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

Industry Newsletter
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IEA – SHC Task 44 / Annex 38

Solar and Heat Pump Systems

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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

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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/.

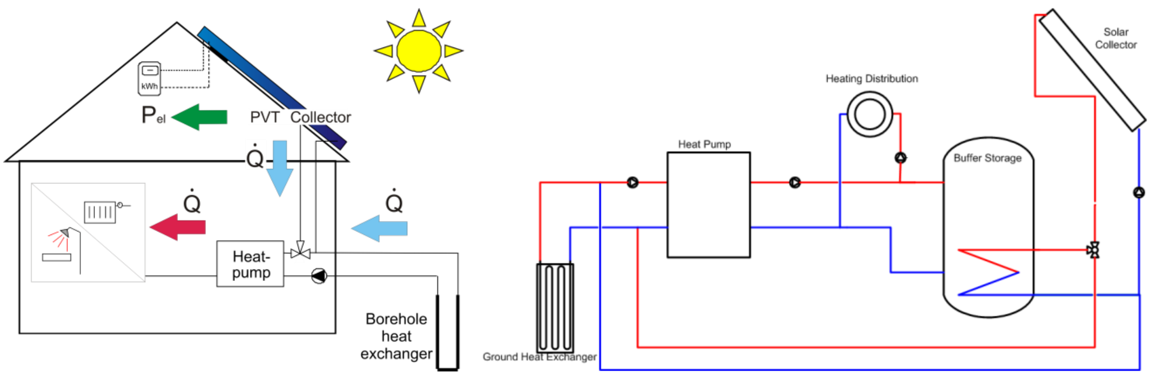
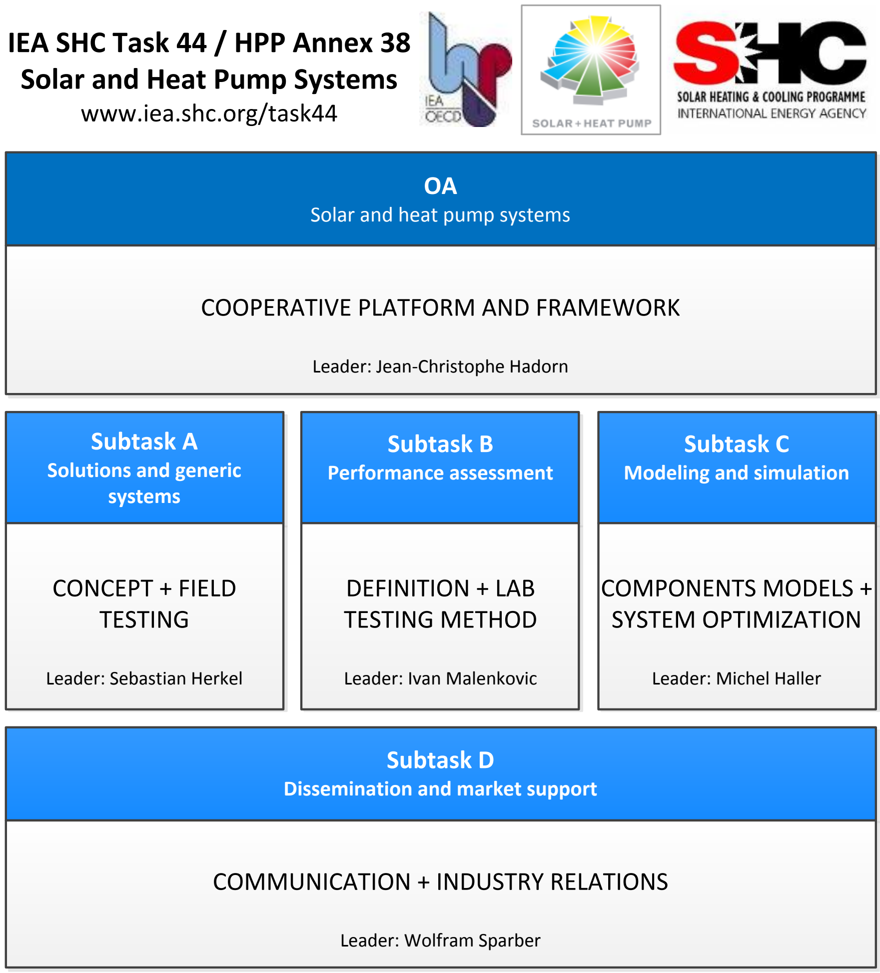


Figure 1 and 2: S+HP system: Example of a system including PV-T collectors and ground heat exchanger coupled with a water-to-water heat pump (source: ISFH and Fraunhofer ISE).

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

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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.

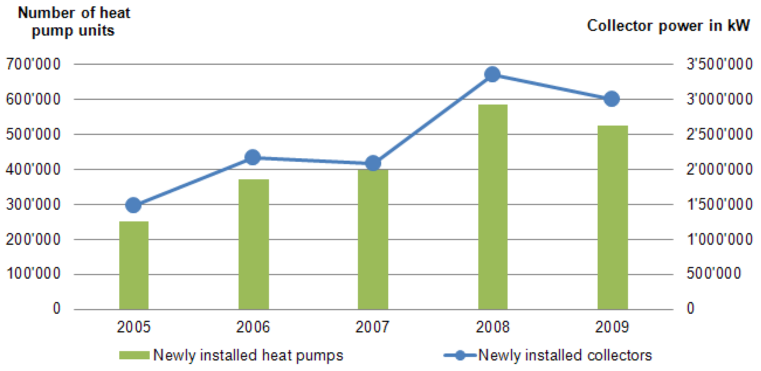

Figure 3: Market development of solar collectors (EU27+CH, data from ESTIF) and heat pumps (AT, CH, DE, FI, FR, IT, NO, SE, UK, data from EHPA) (elaborated by Fraunhofer ISE).

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.

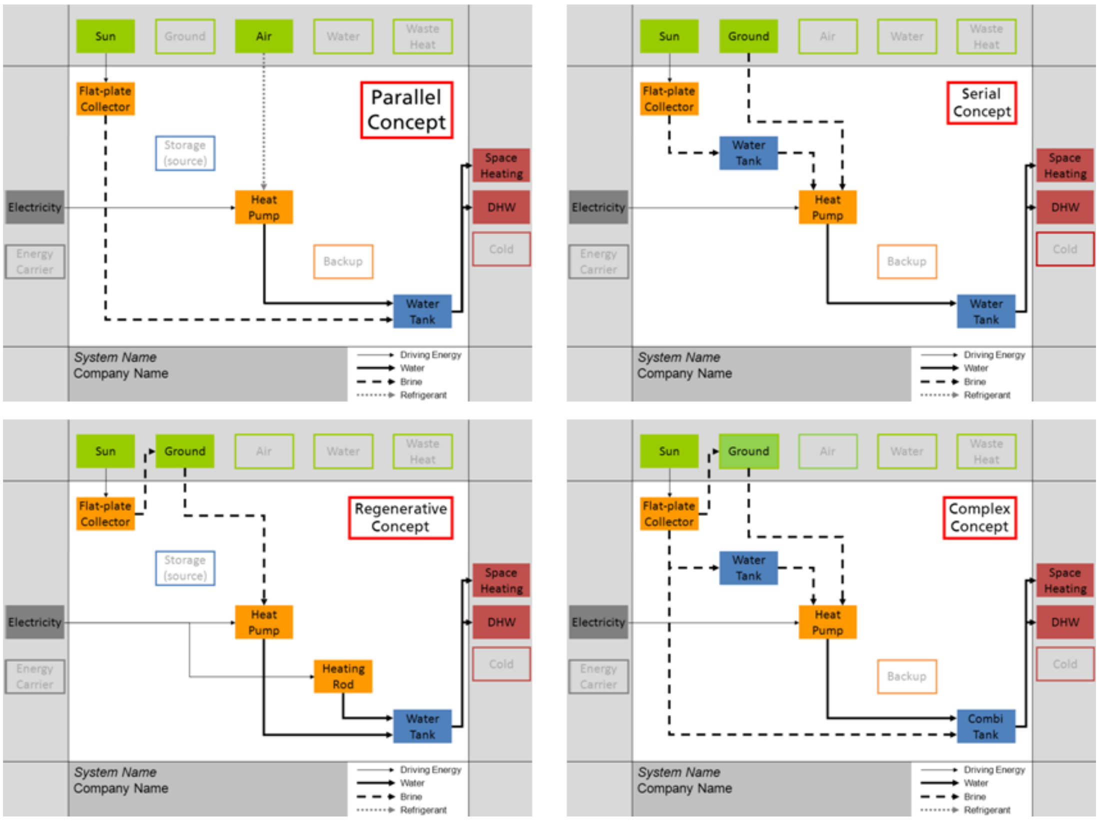

Figure 4: Visualization schemes for typical solar heat pump systems (source: Fraunhofer ISE).

Subtask B:

Performance assessment

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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.

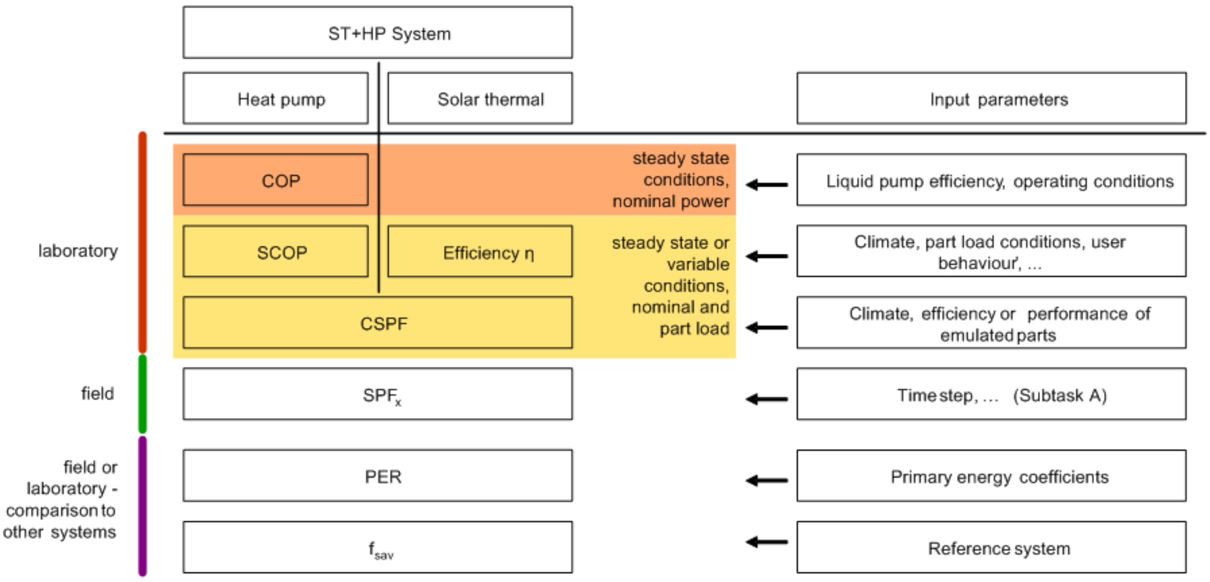

Figure 5: Proposal for a systematic approach to the definition of performance figures for solar heat pump systems (source: AIT).

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.

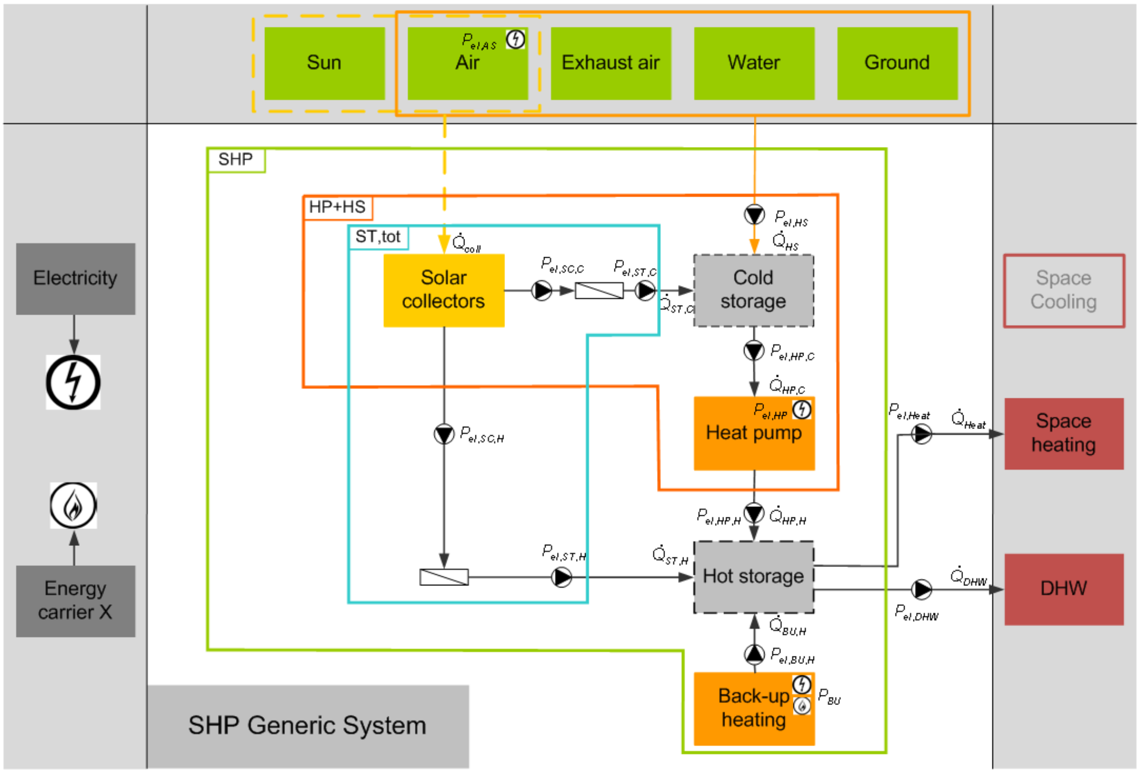

Figure 6: Proposal for a systematic approach to the definition of performance figures for solar heat pump systems (source: AIT)

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

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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).

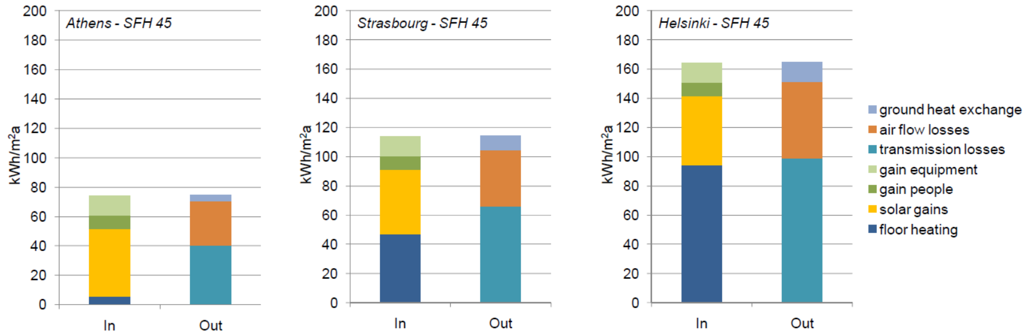

Figure 7: Building energy balances of a Single Family building with an annual heating demand of 45 kWh/(m²year) for Strasbourg climate - SFH 45 - at three different reference location.

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

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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.

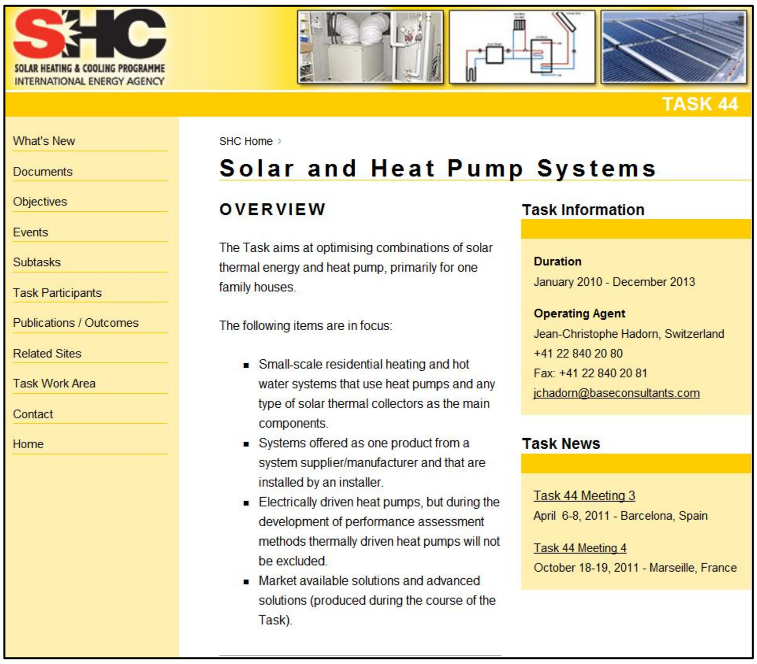

Figure 9: view of the Task 44 / Annex 38 web page (www.iea-shc.org/task44)

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.

[26] Sparber W., Vajen K., Herkel S., Ruschemburg J., Thür A., Fedrizzi R., D'Antoni M., 2011, "Overview on solar thermal plus heat pump systems and review of monitoring results". *ISES Solar World Congress*, Kassel, Germany.

[27] Thole, F. & Hanke, N., 2010, "Solarthermie und Wärmepumpe. Erfarhung aus 3 Heizperioden. Entwicklung einer solaren Systemarbeitzahl". *20. Symposium Thermische Solarthermie*, Kloster Banz, Germany.

[28] Mermoud, F., Hollmuller, P., Lachal B. & Khoury J., 2010, *COP5: Source froide solaire pour pompe à chaleur avec un COP annuel de 5 généralisable dans le neuf et la renovation*. University of Geneve, Geneve, Switzerland.

[29] Witzig, A., Geisshüsler, S., Brönner, P. & Kaminsky, E., 2010, "Planung von Plus-Energie Häusern mit Polysun". *2. OTTI-Symposiums Aktiv-Solarhaus*, Luzern, Switzerland.

[30] Witzig A., Marti J., Brüllmann T. & Huber A., 2008, "Systemoptimierung der Kombination von Solarkollektoren mit Wärmepumpenanlgen". *18. Symposium für Thermische Solarenergie*, Bad Staffelstein, Germany.

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