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

Industry Newsletter
Second issue

SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

IEA
OECD

Industry newsletter

Second issue, 6-2012

IEA – SHC Task 44 / 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/.

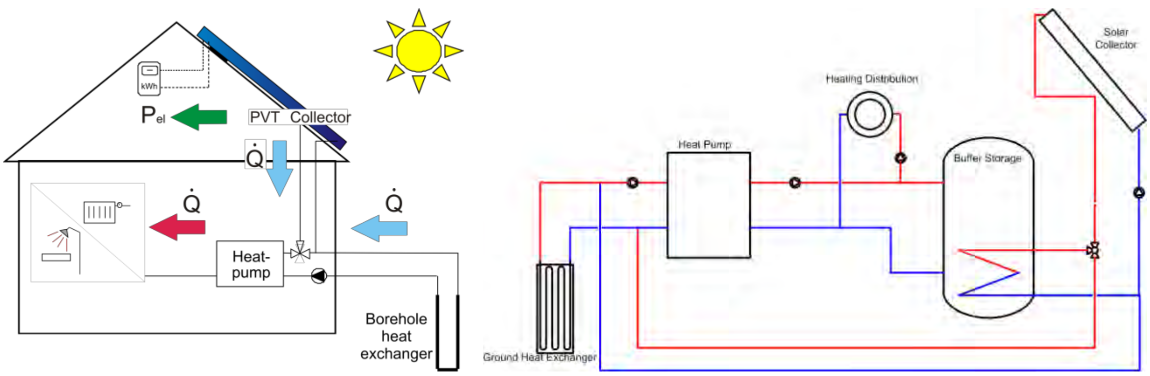
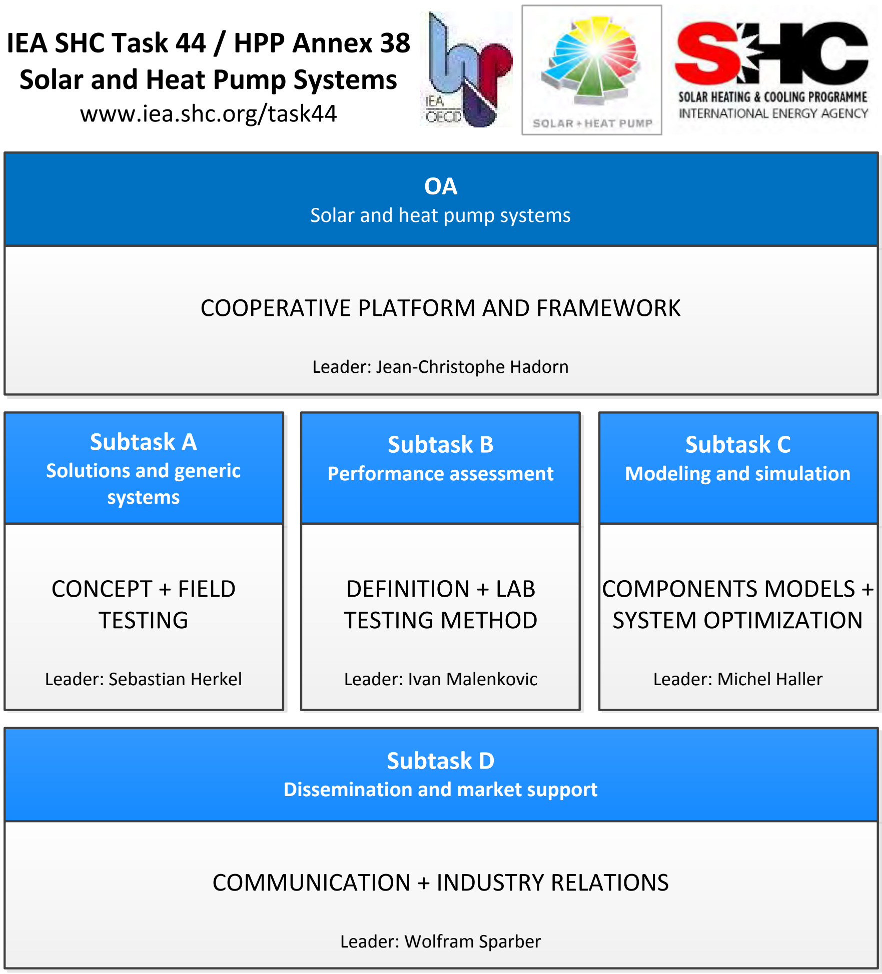


Figure 1: S+HP system: Example of a system including PV-T collectors and ground heat exchanger coupled with a water-to-water heat pump (source: ISFH and Fraunhofer ISE).

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.

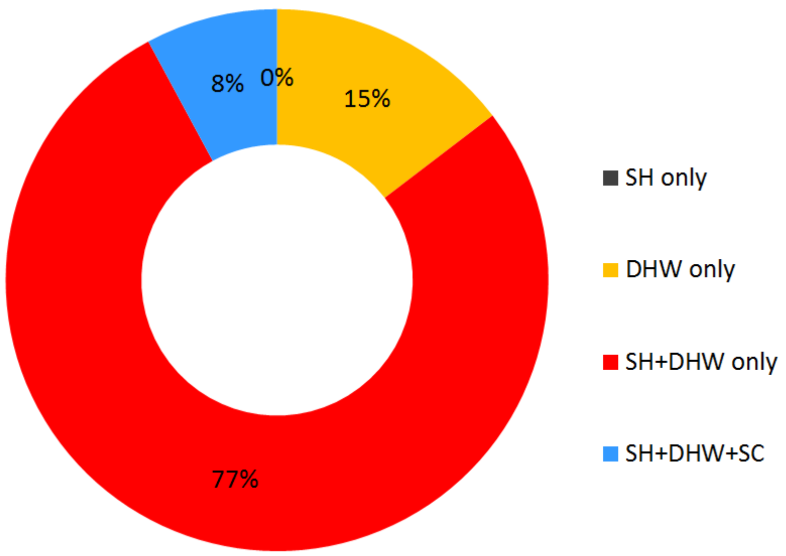


Figure 2: S+HP system classification accordingly to the covered building load.

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.

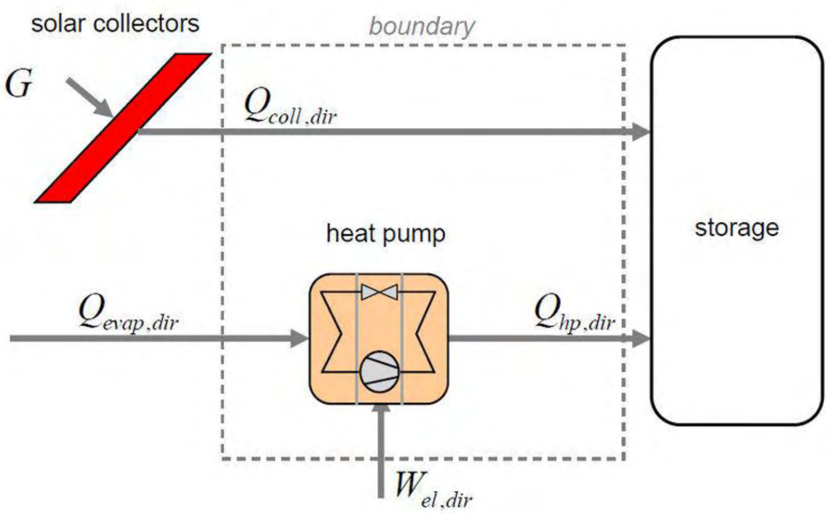


Figure 3: S+HP parallel system (Haller & Frank 2011).

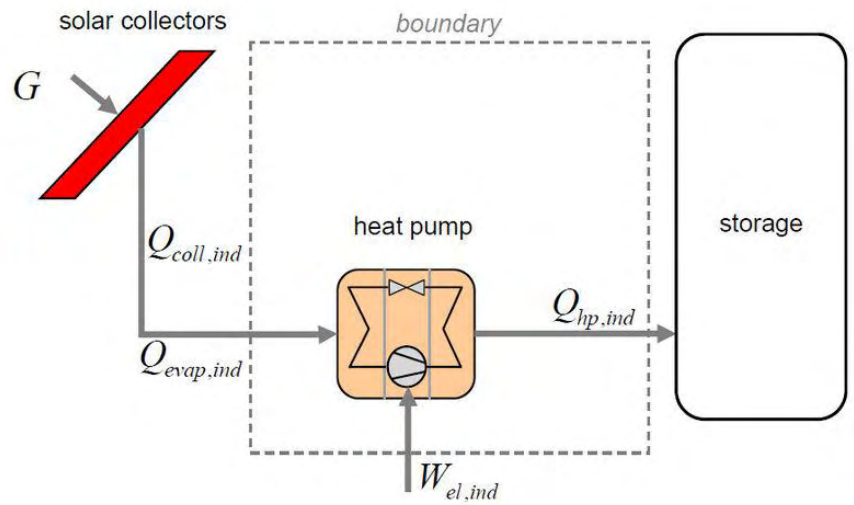


Figure 4: S+HP series system (Haller & Frank 2011).

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.

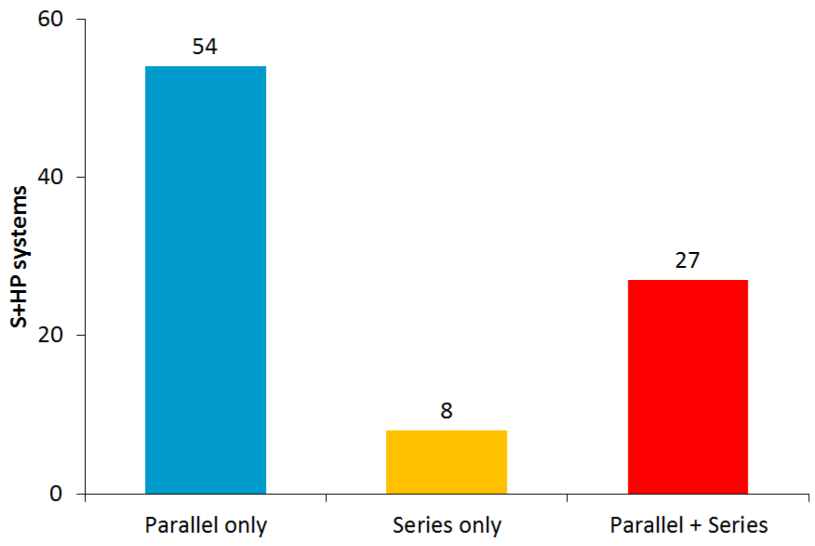


Figure 5: S+HP system classified accordingly to plant layout.

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.

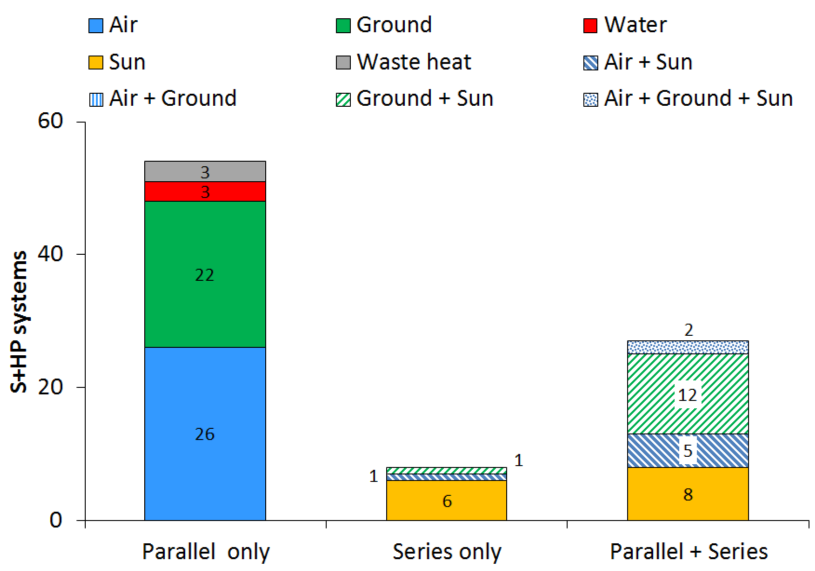
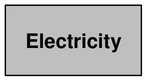


Figure 6: S+HP systems classified accordingly to the plant layout and heat pump source.

Energy flow chart

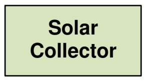
In order to effectively describe S+HP systems, an energy flow chart has been created (Figure 7). This diagram has been developed accordingly to a source-sink approach, in which any component can virtually supply any other (source) with thermal or electric energy, or behaves as a sink of energy from any 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;
  - any other energy carrier fossil or renewable: gas, oil, wood, district heating circuit;

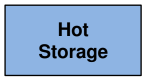


- in dark green **free available renewable energy sources** (RES) are reported:
  - sun;
  - ground;
  - air;
  - water;
  - waste heat;

- in light green the **heat exchangers** between the RES and the systems are shown:
  - solar collectors;
  - ground probes;
  - air/water, air/vapour heat exchangers;



- in dark blue the **storages** are set:
  - 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);

- in dark red the **building loads.**

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.

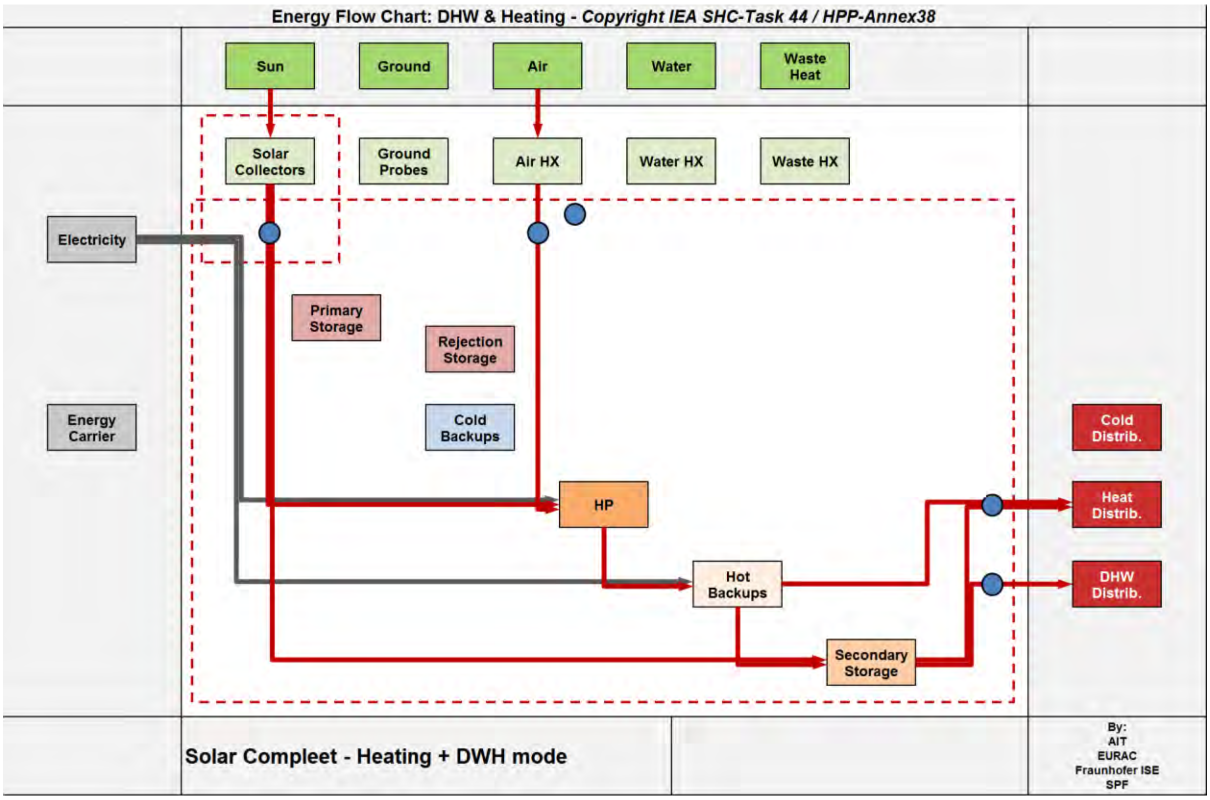


Figure 7: energy flow chart of S+HP system.

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).

Source \ Sink		Electricity	Energy Carrier	Sun	Ground	Air	Water	Waste Heat	Solar Collectors	Ground Probes	Air Heat Exchanger	Water Heat Exchanger	Waste Heat Exchanger	Primary Storage	Rejection Storage	Cold Backups	HP	Hot Backups	Secondary Storage	Heat Distribution	DHW Distribution	Cold Distribution	Solar Pump	Air Pump	Heat Distr.Pump	DHW Distr.Pump	Fans
		El	EC	Su	Gr	Ar	Wt	He	SC	GP	AH	WH	HH	PS	RS	CB	HP	HB	SS	HD	WD	CD	PS	PA	PD	PW	FN
Electricity	El																x	x					x	x	x	x	x
Energy Carrier	EC																										
Sun	Su								x																		
Ground	Gr																										
Air	Ar										x																
Water	Wt																										
Waste Heat	He																										
Solar Collectors	SC																x		x								
Ground Probes	GP																										
Air Heat Exchanger	AH																x										
Water Heat Exchanger	WH																										
Waste Heat Exchanger	HH																										
Primary Storage	PS																										
Rejection Storage	RS																										
Cold Backups	CB																										
HP	HP																	x									
Hot Backups	HB																		x	x							
Secondary Storage	SS																			x	x						
Heat Distribution	HD																										
DHW Distribution	WD																										
Cold Distribution	CD																										

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”.

Source \ Sink		Electricity	Energy Carrier	Sun	Ground	Air	Water	Waste Heat	Heat Distribution	DHW Distribution	Cold Distribution	Solar Pump	Air Pump	Heat Distr.Pump	DHW Distr.Pump	Fans
		El	EC	Su	Gr	Ar	Wt	He	HD	WD	CD	PS	PA	PD	PW	FN
Electricity	El											x	x	x	x	x
Energy Carrier	EC															
Sun	Su															
Ground	Gr															
Air	Ar															
Water	Wt															
Waste Heat	He															
Solar Collectors	SC															
Ground Probes	GP															
Air Heat Exchanger	AH															
Water Heat Exchanger	WH															
Waste Heat Exchanger	HH															
Primary Storage	PS															
Rejection Storage	RS															
Cold Backups	CB															
HP	HP															
Hot Backups	HB								x							
Secondary Storage	SS								x	x						
Heat Distribution	HD															
DHW Distribution	WD															
Cold Distribution	CD															

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).

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
Source		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.

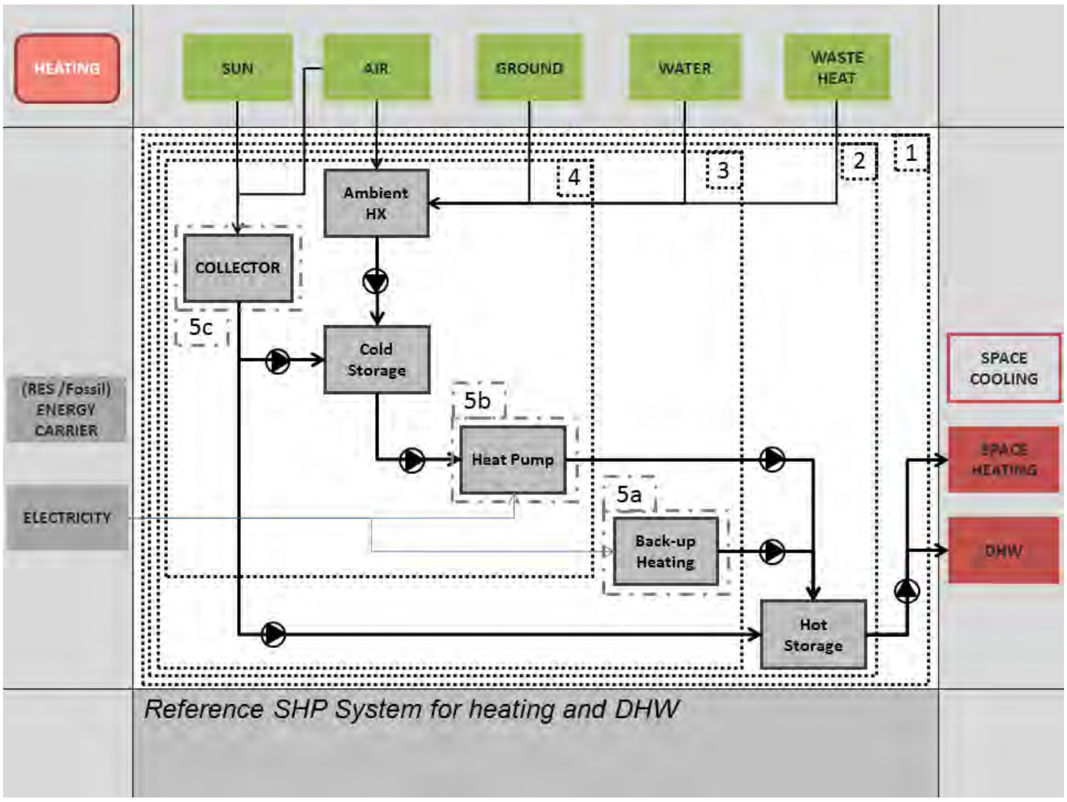


Figure 11: System boundaries for SHP Systems in heating mode

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 Solaire SA
CP 353 Z.I. Ile Falcon
3960 Sierre / Valais
SWITZERLAND
www.energie-solaire.ch

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
0550 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 Laboratorio 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.polomi.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