZERLAND
www.3s-pv.ch

3S PHOTOVOLTAICS
SOLAR BUILDING TECHNOLOGIES