

**IEA SHC – TASK 26**

# Solar Combisystems

**in Austria, Denmark, Finland,  
France, Germany, Sweden,  
Switzerland, the Netherlands  
and the USA**

**Overview 2000**



Edited by  
Jean-Marc Suter, Thomas Letz,  
Werner Weiss, Jürg Inäbnit

  
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Solar Heating & Cooling Programme  
<http://www.iea-shc.org>



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## **Batec A/S**

Danmarksvej 8  
DK 4681 Herfølge  
Tel.: +45 - 56 27 5050 Fax: +45 - 56 27 6787  
e-mail: [admin@batec.dk](mailto:admin@batec.dk)  
<http://www.batec.dk>

## **Borö-Pannan AB**

Bangardsuagen 1  
S-95231 Kalix  
Tel.: +46 - 923 16680 Fax: +46 - 923 13797  
<http://www.boroe.com>

## **Clipsol**

Zone Industrielle  
F-73100 Trevignin  
Tel.: +33 - 479 34 35 39 Fax: +33 - 479 34 35 30  
e-mail: [clipsol@wanadoo.fr](mailto:clipsol@wanadoo.fr)

## **Consolar Energiespeicher- und Regelungssysteme GmbH**

Dreieichstrasse 48  
D-60594 Frankfurt  
Tel.: +49 - 69 619911 44 Fax: +49 - 69 619911 28  
e-mail: [andreas.siegemund@consolar.de](mailto:andreas.siegemund@consolar.de)  
<http://www.consolar.de>

## **Fortum New Technology Business**

P.O. Box 100  
FIN-00048 Fortum  
Tel.: +358 -10 452 4192 Fax: +358 -10 452 5797  
e-mail: [Janne.Jokinen@fortum.com](mailto:Janne.Jokinen@fortum.com)  
<http://www.fortum.com>

## **Novem**

Swentiboldstraat 21  
NL-6130 AA Sittard  
Tel.: +31 - 46 4202202 Fax: +31 - 46 4528260  
<http://www.novem.nl/>

Publisher: *Büro n+1*, Bern, Switzerland

Authors: *Jean-Marc Suter*, Büro n+1, Bern, Switzerland  
*Werner Weiss*, Arbeitsgemeinschaft ERNEUERBARE ENERGIE - AEE,  
Gleisdorf, Austria; *Thomas Letz*, ASDER, Saint Alban-Leyse,  
France

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Graphics: *Thomas Letz*, ASDER, Saint Alban-Leyse, France;  
*Wolf Steinhuber*, Arbeitsgemeinschaft ERNEUERBARE ENERGIE - AEE,  
Gleisdorf, Austria; *Jean-Marc Suter*, Büro n+1, Bern, Switzerland

## **SOLID**

Herrgottwiesgasse 188  
A-8055 Graz  
Tel.: +43 - 316 292840 0 Fax: +43 - 316 292840 28  
e-mail: [solid@styria.com](mailto:solid@styria.com)

## **SOLTOP Schuppisser AG**

St. Gallerstrasse 7  
CH-8353 Elgg  
Tel.: +41 - 52 364 00 77 Fax: +41 - 52 364 00 78  
e-mail: [email@soltop.ch](mailto:email@soltop.ch)

## **SOLVIS- Solarsysteme GmbH**

Marienberger Straße 1  
D-38122 Braunschweig  
Tel.: +49 - 531 28906 37 Fax: +49 - 531 28906 60  
e-mail: [tkrause@solvis-solar.de](mailto:tkrause@solvis-solar.de)  
<http://www.solvis-solar.de>

## **Sonnenkraft GmbH**

Resselstrasse 9  
A-9065 Ebental  
Tel.: +43 - 463 740 958 Fax: +43 - 463 740 958 17  
e-mail: [peter.prasser@sonnenkraft.com](mailto:peter.prasser@sonnenkraft.com)  
<http://www.sonnenkraft.com>

## **Swiss Federal Office of Energy**

Monbijoustrasse 74  
CH-3003 Bern  
Tel.: +41 - 31 322 56 11 Fax: +41 - 31 323 25 00  
<http://www.admin.ch/bfe>

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## Introduction

The IEA, founded in 1974, is an autonomous body within the framework of the Organisation for Economic Co-operation and Development (OECD). Twenty-four member countries and the European Commission carry out a comprehensive programme of energy co-operation. Policy goals include: the ability to respond promptly and flexibly to energy emergencies; environmentally sustainable energy provision and efficient use of energy; research, development and market deployment of new and improved technologies; and co-operation among energy market participants. These goals are addressed within the framework of 40 Implementing Agreements. One of the first R&D Implementing Agreements of the IEA was the "Solar Heating and Cooling Programme" (SHC). Since 1977, 27 projects or "Tasks" have been undertaken by the SHC Programme.

Task 26 is a major research project of the Solar Heating and Cooling Programme. The Task involves 25 experts from 8 European countries and the USA and 11 solar industries. The goal of this research project is to further develop and optimise solar combisystems for detached single-family houses, groups of single-family houses and multi-family houses with their own heating installations. Solar combisystems are solar heating systems which provide both domestic hot water and space heating.

Furthermore, standardised classification and evaluation processes will be developed for these systems within the framework of this project. These processes serve as a basis for the elaboration of suggestions for the international standardisation of combisystem test procedures.

The first result of the joint work is this coloured brochure which gives an overview of relevant existing and new solar combisystem designs in Austria, Denmark, Finland, France, Germany, Sweden, Switzerland, the Netherlands and the USA. The brochure is targeted at architects, engineers, HVAC companies, potential buyers of solar heating systems, and companies manufacturing prefabricated houses.

The brochure presents only those generic systems which have already proved their reliability in several installations. The different system concepts can partly be attributed to the different conditions prevailing in the individual countries. Thus, for example, the smallest systems, in terms of collector area and storage volume are located in those countries in which primarily gas or electrical energy are used as auxiliary energy. In countries such as Switzerland and Austria, in which solar combisystems are preferably coupled with biomass furnaces, larger systems with high fractional energy savings are encountered.

But no matter what the difference, all of these combisystems have one thing in common: they pave the way towards a wide use of sustainable energy sources over the coming decades.

*Werner Weiss*  
Task 26 Operating Agent



# Solar Combisystems for a Sustainable Energy Future

## Why Solar Space Heating?

The increasing concentration of greenhouse gases in the atmosphere and the potential global warming and climatic change associated with it, represent one of the greatest environmental dangers of our time. The reasons for this impending change in the climate can for the greater part be put down to the use of energy, in particular the combustion of fossil fuels and the associated emission of carbon dioxide (CO<sub>2</sub>).

Today, the world's energy supply is based mainly on the non-renewable sources of energy: oil, coal, natural gas and uranium, which together cover about 82% of the global primary-energy requirements. The remaining 18% are divided approximately two thirds into biomass and one third into waterpower.

The effective protection of the climate, which makes provisions for the future generations will, according to many experts, demand at least a 50% reduction in the world-wide anthropogenic emission of greenhouse gases in the next 50 to 100 years. With due consideration to common population growth predictions and assuming a simultaneity criterion for CO<sub>2</sub> emissions from fossil fuels, one arrives at the demand for an average per-capita reduction in the emissions in industrial countries of approximately 90%. This means one tenth of the current per-capita yield of CO<sub>2</sub> (Fig. 1).

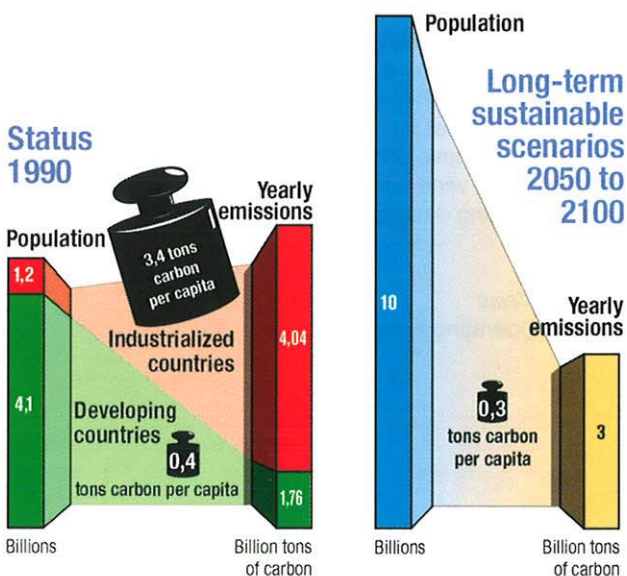


Fig. 1: Per-capita emissions of carbon into the atmosphere required to meet climate stabilisation agreements with a doubling of population levels [1].

A reduction of CO<sub>2</sub> emissions on the scale presented will, however, demand the conversion to a sustained supply of energy which is based on the use of renewable energy with a high share of direct solar energy use.



**Two-family house, Hitzendorf, Austria**

Generic system: Two Stores; Collector area: 92 m<sup>2</sup>; Storage volumes: 0.5 m<sup>3</sup> for domestic hot water, 8.3 m<sup>3</sup> for space heating; Auxiliary heater: wood boiler

The overall solar energy incident on the Earth's surface is more than 10 000 times the world's current primary-energy requirement. There is no doubt that it would be possible to supply technologically advanced countries almost totally with renewable sources of energy in the next 50 to 100 years. This is confirmed by numerous studies based on socio-economic, technological and institutional-structural models on global and national energy supply scenarios [2 – 5].

A reliable, favourably priced and environmentally sensitive supply of energy is an important prerequisite for the continued development of modern societies that aim to uphold and further improve the standard and the quality of life.



**Private house in winter time, Denmark**

Generic system: Two Stores (parallel); Collector area: 26 m<sup>2</sup>; Storage volumes: 0.5 m<sup>3</sup> for domestic hot water, 3 m<sup>3</sup> for space heating



**Single-family house, Eikhorst, Germany**  
 Generic system: Two Stratifiers in Space Heating Storage Tank with External Load-Side Heat Exchanger for DHW 25kW; Collector area: 23 m<sup>2</sup>; Storage volume: 1.5 m<sup>3</sup>; Auxiliary heater: integrated gas burner



Beginning with the Final Report "Our Common Future" of the World Commission on Environment and Development (Brundtland Committee), which was published 1987, and the Conference of the United Nations for the Environment and Development (UNCED) which took place thereafter in 1992 in Rio de Janeiro, the term "sustainable development" became a central idea in the 1990s and the overriding goal of global environmental and development policy [1]. Essential elements for the implementation of the concept of sustainable development in the field of energy are the consideration of energy service delivery instead of energy supply *per se*, the efficient use of energy, and the greater use of renewable energy sources, especially the direct and indirect use of solar energy.

As a result of these climate conferences and the discussion about sustainable development, the European Commission has defined its goals with respect to future development in the field of renewable sources of energy. This is embodied in the White Paper "Energy for the Future: Renewable Sources of Energy" [6]. The Commission has a strategic goal: "... to increase the market share of renewable sources of energy [in the member states; ed.] to 12% by the year 2010." The estimated yearly increase in the installed collector area

named in the White Paper is 20%. Based on this estimate, the solar heating systems in operation in the year 2010 would correspond to an overall installed collector area of 100 million m<sup>2</sup> (Fig. 2).

If the direct use of solar energy for heating purposes via solar collectors, as shown in the sustained energy scenarios, is to make a significant contribution to the energy supply, it is necessary that solar-heating technologies be developed and widely applied over and beyond the field of domestic-hot-water preparation only.



**Row houses, Hoogerheide, The Netherlands**  
 Generic system: Heat Storage in DHW Tank and in Collector Drainback Tank; Collector area: 2.75 m<sup>2</sup>; Storage volumes: 0.080 m<sup>3</sup> for domestic hot water, 0.100 m<sup>3</sup> for solar; Auxiliary heater: integrated gas burner

## The Potential of Solar Space Heating

In recent years the growth rate of the use of solar energy for heating domestic hot water, has shown that solar heating systems are both mature and technically reliable. Every day, worldwide, thousands of systems demonstrate the benefits of this ecologically harmless energy source. Motivated by the success of these hot-water systems, more and more builders are also considering using solar energy for space heating.

The demand for solar heating systems for combined domestic-hot-water preparation and space heating, so-called solar combisystems, is increasing rapidly in several countries (Fig. 3).

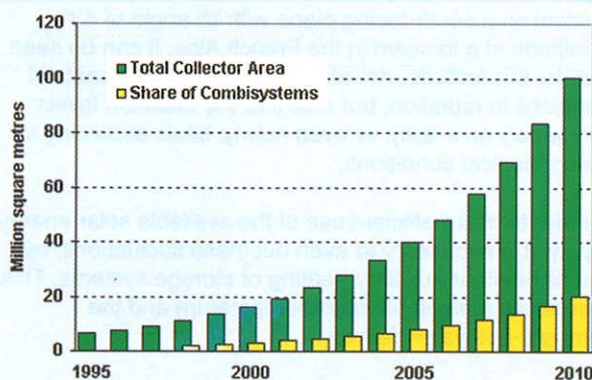


Fig. 2: Total collector area in operation targeted by the European Commission as a strategic goal with respect to future development in the field of renewable sources of energy in the member states. The estimated yearly increase in the total collector area is 20% [6]. Market share of solar combisystems is estimated to be 20%.



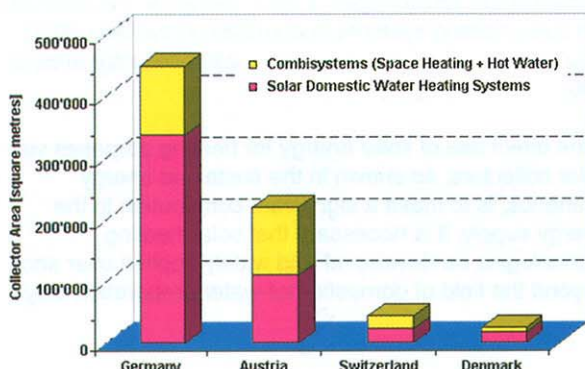


Fig. 3: The 1997 solar collector market in several countries participating in Task 26. Source: 3<sup>rd</sup> Industry Workshop of Task 26, Stuttgart, October 1999.

A realistic approach is to assume that in the next ten years, about 20% of the yearly installed collector area will be used for solar combisystems. This means that in accordance with the „White Paper“ of the European Commission, in the countries of the European Union alone, around 120'000 solar combisystems with 1,9 million square metres of collectors should be installed annually.

The combination of thermally well-insulated buildings, low-temperature heat emission systems and solar heating systems with short-term heat storage, allows the heating requirements of a single- or multi-family dwelling to be met in a user-friendly way at an acceptable cost. In comparison to systems with a seasonal storage, the costs of which are currently not justifiable for single-family houses, this combination is more cost-effective.

## Is Solar Space Heating Possible Everywhere and in Each Building?

Currently installed systems clearly show that solar space heating is possible even for mid- and northern European climatic conditions. However, before a solar-powered



**Private house, Raisio, Finland**

Generic system: Space Heating Store with a Single Load-Side Heat Exchanger for DHW; Collector area: 7.5 m²; Storage volume: 0.3 m³ for domestic hot water and space heating

heating system is installed, due attention must be paid to solar energy availability, space heating energy demand, and heat storage.

## Solar Energy Availability

In northern latitudes the solar energy available in summer is more than twice that available in winter. Virtually the opposite applies to the energy demand for space heating, as this heating load is dependent upon the outside air temperature. However, measurements of solar radiation and temperature in the transitional periods (September - October and March - May) clearly show that solar radiation availability is relatively high at the beginning and end of the space heating season, paving the way for solar space heating.

There is another interaction between solar radiation and space heating demand: solar radiation on the building and through the windows produces heat. This is the so-called passive solar heating. This heat no longer needs to be emitted by the space heating system. The description of these effects lies beyond the scope of this brochure.

### Single-family house, Savoie, France

Generic system: Advanced Direct Solar Floor;  
Collector area: 15 m²; Storage volume: heating floor and 0.5 m³ for domestic hot water



Figure 4a shows daily values of the solar radiation incident on a south-facing plane with tilt angle of 43° (= latitude at a location in the French Alps. It can be seen that, for this latitude, not only are there strong seasonal variations in radiation, but also that the radiation levels vary widely on a daily, or even hourly, basis according to meteorological conditions.

In order to make efficient use of the available solar energy supply, it is necessary to even out these fluctuations, by means of either auxiliary heating or storage systems. This ensures an acceptable room temperature and the domestic-hot-water delivery.

To give an idea of how the available solar radiation varies throughout Western, Central and Northern Europe, Figure 4b shows monthly values, averaged over several years, of the solar radiation available at the three reference meteo-



rological stations selected by Task 26. The receiving surface is south-facing and its tilt angle is equal to the local latitude. It can be seen that differences from one location to the other are larger in winter than in summer. Such differences are strongly dependent on the regional climate, the effect of which may even out that of the latitude: Zürich and Stockholm, two cities with a latitude difference of  $22^\circ$ , have similar solar radiation resources, whereas Zürich and Carpentras, with only a  $3^\circ$  difference in latitude, show considerable differences in solar radiation. But, of course, the contrast between summer and winter radiation availability is larger at northern latitudes.

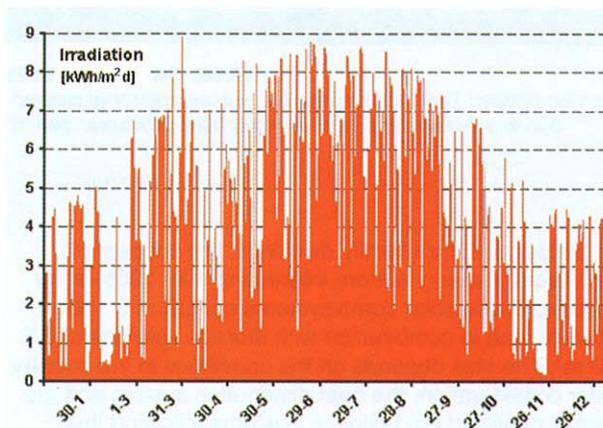


Fig. 4a

a) One year of measured data of the daily solar irradiation on a south-facing plane with a tilt angle of  $43^\circ$ , at a location in the French Alps.

b) Monthly values, averaged over several years, of the solar irradiation on a South facing plane with a tilt angle equal to local latitude, for the three reference meteorological stations selected by Task 26.

## Space Heating Energy Demand of Buildings

For new houses, even before the purchase of land or the beginning of any planning process, particular attention should be paid to solar access, and the type and orientation of the building. Southern facing slopes receive, in winter, 10-30% more solar radiation than northern slopes. Similarly, shading objects should be avoided. In spring and fall they may cause large reductions in solar heat production, especially at northern latitudes.

Another basic requirement for the efficient use of solar heating systems is a high insulation standard of the building. In general, a badly insulated house should first have its insulation improved before a solar heating system is considered.



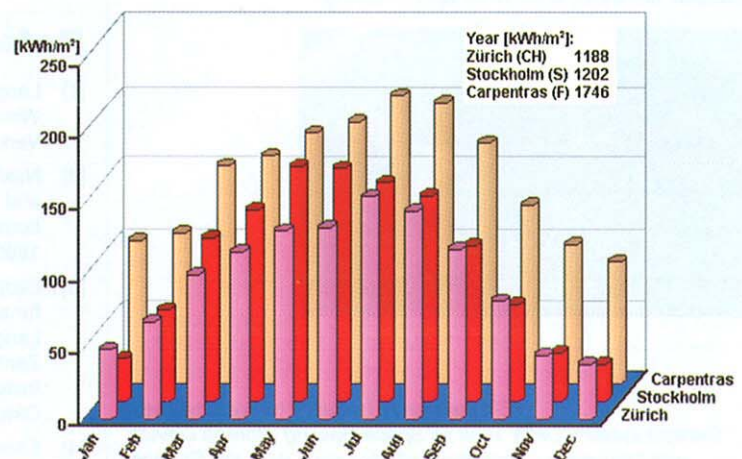
Single-family house, Sala, Sweden

Generic system: Space Heating Store with DHW Load-Side Heat Exchanger(s) and External Auxiliary Boiler (Advanced Version); Collector area:  $18.5 \text{ m}^2$ ; Storage volume:  $2 \times 0.75 \text{ m}^3$  for space heating; Auxiliary heater: wood pellets boiler

New houses, built according to the current building standards, as well as refurbished buildings offer the ideal opportunity for solar space heating. A low-temperature heat emission system with low flow and return temperatures<sup>1</sup> is an additional favourable prerequisite for solar space heating.

<sup>1</sup> A low return temperature at the outlet of the heat emission system is even more important in the case of solar space heating than a low flow temperature.

Fig. 4b



## Heat Storage

The wide fluctuations in incident solar radiation shown in Figure 4a can be evened out by the use of a heat storage system. The following possibilities are available for balancing out the variations in energy supply and demand:



- Hourly, or even overnight, variations can be simply compensated for by the thermal capacitance of the heat emission system (e.g., floor heating) or the storage mass of the building, if temperature variations in indoor climate are allowed.
- If insufficient solar radiation is available for several days, a small or moderate water storage volume can be used to store energy from previous days excess periods in order to make up the difference.
- Seasonal variations in solar energy supply can be compensated for by the use of a seasonal storage. Several systems in recent years have shown that it is possible to store summer heat in large water reservoirs (60 - 130 m<sup>3</sup>) for use in winter. However, solar heating systems with a seasonal storage will first be used in large systems, in conjunction with district heating, because specific storage costs decrease drastically with increasing size. This concept may even lead to solar-only systems, without auxiliary energy source. Interesting examples are available in Sweden, Denmark and Germany [7, 8].



**Hotel, Carinthia, Austria**

Generic system: Two Stores (parallel), with an additional connection to a swimming pool in summer; Collector area: 144 m<sup>2</sup>

For single- and multi-family dwellings, the concept of partial solar heating is more interesting than 100%-solar systems. These solar combisystems consist of 5 - 50 m<sup>2</sup> collector area in combination with storage volumes of 0.5 to 3 m<sup>3</sup>. The size depends on the conditions in the country under consideration, the heat distribution system and the thermal quality of the building. Systems following this partial solar heating concept can readily achieve moderate to high solar contributions, at reasonable costs.

## Chalet in the Alps

Generic system: Advanced Small DHW Tank in Space Heating Tank; Collector area: 8 m<sup>2</sup>; Storage volumes: 0.22 m<sup>3</sup> for domestic hot water, 0.95 m<sup>3</sup> for space heating



## Single-family house, The Netherlands

Generic system: DHW Tank as Space-Heating Storage Device with Drainback Capability; Collector area: 4.32 m<sup>2</sup>; Storage volume: 0.240 m<sup>3</sup> for domestic hot water and space heating; Auxiliary heater: integrated gas burner



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# How Can One Compare the Many Generic Combisystems?

The purpose of this section is to provide non-engineers the basic technical understanding required to make a meaningful intercomparison of the various generic combisystems presented in the following chapter.

## Comparison of Combisystems with Solar Water Heaters

Solar combisystems are similar to solar water heaters in the collection of solar energy and the transport of the produced heat to the storage device. The major difference is that the installed collector area of a combisystem which provides two energy consumers, is larger than in the case of a solar water heater which supplies only one consumer (Table 1).

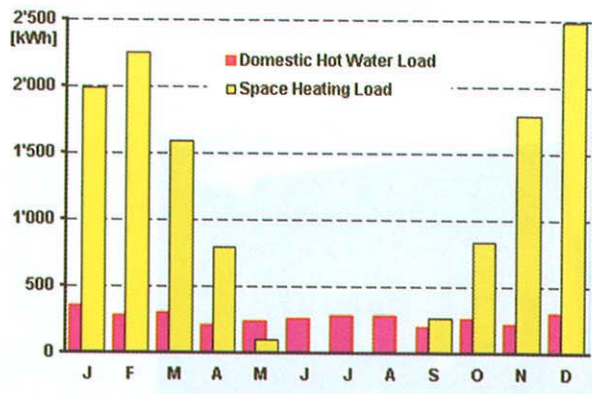


Fig. 5: An example of seasonal variations of the (measured) heat demand for space heating and DHW in a well insulated building in France

Table 1: Features of the two different heat loads: space heating and hot water

### Space Heating System

Large seasonal variation, due mainly to the variation in outside air temperature; no heat demand in summer (Fig. 5)

Daily profile shows a continuous, moderate heat demand, with some periods of reduced or zero demand, e.g., at night, or when the control unit gives priority to charging the hot-water store, or in most periods with solar through windows (passive solar gains). See Fig. 6a

Relatively low delivery temperature (typically 30 to 50 °C, depending on heat emission system design and weather conditions); but relatively high return temperature (25 to 45 °C, varying together with the delivery temperature); small temperature difference between hot and cold parts of space heating loop

Oxygen-free non-corrosive water in closed loop

### Domestic-Hot-Water (DHW) Load

All-year-round heat demand, with small seasonal variation (Fig. 5)

Daily profile shows a lot of short, high-power peaks, with extended periods without DHW consumption (Fig. 6b). In multi-family houses: smoother daily profiles

Low temperature of water entering the system (4 to 20 °C, location and season dependent); high delivery temperature (45 to 60 °C); large temperature difference between hot and cold water

Oxygen-rich corrosive water, run to waste after use

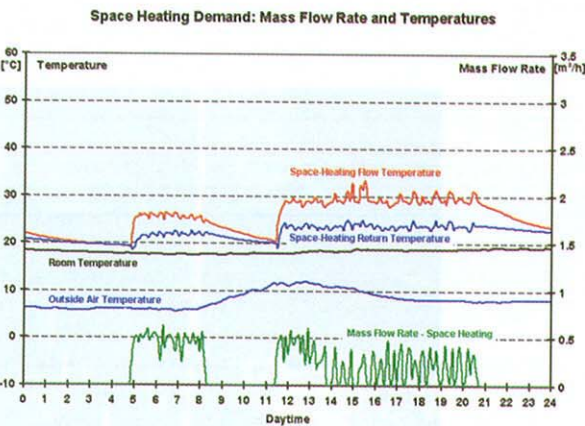
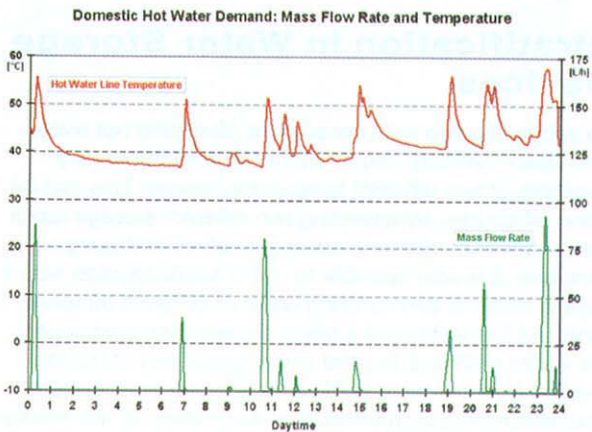


Fig. 6a

Typical daily profiles of heat demand for (a) space heating and (b) DHW in a single-family dwelling near Graz, Austria. The heat supply to space heating was interrupted twice on the day of the measurements (Nov. 3): at night, and in the morning hours. This second break is due to passive solar heating of the house through its large south-east windows. Clouds ended this process

at about 11:20. With regard to DHW shown in Part (b), draw-off peaks appear mainly before noon for cooking and in the evening and night. Small DHW draw-offs for, e.g., hand washing may not have been recorded. Note: After water flow in a line is stopped, the water temperature decreases slowly towards the temperature of its surrounding.

Fig. 6b







**Two-family house, Egg, Austria**

Generic system: Large Tank-in-Tank for Seasonal Storage; Collector area: 50 m<sup>2</sup>; Storage volumes: 0.35 m<sup>3</sup> for domestic hot water, 21 m<sup>3</sup> for space heating

How much heat is needed in a year for space heating in comparison to domestic hot water, depends on the building size, thermal insulation, ventilation, passive solar use, internal heat loads as well as on the number of its inhabitants. Usual figures indicate a DHW heat demand amounting to 10 to 40% of the total heat demand for space heating and DHW.

In a combisystem there are at least two energy sources used to supply heat to the two heat consumers: the solar collectors deliver heat as long as solar is available, and the auxiliary energy source (oil, gas, wood, electricity, etc.) supplements the missing solar. As a general rule, collectors should be operated at the lowest possible temperature in order to have a good efficiency; at high temperature they have significant heat losses. Other individual requirements arise from the auxiliary heat source selected.

**The key challenge for the engineer creating a combisystem is how to combine the different requirements of heat suppliers and heat consumers into one single, cost-effective, durable and reliable heating system, achieving the most benefit from each installed square metre of collectors.**

### Stratification in Water Storage Devices

To supply the two heat consumers (domestic hot water and space heating), water should be simultaneously available at two different temperature levels. This can be done, of course, by operating two different storage tanks with a clever control unit acting on valves and pumps. However, it is also possible to use a single storage tank if care is taken to avoid mixing water of different temperatures. As hot water has a lower density than cold water, hot water is always located in the upper part of the storage tank; conversely, cold water is found at its bottom. This feature is called **vertical stratification** of the storage tank.

**Private house, Rättvik, Sweden**

Generic system: Space Heating Store with DHW Load-Side Heat Exchanger(s) and External Auxiliary Boiler; Collector area: 10 m<sup>2</sup>; Storage volume: 3 x 0.5 m<sup>3</sup> for domestic hot water; Auxiliary heater: wood burner



Stratification can be built up by adding heat (*charging*) at the top of the store or by removing heat (*discharging*) from the lower part of the store. Charging or discharging can be achieved either **directly** via inlets/outlets where the water is injected/removed to/from the store, or **indirectly** via a heat exchanger placed inside the store and surrounded by store water. Heat exchangers placed inside the store tend to create zones of uniform temperature above (in the case of charging) or below (in the case of discharging). For example, in the first case, heated water from an immersed heat exchanger rises and simultaneously mixes the water above the heat exchanger. Heat exchangers can therefore only create a limited amount of stratification and in some cases can destroy existing stratification (**mixing**). Direct charging and discharging can create good stratification, but only if the inlets are designed correctly and if the inlets and outlets are at heights that are well adjusted to the total system design.



**Single-family house with solar-assisted electrical heating, Suomusjärvi, Finland**

Generic system: Space Heating Store with DHW Load-Side Heat Exchanger(s) and External Auxiliary Boiler; Collector area: 15 m<sup>2</sup>; Storage volume: 2.5 m<sup>3</sup> for space heating



### Classification of Generic Combisystems

It should be now clear that the main differences between the various generic combisystems are related to the **heat storage and heat management philosophy** chosen by the design engineer: the decision whether or not to store the heat produced by the auxiliary heater; the number of storage tanks; the design of the loop(s) the fluid of which will serve as heat storage medium; the type of the heat exchangers used for transferring the heat from one medium to another; the geometry of the fluid inlets into the storage tanks and the flow rates used, both having an impact on the mixing in the stores; the geometry of mechanical inserts called **stratifiers**, aimed at enhancing stratification; the control algorithms used; and the dimensions of all components.



**Hotel at 2000 m altitude, Silvretta, Austria**

Generic system: Small DHW Tank in Space Heating Tank;  
Collector area: 60 m<sup>2</sup>; Storage volumes: 3 x 0.31 m<sup>3</sup> for domestic hot water, 14 m<sup>3</sup> for space heating; Auxiliary energy source: electricity



**Single-family house, Indre-et-Loire, France**

Generic system: Advanced Direct Solar Floor;  
Collector area: 17 m<sup>2</sup>; Storage volume: heating floor and 0.5 m<sup>3</sup> for domestic hot water

Accordingly, the IEA Task 26 has identified **two main features** characterising combisystems:

- The method used for **storing the heat produced for space heating by the solar collectors**; this heat storage may, or may not, be combined with DHW storage, and also with storage of the heat produced for space heating purposes by the auxiliary heater. Four *heat management categories related to stratification*, denoted respectively A, B, C, and D (see Table 2), describe this first feature. B and D may be combined.



**Flat roof top installation, Switzerland**

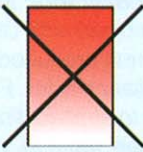
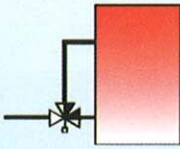

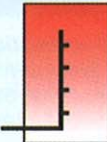
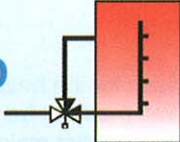
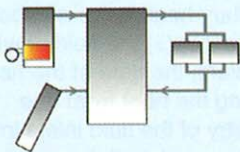
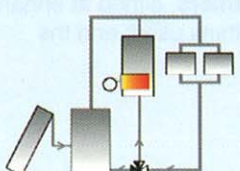
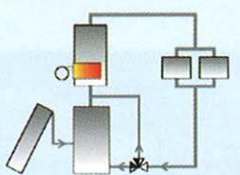
Generic system: Advanced Small DHW Tank in Space Heating Tank; Collector area: 28 m<sup>2</sup>; Storage volumes: 0.5 m<sup>3</sup> for domestic hot water, 2.8 m<sup>3</sup> for space heating

- The management philosophy chosen for the **heat produced by the auxiliary heater**: Will this heat be stored? For how long? How does the controller make sure that the auxiliary supplies just the heat that the solar collectors cannot deliver? Three *auxiliary heat management categories*, denoted respectively M, P, and S (see Table 2), describe this second feature.

The categories a particular combisystem belongs to may be determined by analysing its hydraulic scheme, without doing any measurement on the system.



Table 2: Classification of solar combisystems

Feature 1: Heat Storage Categories	Feature 2: Auxiliary Heat Management Categories
<p><b>A</b>  No controlled storage device for space heating</p> <p><b>B</b>  Heat management and stratification enhancement by means of multiple tanks ("distributed storage") and/or multiple inlet/outlet pipes and/or 3- or 4-way valves to control the flows through inlet/outlet pipes</p> <p><b>C</b>  Heat management using natural convection in storage tanks and/or between them to maintain stratification to a certain extent – but without built-in stratification device</p> <p><b>D</b>  Heat management using natural convection in storage tanks and built-in stratification devices ("stratifiers") for further stratification enhancement</p> <p><b>B/D</b>  Combination of B and D: Heat management by means of natural convection in storage tanks and built-in stratification devices as well as multiple tanks and/or multiple inlet/outlet pipes and/or 3- or 4-way valves to control the flows through inlet/outlet pipes</p>	<p><b>M</b>  Mixed mode: The space-heating loop is fed from a combined store charged by both solar collectors and the auxiliary heater</p> <p><b>P</b>  Parallel mode: The space-heating loop is fed <i>alternatively</i> by the auxiliary heater and by the solar collectors (or a storage unit for solar heat); or there is no hydraulic connection between the solar-heat distribution and the auxiliary-heat emission</p> <p><b>S</b>  Serial mode: The space-heating loop may be fed by the auxiliary heater, or by both the solar collectors (or a storage unit for solar heat) and the auxiliary heater <i>connected in series</i> on the return line of the space-heating loop<sup>1</sup></p> <p><sup>1</sup> In periods in which the solar collectors are able to cover alone the whole space heating demand, the space heating water, after being heated up by solar, flows through the turned-off auxiliary boiler. However, in some systems it is possible to by-pass the auxiliary heating device by means of manually operated valves.</p>

In this document the classification code of a solar combisystem will include one letter for Feature 1 and a second letter for Feature 2.

In addition, there are **three optional features** that will be indicated by lower-case symbols after the main code, if relevant for the generic system under consideration:

- "d" indicates that the solar combisystem is a *drainback system*, i.e., a solar thermal system in which, as part of the normal working cycle, the heat transfer fluid is drained from the solar collectors into a storage device when the pump is turned off, and refills the collector when the pump is turned on again.
- "i" indicates that there is a *gas or oil burner integrated* into and sold with the storage device. The "i" indicator always implies the mixed mode as the auxiliary heat management category ("M" as second main code letter).

- "l" indicates that the combisystem may be used with an auxiliary energy source like wood in the form of *logs*, which require a *long* running time of the auxiliary boiler at more or less fixed power. A long-running-time auxiliary requires the capability of storing the heat produced until it is needed by the heat consumers. For some of the systems presented, hydraulic scheme and dimensioning have to be adapted accordingly<sup>2</sup>.

<sup>2</sup> There are other kinds of biomass fuels, e.g. wood chips or pellets, that do not require similar storage capacitance, because the corresponding boilers have nearly the same characteristics as gas or oil-fired boilers: their thermal power may be modulated in a simple way, e.g. through intermittent operation.



## The Generic Combisystems Considered by Task 26

#	Generic System Designation	Category code <sup>1</sup>	Country
1	Basic Direct Solar Floor	AP	France
2	Heat Exchanger between Collector Loop and Space-Heating Loop	AS	Denmark
3	Advanced Direct Solar Floor	AP	France
4	DHW Tank as a Space-Heating Storage Device	CS	Denmark
5	DHW Tank as Space-Heating Storage Device with Drainback Capability	CMid	The Netherlands
6	Heat Storage in DHW Tank and in Collector Drainback Tank	CMid	The Netherlands
7	Space Heating Store with a Single Load-Side Heat Exchanger for DHW	CMi	Finland
8	Space Heating Store with Double Load-Side Heat Exchanger for DHW	CMi	Switzerland
9	Small DHW Tank in Space Heating Tank	CMl	Switzerland, Austria
10	Advanced Small DHW Tank in Space Heating Tank	BS	Switzerland
11	Space Heating Store with DHW Load-Side Heat Exchanger(s) and External Auxiliary Boiler	CMl	Finland, Sweden
12	Space Heating Store with DHW Load-Side Heat Exchanger(s) and External Auxiliary Boiler (Advanced Version)	BMl	Sweden
13	Two Stores (series)	BMl	Austria
14	Two Stores (parallel) (2 different versions)	BP or BMl	Austria
15	Two Stratifiers in a Space Heating Storage Tank with an External Load-Side Heat Exchanger for DHW	DMil	Germany
16	Conical Stratifier in Space Heating Store with Load-Side Heat Exchanger for DHW	DSd	Germany
17	Tank Open to the Atmosphere with Three Heat Exchangers	DS	Germany
18	Finned-Tube Load-Side DHW Heat Exchanger in Stratifier	B/DSl	Germany
19	Centralised Heat Production, Distributed Heat Load, Stratified Storage	B/DMl	Austria
20	Large Tank-in-Tank for Seasonal Heat Storage	BM(l)	Switzerland
21	Large Stratified Tank for Seasonal Heat Storage, Air Heating System	BM/S(l)	Germany

<sup>1</sup> Indications in parentheses refer to options.

The order of the combisystems' presentation has been chosen so that the reader may easily follow step by step the similarities and the differences of the systems. For

each combisystem a single data sheet may be found in the following pages presented in the same order as in the above table.



## A "Guided Tour" of the Generic Combisystems

The first six generic combisystems have **no store with water from the space-heating loop**. The storage fluid is either domestic hot water, or water of the collector loop in the case of a drainback system. The heat storage can also be in the concrete of a floor heating system.

The simplest solar combisystem (**#1**) is the French "**Basic Direct Solar Floor**". The collector array is directly connected to the heating floor; the floor acts as both the store and the heat exchanger. A connection in the hydraulic loop provides for solar DHW heating, especially outside the heating season. The auxiliary heater for space heating is often a wood stove. The inhabitants are responsible for comfort control, as no connection is provided between the solar heating system and the stove. The room temperature may have large fluctuations, depending on the user's skill.



**38 identical houses, Toarps Ekeby, Malmö, Sweden**

Generic system: Space Heating Store with DHW Load-Side Heat Exchanger(s) and External Auxiliary Boiler; Collector area: 7.5 m<sup>2</sup>; Storage volume: 0.5 m<sup>3</sup> for space heating

**Private house, Ludesch, Vorarlberg, Austria**

Generic system: Large Tank-in-Tank for Seasonal Storage; Collector area: 42 m<sup>2</sup>; Storage volumes: 0.3 m<sup>3</sup> for domestic hot water, 7 m<sup>3</sup> for space heating



**Garden installation, Switzerland**

Small DHW Tank in Space Heating Tank; Collector area: 18 m<sup>2</sup>; Storage volumes: 0.5 m<sup>3</sup> for domestic hot water, 2 m<sup>3</sup> for space heating



### In the Danish system "**Heat Exchanger between Collector Loop and Space-Heating Loop**" (**#2**) the heat distribution

system for space heating – in this case either radiators or a heating floor – is also connected, via a heat exchanger, to the solar collector loop without any intermediate store. Here there is only one stratified DHW store instead of the two as in the French system #1. The objective of the heat exchanger, which is series-connected to the auxiliary boiler on the space heating return line, is to allow for normal water instead of an antifreeze solution to be used in the space-heating loop.

### Unlike the "Basic Direct Solar Floor" the second French system "**Advanced Direct Solar Floor**" (**#3**)

integrates the auxiliary heating into the solar heating system. Accordingly, it is operated automatically, in the parallel mode. There are two heat exchangers in the DHW storage tanks. However, only some of the solar heat may be retained in

the small DHW stores when there is no immediate space heating demand; the largest fraction still goes directly to the heating floor as in the basic case.

In the next system "**DHW Tank as a Space-Heating Storage Device**" (**#4**) from Denmark, the DHW tank is also used as a space-heating storage device. This DHW tank is the only storage tank in the system and is provided with three immersed heat exchangers, each with a dedicated function. If solar heat is available in the store for space heating, it is used to preheat the returning water from the heat distribution loop ahead of the auxiliary boiler (serial mode).



The Dutch system “**DHW Tank as Space-Heating Storage Device with Drainback Capability**” (#5) has a similar structure to System #4. The major differences are the drainback feature and the gas boiler integration into the storage tank. The collectors are drained as soon as the circulating pump stops. The drained water is retained in the mantle heat exchanger until the control unit turns on the pump again.

The second Dutch system “**Heat Storage in DHW Tank and in Collector Drainback Tank**” (#6) has many similarities to System #5. However, System #6 has two stores whereas System #5 has only one store with a mantle heat exchanger. A special feature is the use of the collector drainback tank as a heat store. Accordingly, there is a heat transfer capability between this store and the DHW store, in the form of an immersed heat exchanger and a loop operated by gravity (thermosiphon; no pump in this loop). The heat is delivered to the space-heating loop via a second immersed heat exchanger. Gas is the only possible auxiliary energy source for System #6, which has an integrated burner.



**Single-family house, Savoie, France**

Generic system: Basic Direct Solar Floor; Collector area: 14 m<sup>2</sup>; Storage volume: heating floor and 0.3 m<sup>3</sup> for domestic hot water; Auxiliary energy: wood for space heating, electricity for DHW

*This completes the short description of the combisystems using either DHW or the concrete of the floor for the storage of heat for space heating purpose. Systems #7 to #21 all store heat for space heating in a medium other than in the domestic hot water, mostly the **water of the space-heating loop itself**. This often includes the main body of water in the heat store.*

The Finnish system “**Space Heating Store with a Single Load-Side Heat Exchanger for DHW**” (#7) has many similarities with Systems #4 and #5. However, the storage medium is now space heating water and the DHW is heated up via a **load side heat exchanger**. Such heat exchangers have to be large, as the heat power transferred through them when DHW is drawn off is very high. In addition, the temperature drop

across the heat exchanger must be kept small, otherwise, the DHW consumer will be supplied with water colder than the desired (set-point) temperature. This system has either an oil or gas burner integrated into the store.



**Private house, Katzelsdorf, Austria**

Generic system: Two Stores (series); Collector area: 40 m<sup>2</sup>; Storage volumes: 0.3 m<sup>3</sup> for domestic hot water, 4 m<sup>3</sup> for space heating

The Swiss system “**Space Heating Store with Double Load-Side Heat Exchanger for DHW**” (#8) has a double load-side heat exchanger to enhance stratification and either an integrated oil or gas burner. The other features are similar to those of System #7. System #8 is also similar to the Scandinavian System #11, except that in System #11 the burner is always located outside the store.

**Private house, Sweden**

Generic system: Space Heating Store with DHW Load-Side Heat Exchanger(s) and External Auxiliary Boiler (Advanced Version); Collector area: 20 m<sup>2</sup>; Storage volume: 2 m<sup>3</sup> for space heating





### **Private house, Smedjans ekeby, Jönköping, Sweden**

Generic system: Space Heating Store with DHW Load-Side Heat Exchanger(s) and External Auxiliary Boiler; Collector area: 7.5 m<sup>2</sup>; Storage volume: 0.75 m<sup>3</sup> for domestic hot water; Auxiliary energy sources: electricity and wood



The next system, “**Small DHW Tank in Space Heating Tank**” (#9), originates from Switzerland and is found today also in Austria. This system replaces the double load-side heat exchanger of System #8 by a small but tall stainless steel tank placed inside the space heating tank. The DHW contained in the small tank is heated by the surrounding space-heating water; it is ready for DHW draw-off at high rates at the same temperature as in the store, although the draw-off volume is limited by the small tank capacity. The size of the small tank is optimised according to the user's minimum DHW temperature requirements as well as their draw-off volume and profile. After a large draw-off the small tank needs 30 to 60 minutes to recover to the set-point temperature. The auxiliary boiler delivers its produced heat directly into the store. Long-running-time auxiliary boilers may be installed with System #9.

The 3<sup>rd</sup> Swiss system “**Advanced Small DHW Tank in Space Heating Tank**” (#10) has two features to enhance the stratification in the store. It combines: (i) a load side heat exchanger and a small tank for DHW and (ii) an additional immersed heat exchanger and a 3-way valve in the collector loop to directly heat up the upper part of the store, whenever possible. The auxiliary heat management is in the serial mode. Long-running-time auxiliary boilers may also be installed with System #10.

The Scandinavian system “**Space Heating Store with DHW Load-Side Heat Exchanger(s) and External Auxiliary Boiler**” (#11) may be compared, on the one hand, with System #7 and on the other

with System #8 (see the corresponding data sheets). A second load side heat exchanger for DHW is common but not always provided, and provision is made for the coupling to either a conventional auxiliary boiler or a long-running-time auxiliary boiler. System #11 may also be compared to System #4 where the respective roles of DHW and space heating water in the storage devices have been interchanged and the auxiliary heat management is different.

The Swedish system “**Space Heating Store with DHW Load-Side Heat Exchanger(s) and External Auxiliary Boiler (Advanced Version)**” (#12) is an advanced version of System #11. A 3-way valve is provided together with a second immersed heat exchanger in the collector loop, and a 4-way valve, with two outlets from the store, in the space-heating loop. In this way, stratification in the storage tank is enhanced.

The next group of systems all have **two stores** and, accordingly, features like valves, pumps, pipes, sensors and control facilities direct the heat to the one or the other store, depending on the relevant control temperatures in the system.

In the Austrian system “**Two Stores (Series)**” (#13), both the solar heat and the auxiliary heat for DHW first pass through the space heating store before being transferred to the DHW store by a separate loop with a pump, heat exchanger and corresponding control. Solar heated fluid is injected into the space heating store at two different heights via an external heat exchanger as a stratification-enhancing feature. Long-running-time auxiliary boilers may be installed with this system.

“**Two Stores (Parallel)**” (#14) is also an Austrian system, with two versions: one for an oil or gas auxiliary boiler, and the second one for a long-running-time auxiliary boiler. “Parallel” means that the solar heat as well



### **Single-family house, Isère, France**

Generic system: Advanced Direct Solar Floor; Collector area: 16 m<sup>2</sup>; Storage volume: heating floor and 0.5 m<sup>3</sup> for domestic hot water; Auxiliary heater: gas boiler



**Single-family house in winter time,  
Jennersdorf, Austria**

Generic system: Two Stores (Series); Collector area: 44 m<sup>2</sup>; Storage volumes: 0.3 m<sup>3</sup> for domestic hot water, 4.8 m<sup>3</sup> for space heating



as the heat produced by the auxiliary boiler may be directed either to the space heating store or to the DHW store, by means of valves and a controller. In the case of a gas or oil boiler as auxiliary, the auxiliary heat management is in the parallel mode.

The following four systems from Germany all have **built-in stratifiers** in the storage tank, mostly vertically mounted along the tank axis, in addition to possible stratification enhancing features like those described for the previous systems.



**Single-family house, Savoie, France**

Generic system: Advanced Direct Solar Floor; Collector area: 16 m<sup>2</sup>; Storage volume: heating floor and 0.5 m<sup>3</sup> for domestic hot water; Auxiliary heater: gas boiler

The first system, called “**Two Stratifiers in a Space Heating Storage Tank with an External Load-Side Heat Exchanger for DHW**” (#15) is fitted with an integrated gas burner. Other external auxiliary heaters may also be used. The solar heat exchanger is located in the lower part of a stratifier whose upper part is provided with several horizontal outlets for stratified charging of the storage tank. A second stratifier is provided for the return line of the space-heating loop. The load-side DHW heat exchanger is external, with a variable-speed circulating pump on the primary side.

The next system “**Conical Stratifier in Space Heating Store with Load-Side Heat Exchanger for DHW**” (#16) is a German

drainback system. The solar heat exchanger is conically shaped and again located in the lower part of a stratifier. A horizontal plate minimises water mixing between upper “DHW part” and lower “space heating” part of the tank. The load side DHW heat exchanger is a long, spirally wound, pipe mounted near to the storage tank sidewall. The auxiliary heat management is in the serial mode.

In System #17 “**Tank Open to the Atmosphere with Three Heat Exchangers**” from Germany the heat storage medium is water at atmospheric pressure in a so-called pressureless or open store. Hence, heat exchangers are used for heat transfer from the solar collector loop, from and to the space heating/ auxiliary heat source loop, and to DHW. Stratifiers are used both for the solar heat exchanger and for the load side DHW heat exchanger. This load side stratifier has a long “tail” directing the tank water, after it has been cooled down by DHW in the heat exchanger, to the tank bottom, hence minimising mixing with warmer water. The auxiliary heat management is in the serial mode.

The 4<sup>th</sup> German system “**Finned-Tube Load-Side DHW Heat Exchanger in Stratifier**” (#18) combines several features

already encountered in other systems with one unique feature: a compact load-side DHW heat exchanger built from finned tubes mounted in the upper part of a stratifier similar to that in System #17. This stratifier, however, has a valve to regulate the flow of water sinking to the bottom of the store aiming to further improve stratification. The other features of this system are an external heat exchanger in the collector loop, with selective heat transport to the storage tank at two different heights, and the auxiliary heat management in the serial mode.

*This completes the description of the combisystems designed principally for buildings housing up to 2 to 3 families (collector area smaller than 50 m<sup>2</sup>; however, some of the designs are also suitable for larger buildings).*



*Single-family house, Jura, France*



Generic system:  
Advanced  
Direct Solar  
Floor;  
Collector area:  
17 m<sup>2</sup>; Storage  
volume:  
heating floor  
and 0.5 m<sup>3</sup> for  
domestic hot  
water

The following Austrian system “**Centralised Heat Production, Distributed Heat Load, Stratified Storage**” (#19) is designed for large buildings or building groups. The collector area may reach 800 m<sup>2</sup>. A local heating network connects the individual houses or flats to the central storage tank (up to 60 m<sup>3</sup>). DHW is prepared and stored in a decentralised way; by night, the local heating network is operated at a higher temperature enabling the charging of all decentralised DHW stores. All heat exchangers are external. The central store is fitted with two stratifiers (collector loop and local network return line).

*As an opportunity for further developments, Task 26 also considered the following two generic systems but did not go into as many details as for the smaller systems (#1 to #19).*

System #20 “**Large Tank-in-Tank for Seasonal Heat Storage**” from Switzerland is derived from System #9, a smaller one of similar configuration. It is sized in such a way that a large fraction

of the yearly heat demand may be supplied by solar. In the climatic conditions of central and northern Europe this implies that the excess heat produced in the summer months is stored for use in wintertime, so-called **seasonal storage** of solar heat. These systems are technically feasible, but less cost-effective than the small ones. However, they could become an important option in the mid-term, when large contributions from solar energy will be required.

System #21 “**Large Stratified Tank for Seasonal Heat Storage, Air Heating System**” also stores summer heat in a large stratified tank for later use in the winter. In this German system, space heating is air-based with a ventilation system. The system is, so far, a prototype installed in a well-insulated office building with a cogeneration unit as the auxiliary heating device.



*Private house, Leksand, Tottie, Sweden*

Generic system: Space Heating  
Store with DHW Load-Side Heat  
Exchanger(s) and External  
Auxiliary Boiler; Collector area:  
10 m<sup>2</sup>; Storage volume: 1.5 m<sup>3</sup>  
for space heating; Auxiliary  
heater: woodburner

## General Remarks on the Data Sheets

The *collector area and storage volume ranges* indicated at the top of each data sheet are just typical figures. Different dimensions are also possible in practice.

The *cost figures* mentioned in the data sheets have to be interpreted cautiously. They are just *typical costs* and may be subject to *large variations* in each particular case in practice.

For each generic combisystem the **total cost without taxes** includes the following components and their installation:

- solar collectors mounted into the roof (integrated collectors)
- collector piping with insulation
- solar hydraulic equipment (storage tanks, pump, valves, controllers,...)
- auxiliary boiler
- boiler piping with insulation
- antifreeze fluid
- space-heating loop (heat distribution lines and heat emission devices) designed for heating rooms with a total floor area of 130 m<sup>2</sup>

The total cost of a *reference system in the same country of origin* is given for comparison. The *difference* between the cost of the solar combisystem and the cost of this reference system is believed to be more reliable for system intercom-

parison than the total cost itself, even within a single country. However, when comparing figures, the reader should remember that the *economic background of the manufacturer*, the *national market structure and price level* as well as the *level of comfort* offered by the systems under consideration are also reflected in the cost information.

The choice of the *reference system* depends on the generic system under consideration. The reference system has no solar collector, but has the same auxiliary energy source, the same heat distribution lines and heat emission devices, and a comparable DHW production unit as well as a similar controller. The heating services delivered to the inhabitants in the form of space heating and domestic hot water by both the solar combisystem and its reference system are supposed to be equivalent.

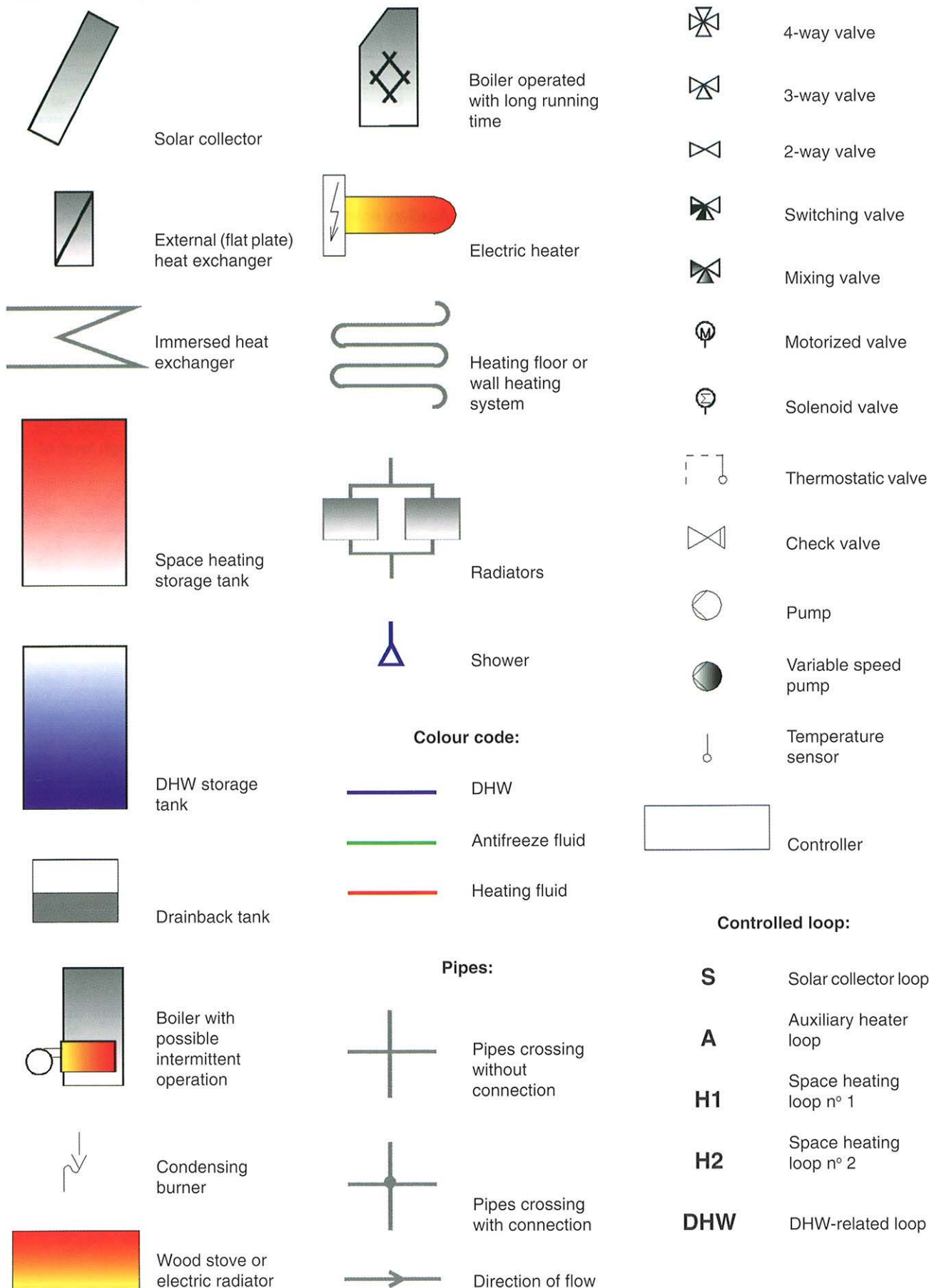
In a lot of cases the *auxiliary heating concept* indicated in one particular data sheet may be replaced by another one. For instance, an integrated gas burner can be replaced by a built-in electric heater or a heat exchanger with external auxiliary heater. The specific heat transfer characteristics of the different devices should be taken into account.

For some generic system concepts, system units may be connected in *cascade* to match a larger space heating and DHW load.



# Data Sheets of the 21 Generic Solar Combisystems

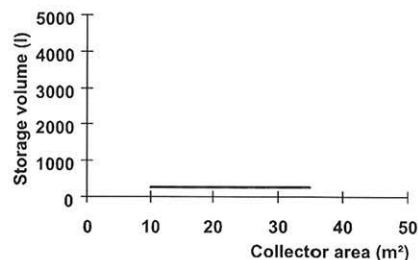
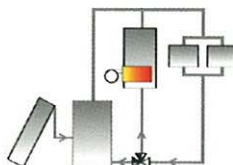
## Symbols (adapted from ISO 4067/1)







AP



### Main features

This combisystem features heated floors which combine the functions of the heat emitter and space heating storage. The heat transfer fluid heated by collectors flows, without intermediate heat exchanger, in the concrete slabs. The typical slab thickness is increased between 12 and 15 cm, so as to store the solar energy and shift its restitution to the evening. This system was developed at the end of the 70's, to simplify former hydraulic schemes.

### Heat management philosophy

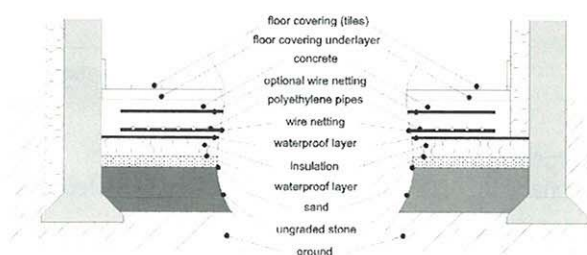
Each of the two pumps is under control of a differential controller. Priority is given to the load (DHW or space heating) with the lowest temperature level, so that the solar collector works with the highest efficiency.

If the temperature at the outlet of the heating floor is higher than the set-point temperature, the pump of the space-heating loop is turned off in order to prevent overheating in the house.

### Specific aspects

All the components shown in the central box of the hydraulic scheme are factory assembled in compact units, which makes the work of the installer in the house easier.

Because of the solar floor, this system is well suited for new houses, or for retrofits where the floors are being rebuilt. The figure below is an example of a heating floor built on the ground. For floors located above heated or unheated rooms, other construction is possible. In addition to the increased slab thickness, the only difference between the typical heating floor and the solar floor is the location of the polyethylene pipes at the bottom of the slab.

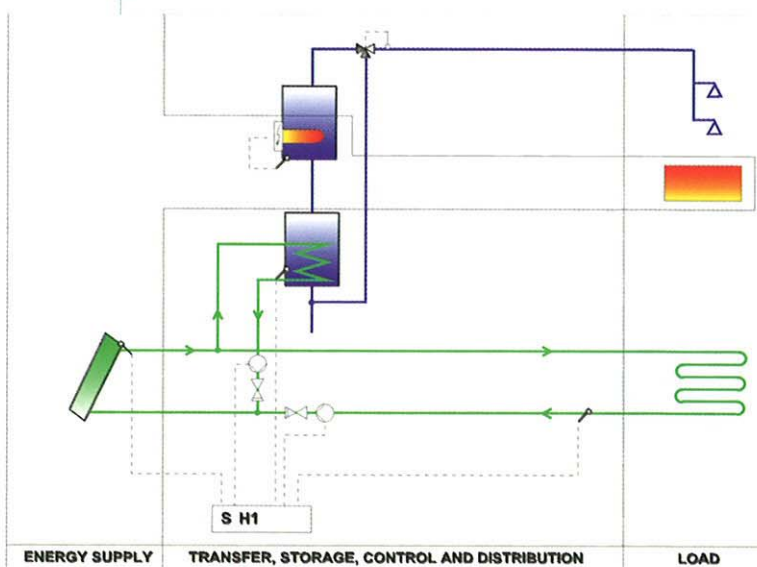


### Influence of the auxiliary energy source on system design and dimensioning

Auxiliary energy for space heating is delivered to the house with an independent system, such as a wood stove or electric radiators. The auxiliary electric heater for DHW may be integrated in the upper part of the solar DHW tank.

### Cost (range)

A typical system with 15 m² of solar collectors, a 250 litre tank, components for the heating floor, pipes and installation, auxiliary energy provided by a wood stove and an electric tank for DHW, costs about 13 000 EUR. Self-installation is made easy through the high level of



components integration, so the total cost can decrease to about 11 500 EUR. Costs for the reference system including only a wood stove and an electric tank for DHW are about 2 000 EUR.

### Market distribution

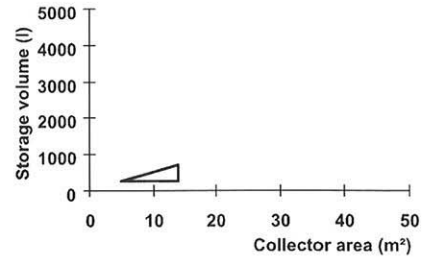
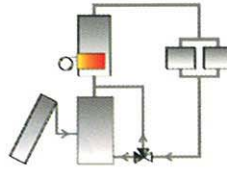
This system is marketed mainly in France and is almost the only type installed between 1986 and 1992; solar heating systems with water storage disappeared in France twenty years ago. More than 300 units were sold prior to 2000, utilising more than 4 500 m² of solar collectors.  
Manufacturer: CLIPSOL.







AS



### Main features

This system is derived from a standard solar domestic-hot-water system, but the collector area has been oversized in order to deliver energy to an existing space heating system. The connection between the solar and the existing system is made through a heat exchanger included in the return pipe of the space-heating loop. The store is only devoted to DHW preparation, with two immersed heat exchangers: the solar one in the bottom of the tank, and the auxiliary one at the top. A three-way valve directs the antifreeze fluid coming from the collector either to the DHW heat exchanger, or to the space-heating heat exchanger.

### Heat management philosophy

The controller doesn't manage the auxiliary part of the system. As long as the temperature at the collector outlet is higher than either the return temperature from the space-heating loop or the temperature at the bottom of the tank, the pump of the collector loop operates. The three-way valve is managed so as to deliver solar energy to the space-heating loop, i.e. when the temperature at the collector outlet is lower than the temperature at the bottom of the tank, or when the storage is warm enough (temperature at the top of the store higher than the set-point temperature). When the domestic-hot-water temperature is too low, auxiliary heat is delivered to the tank through the two-way valve.

### Specific aspects

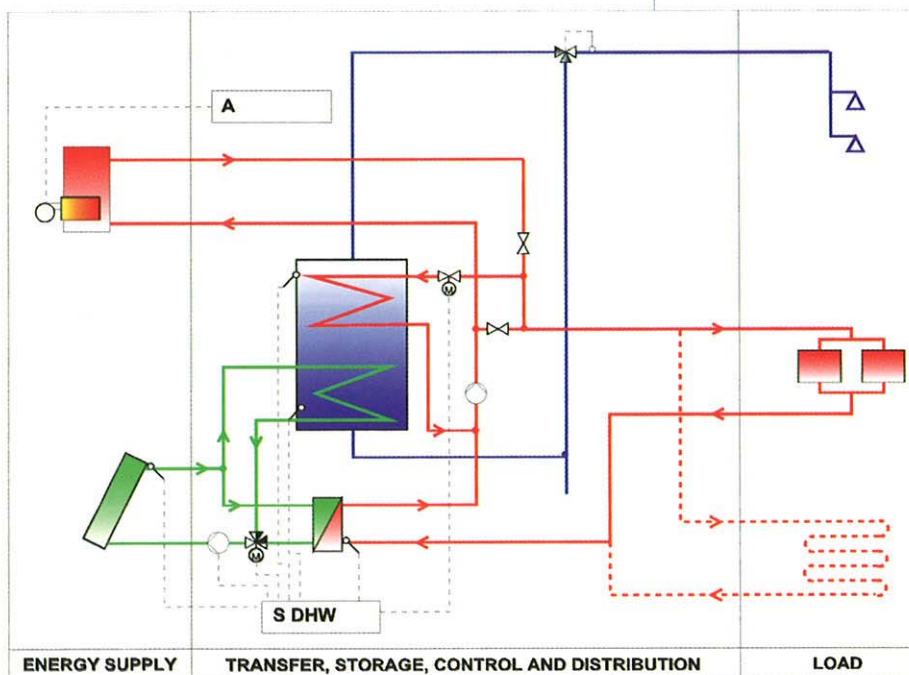
Due to the lack of store for space heating, the solar gain will be increased the more variations of indoor temperature the inhabitants tolerate. In this system, the building itself plays the role of space heating store. Therefore, the system will work better with a high-capacitance heat emission system, like heating floors. Solar-induced variations in the indoor temperature are only possible when the boiler is turned off (i.e. in summer). The system could be controlled so that it delivers heat to the space-heating loop independently of any space heating needs if there is a risk of overheating in the system.

### Influence of the auxiliary energy source on system design and dimensioning

This system can work with any auxiliary energy source (gas, fuel, wood, district heating). It could be also used with separated electric radiators.

### Cost (range) (for one-family houses)

A typical system with 7 m<sup>2</sup> of solar collectors and a 280 litre store costs about 5 200 EUR. This amount only includes the solar part (collectors, storage device, controller and heat exchanger, installation), since the auxiliary part (boiler, radiator circuit) already exists. Total cost for complete heating system with solar is 13 800 EUR, and reference cost for complete heating system without solar is 9 300 EUR.



### Market distribution

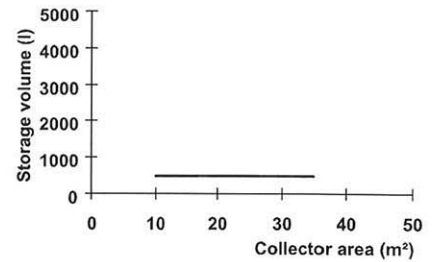
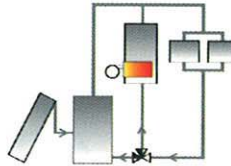
This system is the most common in Denmark. Prior to 2000, about 100 000 m<sup>2</sup> of solar collectors have been installed by 12 manufacturers and 400 to 800 installers all over Denmark. Manufacturer: Batec A/S, others







AP



### Main features

This combisystem is an enhancement of the Basic Direct Solar Floor concept. The basic idea is to couple the heat emission device of the space heating to both the auxiliary heater and the solar collectors in such a way that inhabitants can benefit from the heating-floor comfort throughout the heating season. A heat management philosophy is used to optimise the solar-heat sharing between DHW production and space heating.

### Heat management philosophy

The floor mixing-valve is under control of a heating curve derived from a predicted outside air temperature and the room temperature. When solar energy is delivered to the floor, the flow temperature in the floor is allowed to rise in such a way that the room temperature exceeds the auxiliary set-point room temperature by at most 4 °C. But when auxiliary energy is delivered to the floor, the space-heating loop pump is turned off as soon as the room temperature exceeds the auxiliary set-point room temperature by 0.5 °C. The auxiliary boiler is controlled by the solar controller in such a way that the heat losses are reduced when no auxiliary energy is needed. In summer, both DHW tanks are used for solar-energy storage.

### Specific aspects

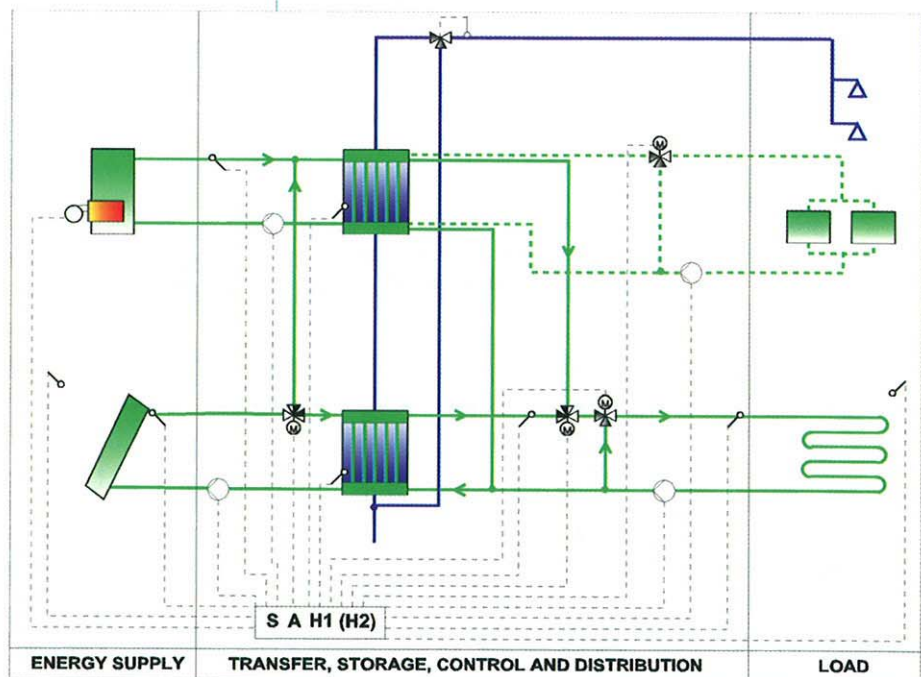
The manufacturer has developed a special DHW tank with two functions: heat storage for DHW; and hydraulic decoupling of collector, auxiliary boiler, and heating-floor loops. All of the components shown in the transfer, storage, control and distribution region of the hydraulic scheme are factory-assembled in compact units, which makes the installation easier. Because of the heating floor, this system is well suited for new houses, or for retrofits where the floors are being rebuilt. Monitoring features are included in the controller, which can compute energy balances and to send the information to a remote computer through a built-in modem. In this way, proper operation can be verified.

### Influence of the auxiliary energy source on system design and dimensioning

A gas, oil or electrical boiler can be easily connected to the storage and control unit. It is also possible to use a wood boiler, but that requires an additional buffer tank.

### Cost (range)

A typical system with 15 m² of solar collectors costs about 17 000 EUR, which can be divided approximately into two halves: (i) the auxiliary part (boiler, heating-floor pipework, auxiliary DHW tank, control,...) corresponding to the reference system (8 500 EUR); and (ii) the solar-related additional investment (solar collectors, solar DHW tank, control,...). The high level of components integration and the possibility of partial self-installation lead to reduced installation costs.

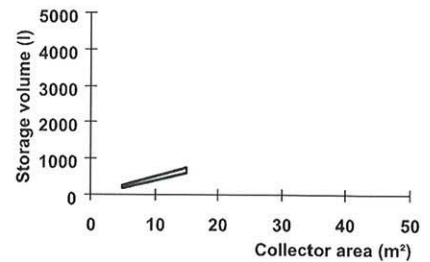
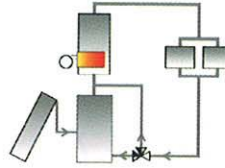


### Market distribution

Like the Basic Direct Solar Floor, this system is only found in France. Only one company manufactures this system. Between 1992 and 2000, more than 300 units were sold, with a total collector area exceeding 4500 m². Manufacturer: CLIPSOL.







## Main features

As is the case for System #2 this system can be added to an existing space heating system. Heat coming from the solar collector is delivered to a DHW tank, which acts also as a small buffer tank for space heating. The DHW store is equipped with three immersed heat exchangers: the solar one in the bottom of the tank, the auxiliary one at the top, and an intermediate one connected to the return line of the space-heating loop. A three-way switching valve directs the fluid from the space-heating loop either to the intermediate heat exchanger, or directly to the auxiliary boiler.

## Heat management philosophy

If the temperature at the collector outlet is higher than the temperature at the bottom of the tank, the pump of the collector loop is on. The three-way valve is controlled so as to deliver solar energy to the space-heating loop, i.e. water flows through the intermediate heat exchanger only when the temperature in the middle of the tank is higher than the return temperature of the space-heating loop. When the DHW temperature is too low, auxiliary heat is delivered to the tank through the two-way valve. The auxiliary part of the system is under control of a separate control unit.

## Specific aspects

Solar heat used for space heating is stored in the domestic hot water tank.

## Influence of the auxiliary energy source on system design and dimensioning

This system can work with any auxiliary energy source (gas, oil, wood, or district heating). It could be also used with separated electric radiators.

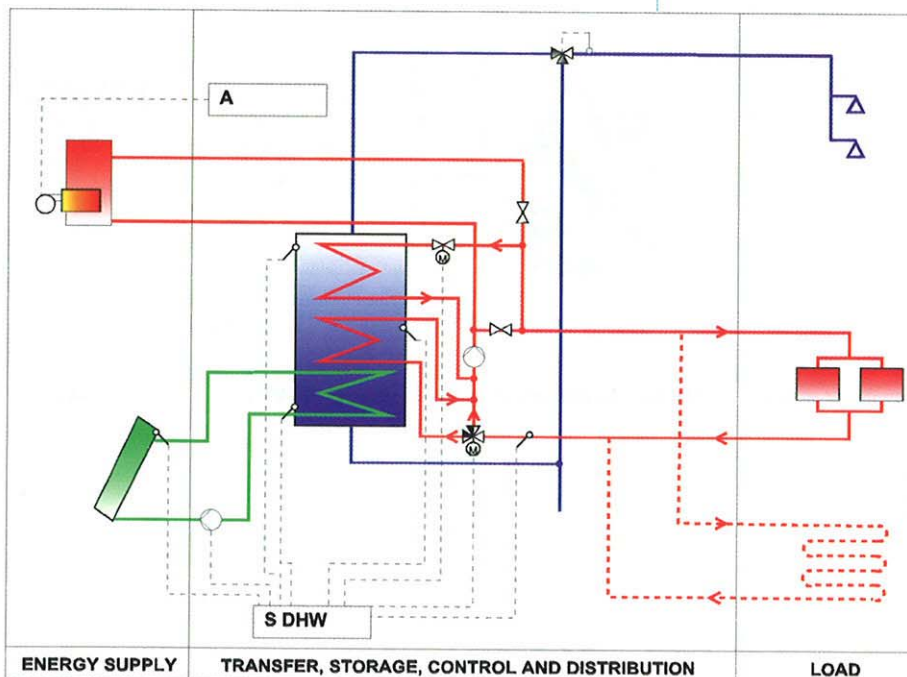
## Cost (range)

A typical system with 15 m² of solar collectors and a 800 litre storage unit costs about 7 000 EUR. This amount only includes the solar part (collectors, storage tank, controller and heat exchanger, installation), since the auxiliary part (boiler, radiator circuit) already exists. Total cost for complete heating system with solar is 15 600 EUR, and reference cost for complete heating system without solar is 9 300 EUR.

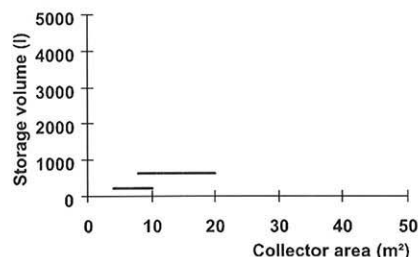
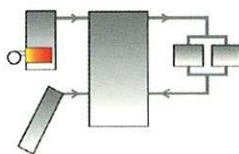
## Market distribution

This system is quite new in Denmark. Only one company markets this system, with a total collector area in operation of 100 m². The system is marketed by the manufacturer and is available anywhere in

Denmark from the nearest installer (400-800 potential installers). Manufacturer: Batec A/S






**CMid**


## Main features

This system is a compact unit for space heating and DHW, with an integrated gas burner. The 240 litre or 650 litre DHW tank is surrounded by a double-wall tank connected to the solar collector. This mantle tank simultaneously works as a heat exchanger and a drainback tank for the collector.

## Heat management philosophy

The pump of the collector loop is under control of a differential controller, which switches the collector loop pump on if the temperature of the collector absorber is well above the temperature in the mantle. If the temperature of the DHW in the auxiliary part is too low, the gas burner is switched on. In the case of radiators as heat emission devices the burner is controlled using two sensors: the room thermostat indicates that there is a heat demand, and an outdoor sensor provides the information needed for tuning on the burner.

## Specific aspects

Overheating and freeze protection are provided by the drainback principle.

## Influence of the auxiliary energy source on system design and dimensioning

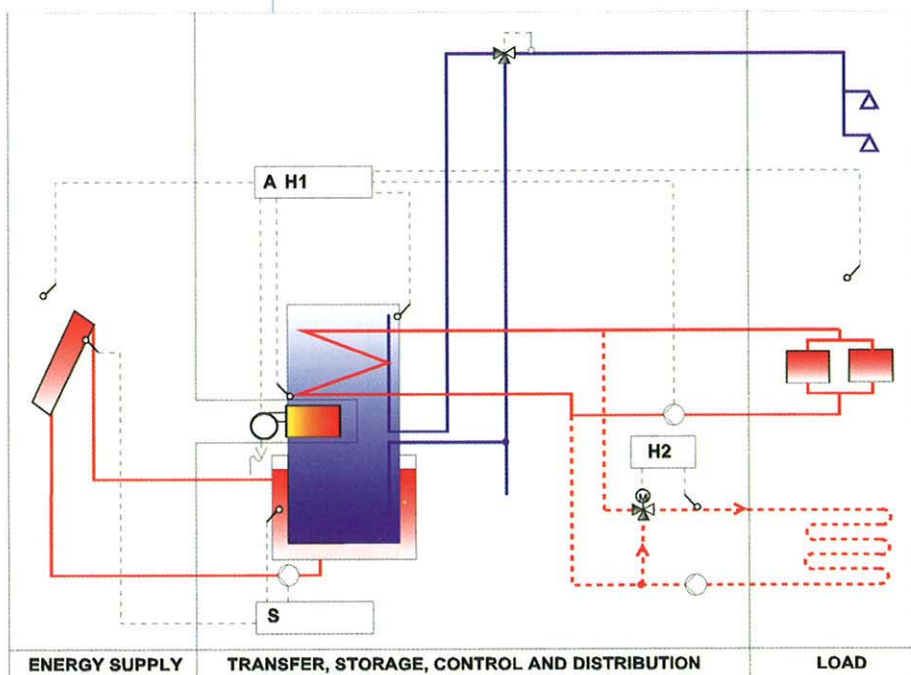
This system is designed with a gas burner integrated in the storage tank. However, the tank can also be provided with an electric element for auxiliary heating.

## Cost (range)

A typical system with 4.2 m² of collector and a 240 litre storage tank with an integrated gas burner costs about 3 500 EUR. Installation costs in a new building amount to approximately 750 EUR for the collector and the heat store. With additional costs for the space heating distribution system (radiators) of about 2 200 EUR, total cost is 6 450 EUR. A similar reference system without solar heating costs about 3 400 EUR with the heat distribution system.

## Market distribution

This system has been marketed in the Netherlands since 1994. In total, 4250 systems have been installed prior to 2000. The total collector area in operation is about 15 000 m².



This system is presented thanks to the Netherlands Agency for Energy and the Environment

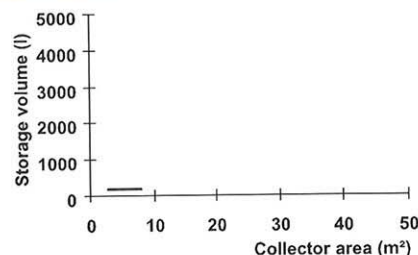
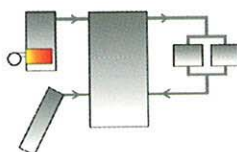
*Netherlands agency for energy and the environment*

# Novem





**CMid**



## Main features

This system is a compact unit for space heating and DHW, with two superimposed storage tanks and an integrated gas burner. The collectors are connected to a 100 litre solar storage tank which also works as the drainback vessel. A DHW preheating heat exchanger is located within this tank. DHW is then further heated in the second tank containing the vertical integrated gas burner.

## Specific aspects

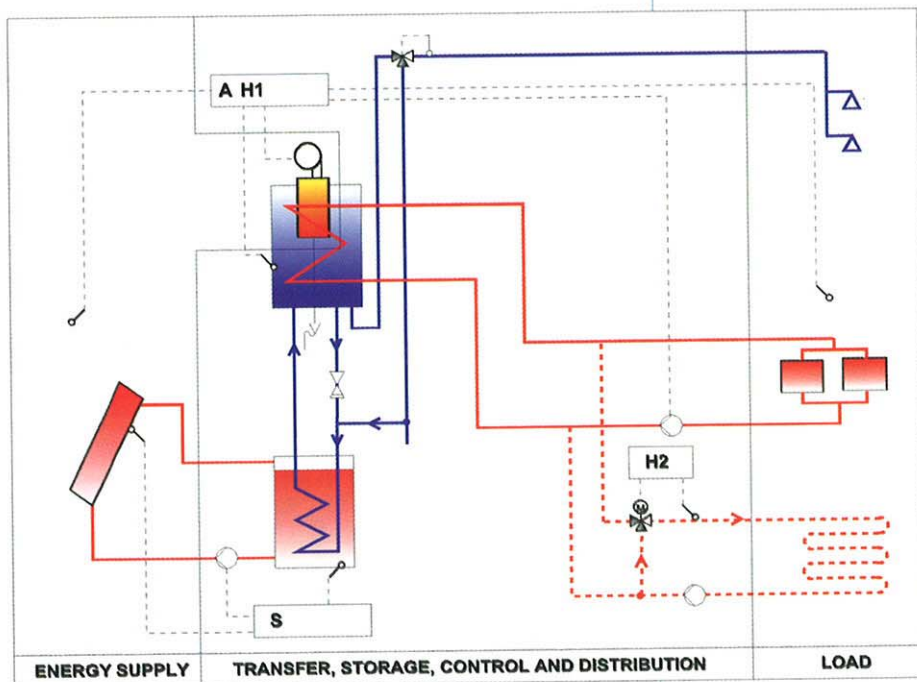
Overheating and freeze protection are provided by the drainback principle.

## Influence of the auxiliary energy source on system design and dimensioning

This system is designed with a gas burner integrated in the storage tank. No other auxiliary energy can be used.

## Cost (range)

A typical system with 4.1 m² of collector and a 180 litre storage tank costs about 3 300 EUR. Installation costs in a new building amount to approximately 750 EUR for the collector and heat store with integrated burner. With additional costs for the space heating distribution system (radiators) of about 2 200 EUR, the total cost is 6 250 EUR. A similar reference system without solar heating costs about 3 400 EUR with the heat distribution system.



## Heat management philosophy

The pump of the collector loop is under control of a differential controller. If the temperature of the DHW in the auxiliary storage tank is too low, the gas burner is switched on. When radiators are used as the heat emission devices, the burner is controlled using two sensors: the room thermostat indicates that there is a heat demand, and an outdoor sensor provides the information needed for tuning on the burner.

## Market distribution

This system was launched on the Dutch market in the autumn of 1999. A number of test systems have since been installed. The manufacturer expects active nationwide sales of this solar unit beginning in 2000.

This system is presented thanks to the Netherlands Agency for Energy and the Environment

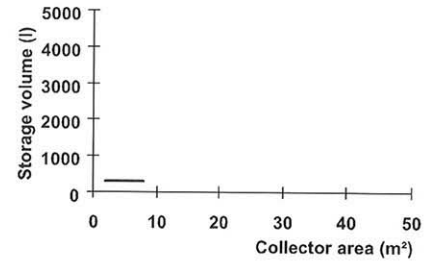
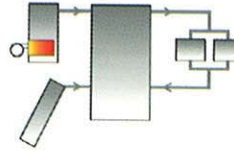
*Netherlands agency for energy and the environment*

**Novem**





CMi



### Main features

This system has a storage volume of 300 l and an integrated oil or gas burner. A solar collector area of 2 to 8 m² can be installed with this system.

### Heat management philosophy

The pump of the solar loop is under the control of a differential controller that also provides storage overheating protection. The burner has its own control by the room and outside air temperatures.

### Specific aspects

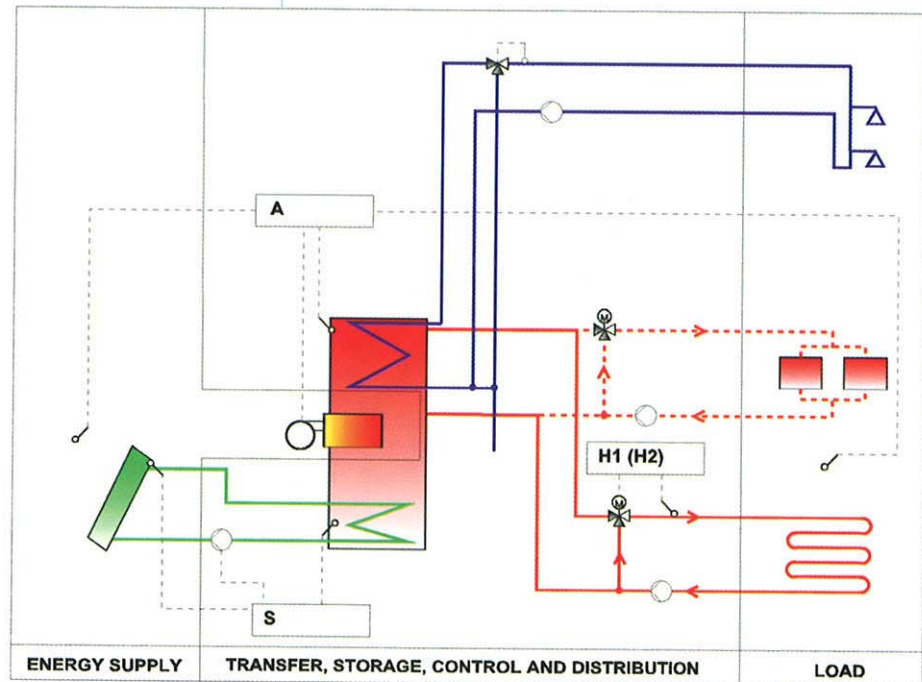
Overheating protection is provided by a large expansion vessel, dimensioned so that it is able to contain the fluid volume expelled from the collectors by the vapour produced in them when stagnation occurs.

### Influence of the auxiliary energy source on system design and dimensioning

This system is always equipped with an integrated oil or gas burner. The solar collector area (1 - 3 collectors, 2.5 m² each) is dimensioned in accordance with the heat demand and the customer's desires.

### Cost (range)

A typical system with 7.5 m² of solar collectors and a 300 litre storage tank costs about 10600 EUR, including a heating floor and the installation costs. A similar reference system without solar heating costs about 7600 EUR.



### Market distribution

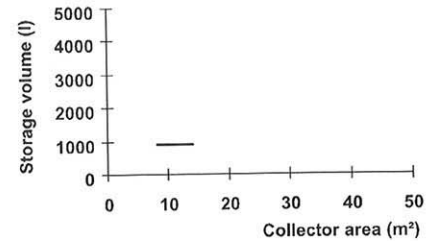
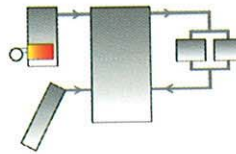
At the end of 1999, about 50 systems were in operation. The oil heating option is more common than the gas heating option.  
System deliverer:  
FORTUM







CMi



### Main features

This system is a compact unit for space heating and DHW, with an integrated gas or oil burner. The storage tank is fitted out with two immersed horizontal finned-coil heat exchangers (one in the upper and one in the lower part) for DHW preparation and a third one in the bottom for the collector loop.

### Heat management philosophy

The speed of the collector loop pump is varied in accordance with the temperature in the middle of the tank and the temperature difference between the collector outlet and the bottom of the storage tank.

The storage tank set-point temperature, which controls the auxiliary burner, is automatically adjusted to the space heating needs.

### Specific aspects

One single controller is in charge of the whole system (collector loop, DHW, space heating and auxiliary burner), with a display that indicates proper operation. Overheating is prevented by cooling the lower part of the storage tank after the sun has set by using the collector as a heat sink. There is no legionella risk because DHW doesn't stagnate in the storage tank.

### Influence of the auxiliary energy source on system design and dimensioning

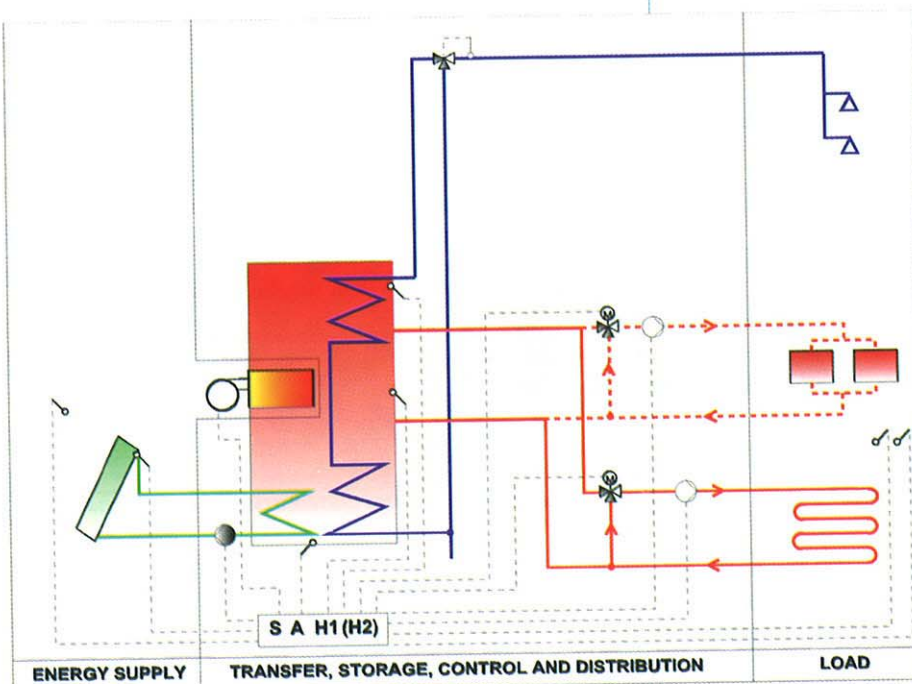
This system can be used with a gas or oil auxiliary burner. Alternately, a wood boiler can be connected directly to the lower part of the storage tank. In such a case, the boiler should be used cautiously to avoid competition between solar and auxiliary energies in the commonly used, lower section of the storage tank.

### Cost (range)

The total cost of the whole system with a gas or oil burner is about 20 000 to 23 000 EUR, for a collector area of 8 to 16 m<sup>2</sup>. Installation costs and a heating floor are included in these figures. A similar reference system without solar heating costs about 11 000 EUR.

### Market distribution

This system is rather new in Switzerland (1998). At the end of 1999 25 systems have been installed with a total collector area of about 300 m<sup>2</sup>. Two companies are marketing this system.



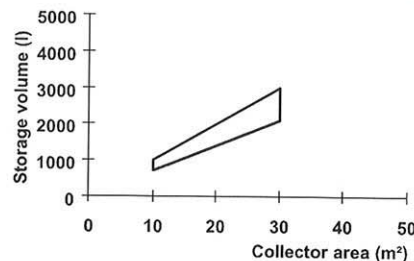
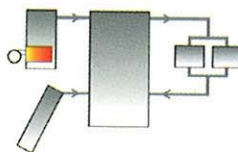
The controller is able to anticipate when solar heat is available from the collector and switch off the burner. Space heating is managed by the controller, taking into account solar passive gains detected by a second room temperature sensor. In the case of heating floors, a storage tank discharge can be forced in order to store heat in the building structure. In such a case, the room temperature may deviate from its set-point value by as much as 5 °C. The control strategy is designed to adjust the start time to improve thermal comfort.

This system is presented thanks to the Swiss Federal Office of Energy





CM/



### Main features

In this system, a DHW tank with a characteristic „mushroom-like“ shape is built in the space heating storage tank. The space heating tank size and the DHW tank size can be independently chosen over a wide range.

### Heat management philosophy

The pump of the collector loop is controlled by a simple differential controller. The heating of the upper part of the storage tank by auxiliary energy is controlled by a thermostat with a typical set-point temperature of 55 °C.

### Specific aspects

The failure of components like pumps and valves in earlier designs has lead to a simple system design to minimize the risk of failure. Overheating is prevented by cooling the lower part of the storage tank after the sun has set, by using the collector as a heat sink.

### Influence of the auxiliary energy source on system design and dimensioning

This system can be used either with a gas or oil auxiliary boiler, or with a long-running-time boiler (e.g., wood in the form of logs).

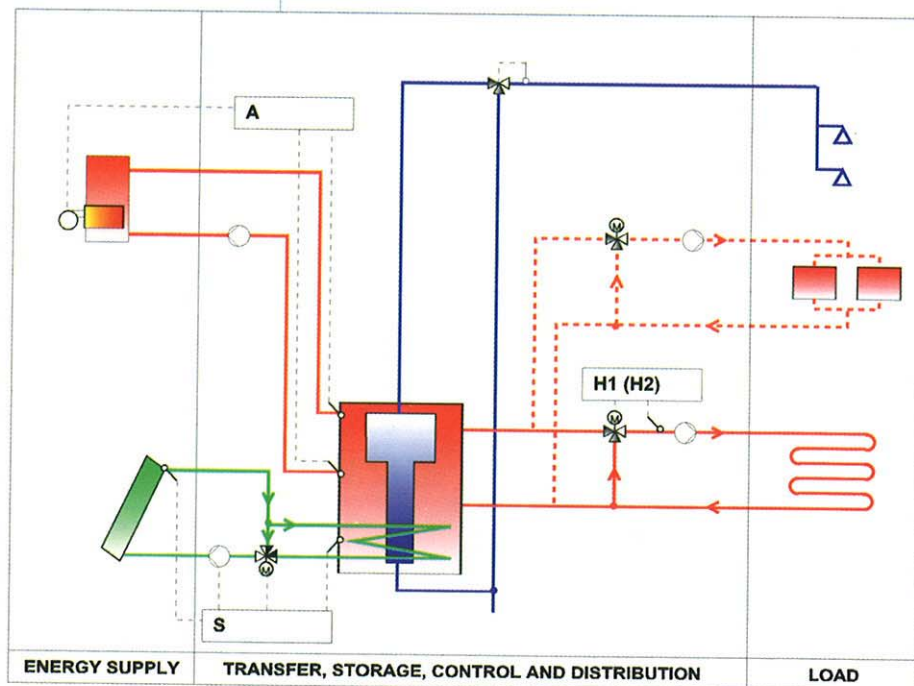
### Cost (range)

The total cost of the whole system in Switzerland is about 17 200 EUR, with a 12 m² collector, a 1 200 litre storage tank, a gas or oil boiler and a heating floor. Installation costs are included in these figures. A similar reference system without solar heating costs about 11 000 EUR.

### Market distribution

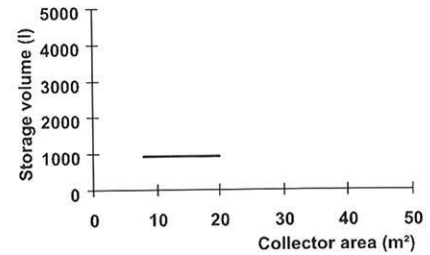
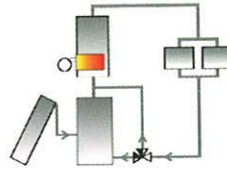
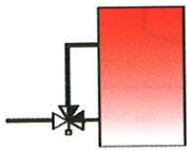
This system is common in Switzerland. Since 1976 more than 100 000 m² collectors have been installed by about 10 companies.

In Austria this system was introduced in 1994. About 3000 systems with more than 50 000 m² collectors have been installed by at least 10 companies.



This system is presented thanks to the Swiss Federal Office of Energy





### Main features

In this system, a DHW tank is built in the space heating storage tank. A heat exchanger is series-connected to the built-in tank, for cold-water preheating and stratification enhancement in the combitank. The total storage capacitance is 950 litres, with 250 litres used for the DHW tank.

For space heating the system works as a preheating system.

### Heat management philosophy

The pump of the collector loop is controlled by a simple differential controller. The heating of the upper part of the storage tank by auxiliary energy is controlled by a thermostat with a typical set-point temperature of 55 °C.

### Specific aspects

Overheating is prevented by cooling the lower part of the storage tank after the sun has set by using the collector as a heat sink.

### Influence of the auxiliary energy source on system design and dimensioning

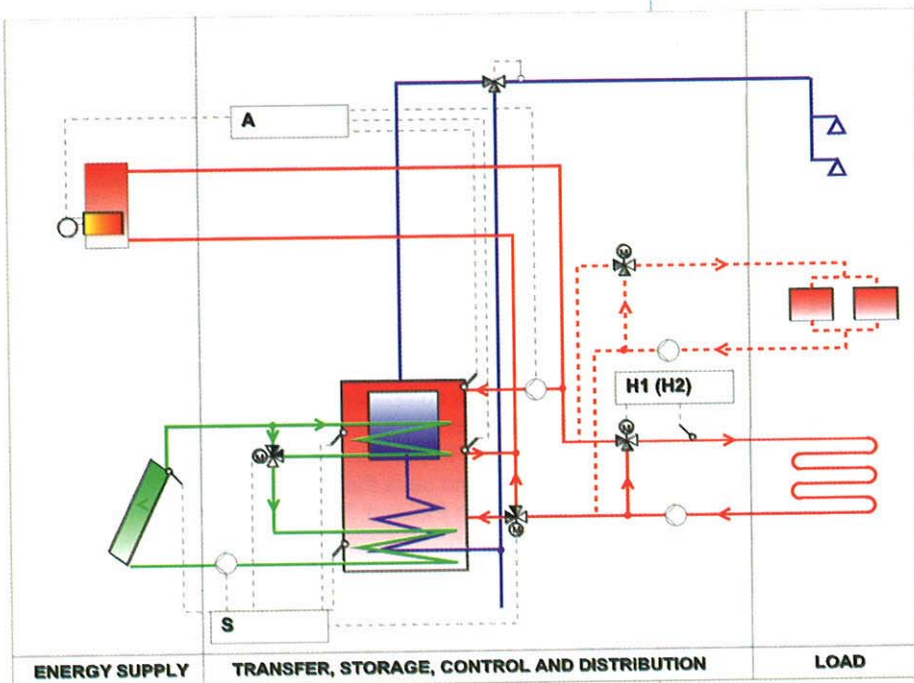
In this system an auxiliary boiler with power modulation, i.e. with gas or oil as the auxiliary energy source, should be used. Modulation can be either by intermittent operation or by burner modulation.

### Cost (range)

The total cost of the system is about 17 700 EUR, for a 12 m² collector, a 950 litre storage tank and a heating floor. Installation costs are included in these figures. A similar reference system without solar heating costs about 11 000 EUR.

### Market distribution

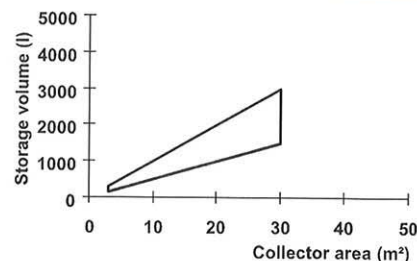
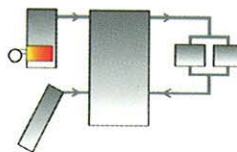
This system is rather new in Switzerland. At the end of 1999 more than 100 systems, with a total collector area of about 1 000 m² have been installed. Manufacturer: SOLTOP







CM/



### Main features

The tank in this system is fitted with an immersed horizontal finned-coil heat exchanger for DHW preparation and another heat exchanger in the bottom for the collector loop. An electric heater, operating on demand, heats the upper third of the tank. The optional use of a wood boiler or a pellet burner is very common in these systems. In Sweden an optional heat exchanger is generally used for DHW preheating as this significantly improves the thermal performance of the system. In Finland, this system is usually designed with a smaller collector area and a smaller storage tank (750 l) than in Sweden.

### Heat management philosophy

The pump of the collector loop is under control of a simple differential controller. The pump is switched off when the temperature at the collector outlet reaches 95 °C. No control for space heating and auxiliary boiler is included in the system. The electric heater is under control of a separate thermostat.

### Specific aspects

Overheating is prevented by using a relatively small expansion vessel (10 - 30% of collector loop volume), and by allowing a high pressure of up to 6 or 9 bar. This ensures that the fluid in the collector does not boil.

Due to the way DHW is prepared, there are no legionella risk.

### Influence of the auxiliary energy source on system design and dimensioning

Depending on the type of auxiliary boiler used, the outlet connection is located at the bottom of the tank (wood logs boiler) or in the middle of it (pellet burner). In the first case, the whole tank is heated up when the boiler is used. In the second case, only the upper part is heated up. One or more buffer tanks can be added in conjunction with a wood boiler. In this way, the boiler's requirement for a large volume is satisfied and the collector loop can still use a part of the whole volume by manually or automatically connecting or disconnecting the buffer tanks. An electric auxiliary heater is always included in the tank.

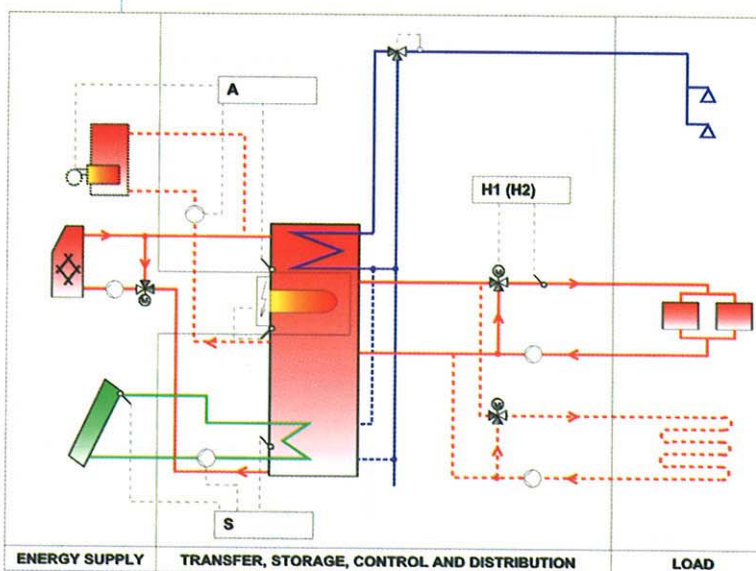
### Cost (range)

Sweden: A typical system with 10 m² of solar collectors and a 1 500 litre storage with a wood boiler as auxiliary, costs about 12 300 EUR. A similar reference system without solar heating costs about 8 600 EUR.

Finland: A typical system with 7 m² of solar collectors and a 700 litre storage without boiler (all auxiliary energy with electricity) costs about 9 100 EUR. A similar reference system without solar heating costs about 6 100 EUR.

### Market distribution

This system has been marketed in Sweden since 1990. About 5 companies have installed 10 000 to 20 000 m² of solar collectors. In Finland this system is quite new. About 80 systems, with 800 m² of solar collectors have been installed, from Helsinki to beyond the Arctic Circle.



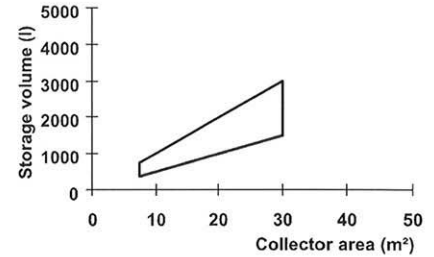
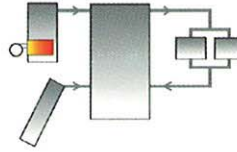
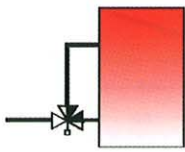
Manufacturers in Sweden: Three or four companies are manufacturing these storage tanks and about the same number of manufacturers produce the collectors. Marketing is by several companies. It is the preferred system among selfbuilders in Sweden involving some 20 small companies. (BoRö pannan AB - industry participant, manufactures and sells the system)  
Manufacturers in Finland: Two companies are manufacturing and four companies are selling these systems in Finland. (FORTUM - industry participant, manufactures and sells the system)



BoRö

Fortum





### Main features

This system is very similar to the previous system but with more sophistication in the collector loop, in the space-heating loop and in the controller. Two immersed heat exchangers are connected to the collector loop to increase the thermal stratification in the storage tank.

### Heat management philosophy

The collector loop pump is turned on under control of the absorber plate temperature. The speed of this pump is then controlled by the temperature difference between the collector outlet and either the temperature of the top or bottom tank sensor, depending upon whether the domestic-hot-water section or space heating section of the tank is to be heated.

The space-heating loop is connected to the tank with a 4-way valve enabling heat delivery from the central part of the tank.

The electric heater is under control of a separate thermostat, but is locked out by the solar controller when the collector loop pump is running.

Monitoring capabilities and the ability to compute energy balances are included in the controller, which can be easily connected to a PC.

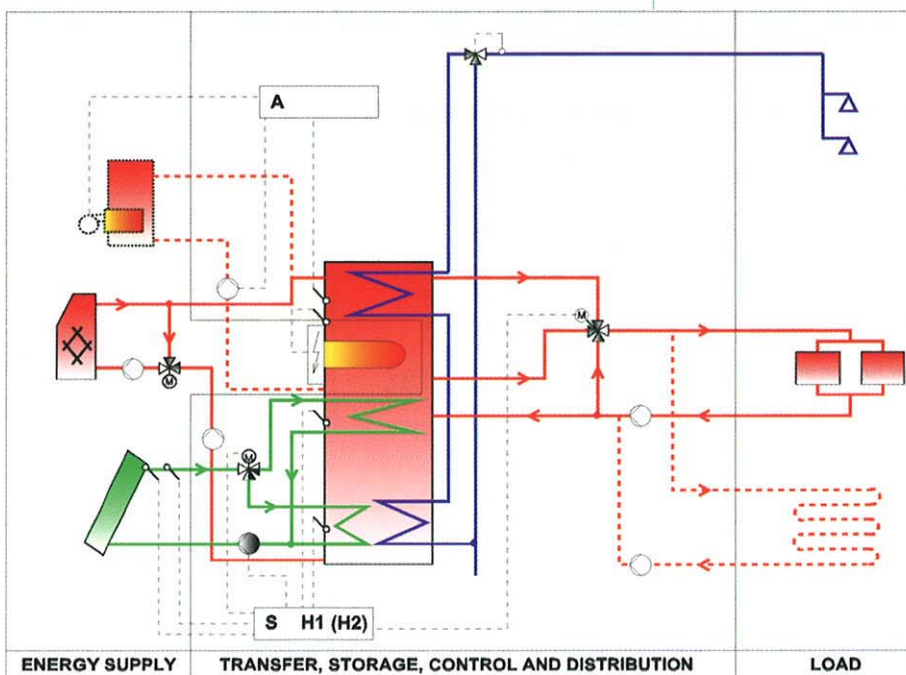
*Specific aspects, influence of the auxiliary energy source on system design and dimensioning are identical to the previous system.*

### Cost (range)

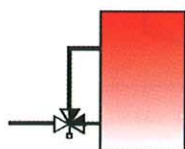
A typical system with 10 m² of solar collectors and a 1 500 litre storage tank with a wood boiler as auxiliary costs about 13 300 EUR. A similar reference system without solar heating costs about 8 600 EUR.

### Market distribution

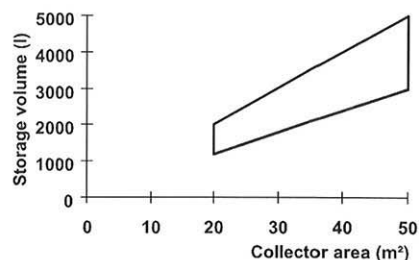
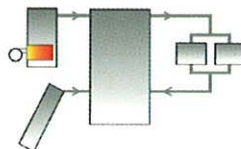
This system has been marketed by one company in Sweden since 1993. This company installed about 2 000 m² of solar collectors. The combitank and controller are generally produced by separate companies.







BM/



### Main features

This is a two-store system in which the space heating and the DHW storage tank sizes can be independently chosen. The collector loop with 20 to 50 m² of solar collectors heats one or more storage tanks (typical main storage tank volume is 60 to 100 litre per m²). This space heating storage is stratified by means of an external valve that appropriately directs hot water from the collector heat exchanger to the middle or top of the tank. The upper part of this storage tank is connected to an auxiliary boiler. DHW is heated by running a pump that circulates space heating water through an immersed heat exchanger in the DHW storage tank (typical DHW storage tank volume is 200 to 500 litres depending on the expected draw-off profile).

### Heat management philosophy

If the temperature at the collector outlet is higher than the temperature at the bottom of the tank, the pump of the collector loop is started. The secondary pump only starts when the temperature at the heat exchanger is higher than the temperature at the bottom of the tank. The three-way valve is operated in accordance with the temperature at the heat exchanger. The DHW pump is started when the temperature in the DHW tank is lower than the set-point temperature, and if the temperature of the space heating store is high enough. If the temperature of the space heating store is lower than the set-point temperature, the auxiliary boiler starts.

### Specific aspects

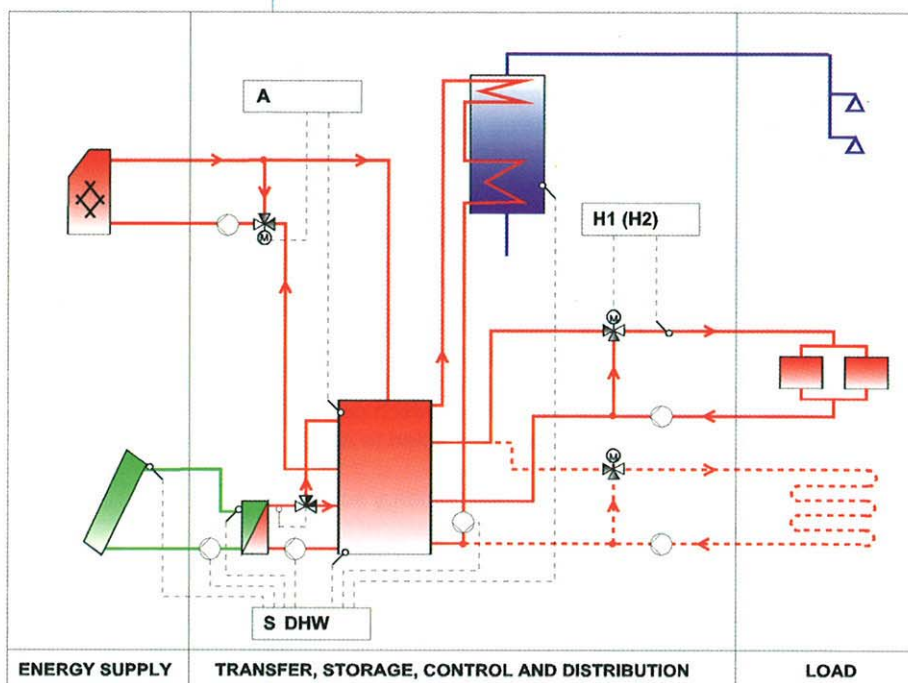
This system is designed for low-flow collectors.

### Influence of the auxiliary energy source on system design and dimensioning

Due to the size of the storage tank, an auxiliary wood boiler can be easily used, but an auxiliary gas or oil boiler can also be connected to the system.

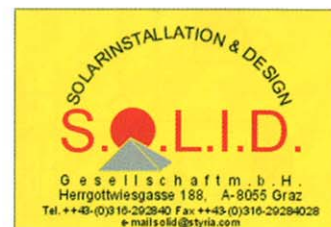
### Cost (range)

A typical system with 30 m² of solar collectors, a 350 litre tank for DHW and a 2 000 litre space heating store costs about 20 300 EUR, with a wood boiler as auxiliary. A similar reference system without solar heating costs about 10 700 EUR.

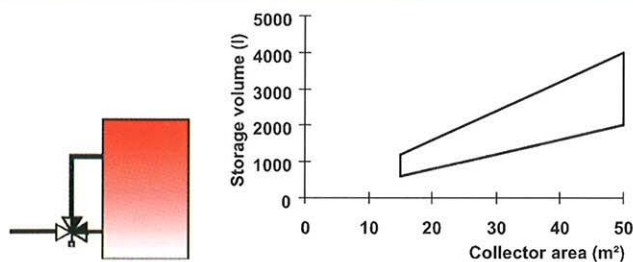


### Market distribution

This system has been distributed in Austria since 1994. Four companies are marketing this system, with a total collector area in operation of about 10 000 m². Manufacturers: SOLID, others







### Main features

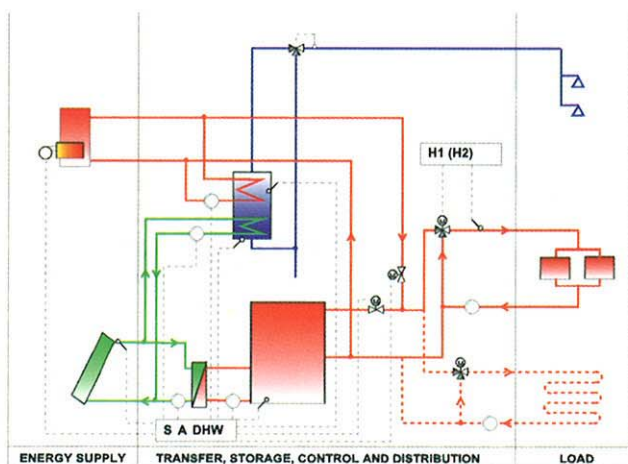
This system is representative of a group of systems. All geometric parameters can be varied. Either immersed or external heat exchangers may be used, as well as stratifiers. Auxiliary boilers with either possible intermittent operation or long running times can be used. In the first case, the boiler can be connected directly to the heat emission loop. In the second case, the space heating storage tank is used as a buffer tank for the boiler.

### Heat management philosophy

In winter, the solar collectors deliver heat to the coldest tank. In summer, priority is given to the DHW tank, which is heated to the maximum temperature allowed before the space heating tank heating begins. If a power-modulating auxiliary boiler is used, heat is delivered directly to the space heating loop as long as the temperature at the top of the space heating tank is below the temperature needed for the space heating loop. Otherwise, the auxiliary boiler is switched off and heat is taken from the space heating tank.

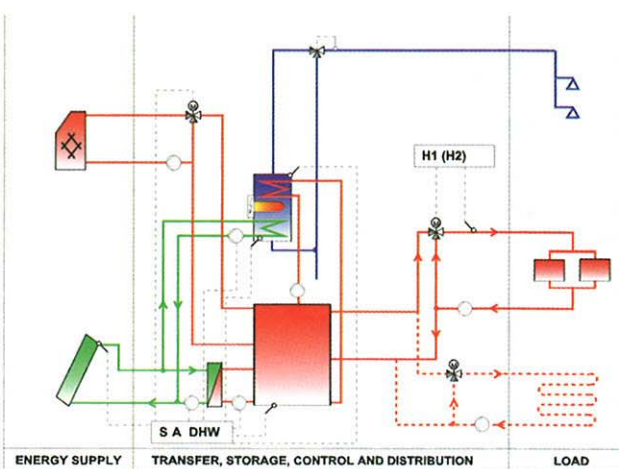
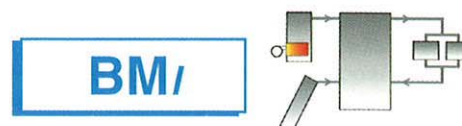
### Specific aspects

Overheating protection is provided by a large expansion vessel, dimensioned so that it is able to contain the fluid volume expelled from the collectors by the vapour produced in them when stagnation occurs.



### Influence of the auxiliary energy source on system design and dimensioning

If an auxiliary solid-fuel boiler is used, the hydraulic scheme is modified as follows: the heat produced by the boiler is delivered always to the space heating tank in order to decouple the boiler and heat load mass flows and to guarantee sufficiently long running time for the boiler. The auxiliary energy for the DHW tank is then delivered from the space heating tank. An electric heater is used during summertime to prevent the boiler from turning on.



### Cost (range)

A typical BP system with 30 m² of solar collectors, 350 litre for DHW and a 2 000 litre heating storage costs about 19 300 EUR, with a gas or oil boiler as auxiliary. A similar reference system without solar heating costs about 8 000 EUR. A typical BM system with 30 m² of solar collectors, 350 litre for DHW and a 2 000 litre heating storage costs about 20 300 EUR, with a wood boiler as auxiliary. A similar reference system without solar heating costs about 10 700 EUR.

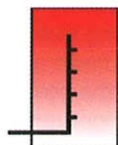
### Market distribution

This system has been distributed in Austria since 1994. Four to five companies are marketing this system, with a collector area of 15 000 m² installed yearly. Manufacturers: Sonnenkraft GmbH, SOLID, others.

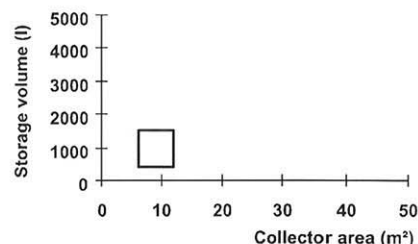
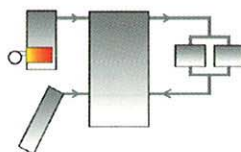
**SONNEN  
KRAFT**  
Willkommen in der Zukunft

SOLARINSTALLATION & DESIGN  
**S.O.L.I.D.**  
Gesellschaft m.b.H.  
Hergottweggasse 189, A-8065 Graz  
Tel. ++43 316 222462 Fax ++43 316 2224623  
mailto:solid@stg.at





DMil



### Main features

This system is constructed as a compact unit, in which all components (auxiliary gas condensing burner, DHW flat-plate heat exchanger with its primary pump) are integrated. Consequently, the installation time is reduced because of the reduction in the number of connections needed. The solar storage tank works as an optimised energy manager for all types of incoming energy (from the solar collectors, a gas burner, etc.) and outgoing energy (domestic hot water, space heating water).

### Heat management philosophy

The speed of the collector loop pump is controlled to reach an optimal loading temperature in the storage tank and also to maintain a minimum flow rate in the collector to ensure good heat transfer. The DHW temperature is brought up to the set-point temperature by controlling the speed of the pump located in the primary loop of the heat exchanger. Heat delivered to the space heating loop is controlled by a variable-flow-rate pump under selfcontrol of the thermostatic valves of the radiators (to save pump energy and to make sure there is no noise produced by the radiator valves). The power of the gas burner can be modulated between 5 and 20 kW, depending on the temperature in the tank and the requested temperature of the space heating loop (calculated from the outside air temperature, the room temperature and the time of the day).

### Specific aspects

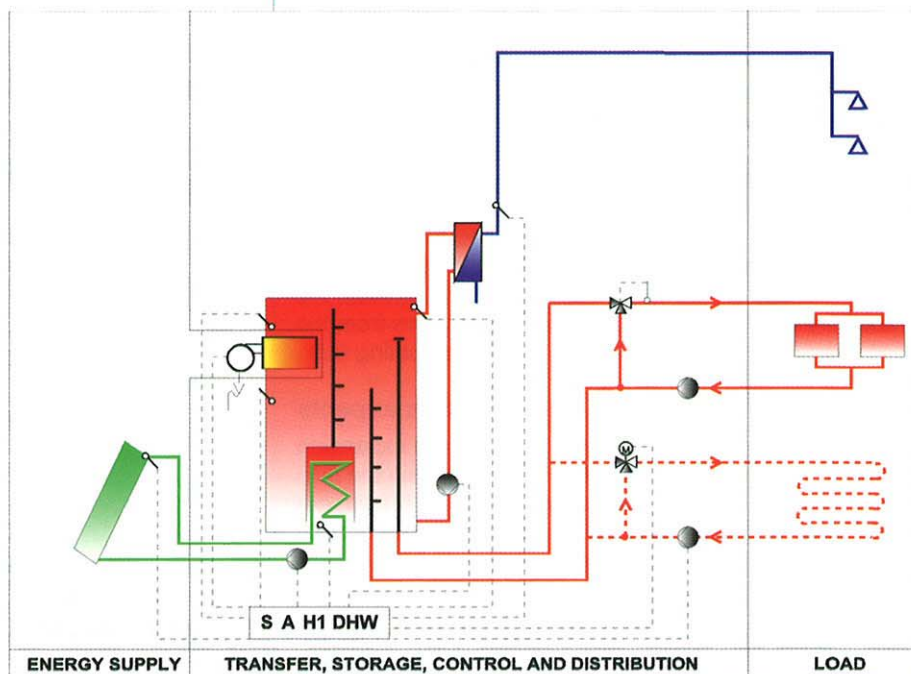
Solar energy input to the storage tank is provided by an immersed low-flow heat exchanger in co-operation with stratifying tubes (low-flow technology). The system must be checked once a year, due to the condensing gas boiler and its burner.

### Influence of the auxiliary energy source on system design and dimensioning

This system is designed with a gas condensing burner integrated in the storage tank. All other auxiliary energy boilers (e.g. wood or pellet burners) can be easily connected to the storage tank without additional heat exchangers.

### Cost (range)

The total cost of the system (space heating emission loop and installation included) is between 13 040 EUR for a 5-m²-collector with a 400-litre-storage-tank system and 16 850 EUR for a 12-m²-collector with a 750-litre-storage-tank system. A similar reference system without solar heating costs about 9 000 EUR.



### Market distribution

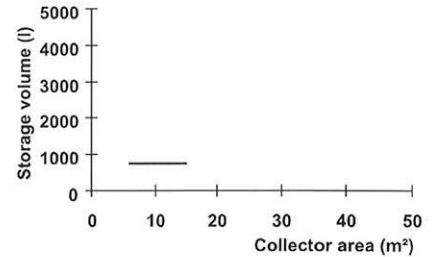
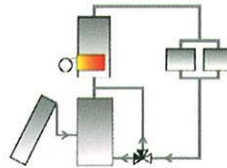
This system has been marketed in Germany since 1997. About 22 sale offices in Germany are marketing this system directly to 800 to 1000 plumbers, with more than 1300 units and 10 000 m² of solar collectors sold to date. Manufacturer: SOLVIS Solar-systeme GmbH, distribution by SOLVIS Energiesysteme GmbH & Co. KG







DS<sub>d</sub>



### Main features

The collector loop of this system works on the drainback principle, using water as heat transfer fluid. The flow rate in the collector loop is variable. The system works as a preheating system for space heating.

### Heat management philosophy

The flow rate in the collector loop can vary from 20 to 100% of the maximum flow. When the temperature at the middle of the storage tank is below 45 °C, the flow rate in the collector loop is adjusted to give a difference of 30 °C between the collector outlet and the middle of the tank. Otherwise, it is adjusted to 15 °C. When the temperature at the middle of the storage tank exceeds 90 °C, or if the temperature difference between the collector outlet and the bottom of the tank drops below 4 °C, the collector loop pump is switched off. When the temperature at the top of the storage tank drops below 54 °C, auxiliary heating is activated. When the temperature at the middle of the storage tank is 3 °C higher than the space-heating loop return temperature, the three-way valve is opened to allow circulation through the tank.

### Specific aspects

The collector loop heat exchanger is placed in a conical stratifier surmounted by a vertical pipe with horizontal outlets at different levels to allow stratified charging of the store. Due to the relatively large opening at the bottom of this stratification device, the flow rate on the secondary side is two to three times larger than the flow rate through the collector loop heat exchanger. For the preparation of DHW a smooth-tube heat exchanger is mounted on the inside of the tank wall. The upper part of the tank only used to heat DHW is separated from the lower part for space heating by a horizontal plate to maintain thermal stratification. The drainback construction gives protection from overheating and freezing.

### Influence of the auxiliary energy source on system design and dimensioning

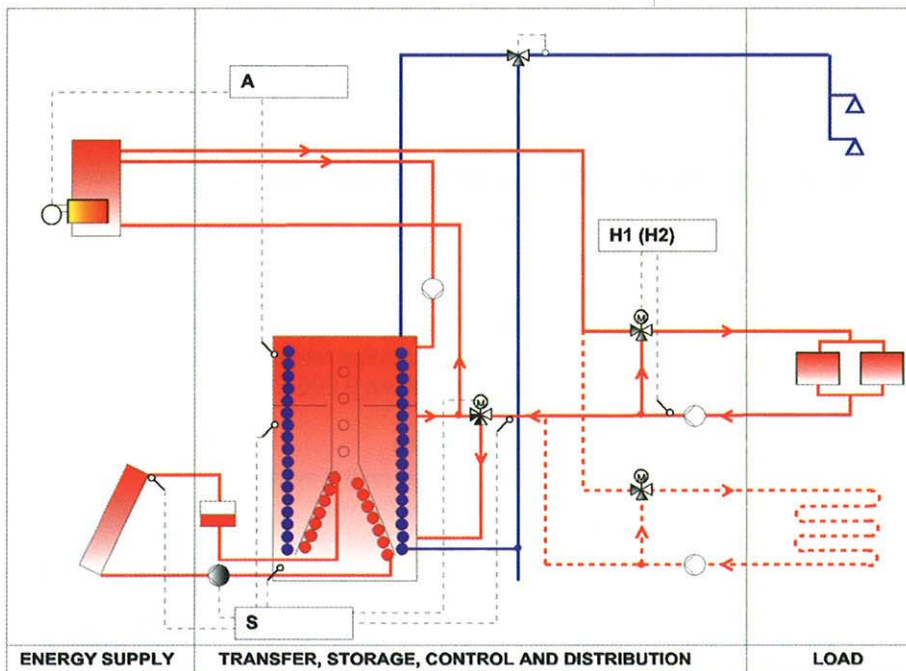
The storage tank works as a preheating device for the boiler. Hence, it is important that the boiler can be operated with intermittent operation. To allow long periods of operation with resulting energy savings, the minimum heating power should be as low as possible.

### Cost (range)

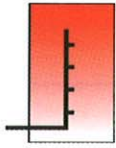
The total cost for this system with 10 m² of solar collectors (auxiliary boiler and radiator loop included) is about 18 450 EUR. A similar reference system without solar heating costs about 9 000 EUR.

### Market distribution

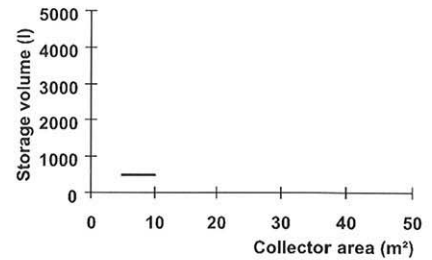
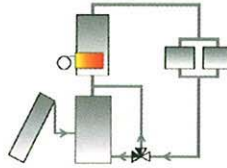
This system has been on the market since 1996. The total collector area in operation is about 1000 m², installed by one company.







DS



### Main features

The heart of this storage tank is three thermosyphon heat exchangers with stratifiers which allow charge and discharge without using pumps. The DHW is heated instantaneously in the upper heat exchanger. This method guarantees the hygienic quality of DHW from large volume tanks. The tank operates at atmospheric pressure and is constructed of long-lasting polypropylene material which avoids corrosion problems. The insulation material is expanded polypropylene foam and complies with environmental requirements regarding production, usage and disposal. The system works as a preheating system for space heating.

### Heat management philosophy

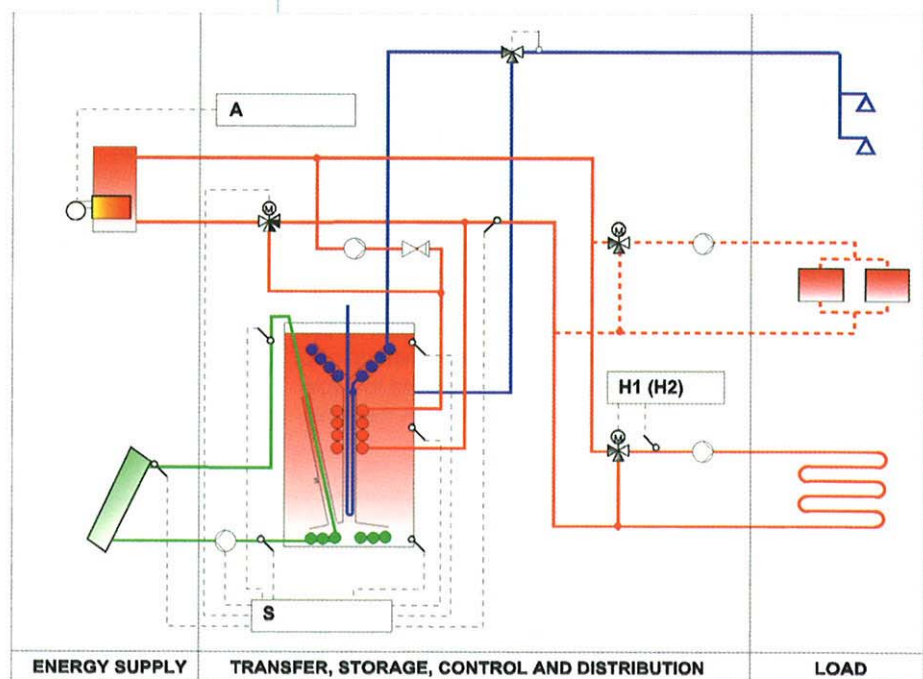
The system is operated in three different modes: Summer mode 1: interval pumping mode when the collector temperature is higher than the temperature at the bottom of the storage tank (pump is run at intervals to give a usable water temperature). Summer mode 2: permanent pumping mode when the collector temperature is higher than a set-point temperature at the top of the tank (e. g. 60 °C). Winter mode: permanent pumping mode when the collector temperature is higher than the temperature at the bottom of the storage tank. An optional control feature is automatic change between summer and winter modes, based on the temperature in the space heating loop.

### Specific aspects

The solar heat exchanger is placed at the bottom of the tank and the tank is charged via a stratifier with two outlets: the lower outlet allows preheating of the lower part of the tank, the upper outlet delivers solar heated water for immediate use. The level of water in the store has to be checked every 2 to 3 years. Instantaneous heating of DHW in the heat exchanger eliminates the risk of legionella. The very light tank makes this system easy to install.

### Influence of the auxiliary energy source on system design and dimensioning

The system is not suitable for wood-fired boilers burning logs because the buffer volume is too small. Electrical heating devices are offered as an option.



### Cost (range)

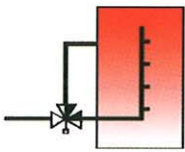
The total cost of the system (auxiliary boiler and heating floor included) is 13 750 to 15 050 EUR, for a collector area of 6 to 10 m². A similar reference system without solar heating costs about 9 000 EUR.

### Market distribution

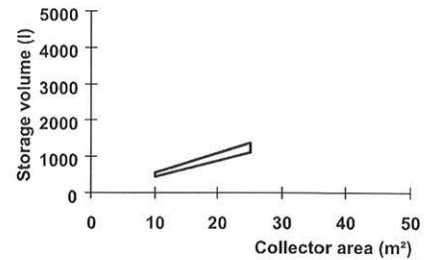
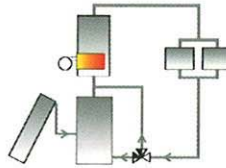
This system has been on the market since 1996, marketed by two companies. The total collector area in operation is about 10 000 m², with about 1400 systems installed by 450 companies in several countries: Germany, Austria, Switzerland, Spain and Belgium. Manufacturer: CONSOLAR







B/DS/



### Main features

This system is a one-store system, in which DHW is instantaneously heated up in a finned-tube heat exchanger with a maximum discharge power of about 50 kW. The DHW heat exchanger is placed at the top of the tank in a vessel with a vertical tube extending to the bottom of the tank. The water circulates by natural convection and the flow rate in the tube is regulated by a thermohydraulic valve. There is an external heat exchanger in the collector loop. Thermal stratification is enhanced by horizontal inlet pipes with two inlet positions for solar heated water and one for the space heating return. Three different sizes of storage tanks are available: 500, 850, and 1200 litre with typical collector areas of 10 to 25 m². The system works as a preheating system for space heating. All auxiliary boilers, with intermittent operation or with long running time can be used.

### Heat management philosophy

The collector pump is controlled by the temperature difference between the collector outlet and the bottom of the store. The boiler used for space heating also supplies auxiliary energy for the DHW cycle at the top of the tank, and is controlled by a thermostat with a typical set-point of 55 to 60 °C. When the temperature in the tank is too low, the boiler supplies heat directly to the space heating distribution loop, thus bypassing the tank and helping to reduce heat losses.

### Specific aspects

In order to achieve a high degree of stratification in the storage tank the flow of water through the vertical tube inside the tank is regulated by a thermohydraulic valve placed inside the tube beneath the heat exchanger. The valve is connected to expansible material at the domestic-hot-water outlet. In this way, the domestic-hot-water outlet temperature is almost constant, independent of the hot-water demand and of the water temperature in the store.

Any discharge of water via the DHW heat exchanger results in cold water (about 20 to 30 °C) flowing through the tube to the bottom of the tank. Overheating protection is provided by a large expansion vessel, dimensioned so that it is able to contain the fluid volume expelled from the collectors by the vapour produced in them when stagnation occurs.

### Influence of the auxiliary energy source on system design and dimensioning

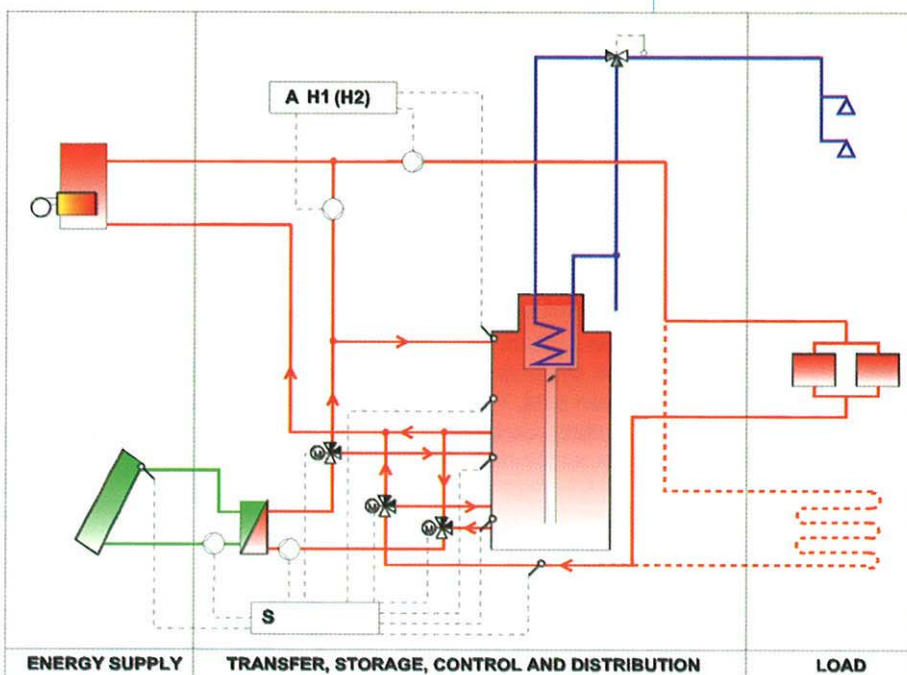
This system can be used either with an auxiliary boiler capable of intermittent operation (gas or oil) or with a long-running-time boiler. In the latter case, the hydraulic scheme is slightly different: the tank is not series-connected in the return line of the space heating loop, but is used as a buffer tank for the boiler.

### Cost (range)

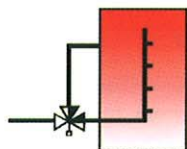
The cost of the tank is between 2300 EUR (500 l) and 3225 EUR (1200 l). The total cost of the system (auxiliary boiler and radiator loop included) is 15 700 EUR for a 10-m²-collector with a 500-litre-storage-tank system, 17 800 EUR for a 14-m²-collector with a 850-litre-storage-tank system, and 18 100 EUR for a 14-m²-collector with a 1200-litre-storage-tank system, respectively. A similar reference system without solar heating costs about 9 000 EUR.

### Market distribution

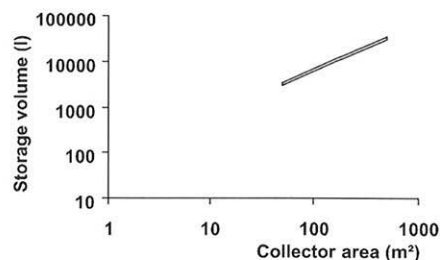
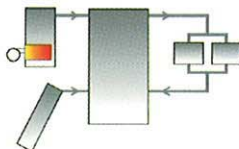
This system has been marketed by one company in Germany since 1997, and several hundred systems have been sold.







B/DM/



### Main features

The system is intended to supply estates of terraced houses or multi-family dwellings. For best possible system operation, low-temperature heating systems (wall or floor heating) are required. The individual houses or flats are supplied from the central storage tank via a local heating network operated at a low temperature (40 °C) for the supply of heat for space heating. The same local heating network is operated at a higher temperature (65 - 70 °C) for heating the decentralised domestic hot water storage tanks. During this period the space heating is switched off.

### Heat management philosophy

**Collector loop:** The collector loop pump starts when the temperature at the collector outlet is higher than the temperature at the bottom of the tank. On the secondary side, the pump only starts when the temperature at the heat exchanger inlet is higher than the temperature at the bottom of the tank. Both pumps are switched off when the temperature at the heat exchanger inlet drops below the temperature at the bottom of the tank. The two loops are operated on a low-flow principle.

**Auxiliary boiler:** The biomass boiler starts up when the solar yields are insufficient to heat the tank to a given temperature for current requirements. The water temperature in the upper part of the main tank should be 45 °C for the supply of heat for space heating. At lower temperatures the boiler is switched on and heats up the tank until the middle sensor shows approximately 70 °C. In the periods reserved for domestic hot water preparation (once or twice a day, depending on the boiler volume and DHW consumption) this sensor must show a temperature of at least 65 °C. Otherwise the boiler is switched on and heats the water to about 70 °C. The volume for the supply/storage of heat for DHW preparation required in the main tank is calculated according to consumption, the volume of the decentralised DHW tanks, the capacity of the pipework between the central tank and the DHW tanks, and the time available for domestic water heating.

**Space heating:** Heat is supplied for space heating using a differential-pressure-regulated network pump and regulated by the outside air temperature. It is available for approximately 20-22 hours depending upon the loading time for the decentralised DHW storage tanks.

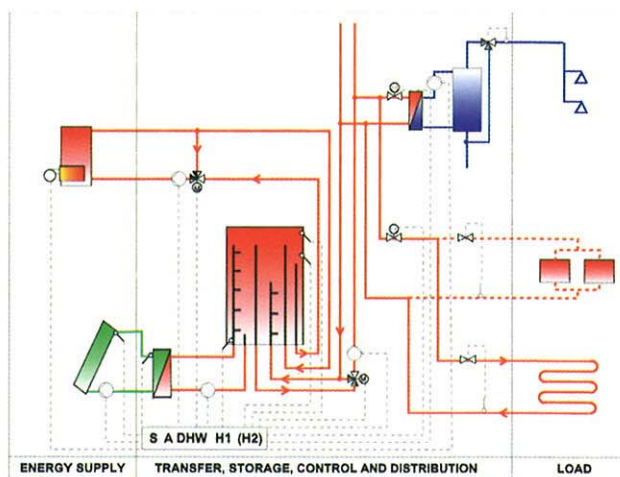
**Preparation of DHW:** The DHW storage tanks are charged to 60 °C once or twice a day (about 2 to 4 hours) at pre-selected „DHW preparation times“. In these periods the heat supply for space heating is interrupted and the network flow line is raised to about 65 °C.

### Influence of the auxiliary energy source on system design and dimensioning

Biomass (woodchips or pellets) is usually used as auxiliary energy. Oil, gas or district heating could be also used.

### Cost (range)

Due to the wide variety of plants, the costs, especially the cost for the heating loop, depend very strongly on the number and sizes of dwellings as well as on the collector size. Therefore, for easier comparison, both the total and the reference costs are given for systems excluding the heating loop and are related to the collector area. The cost for the solar heating system includes the roof-mounted collectors, collector pipework with insulation, solar hydraulic equipment, antifreeze fluid and a wood chip boiler. The total cost varies between 720 EUR/m² for a small system (50 m² collector / 3 m³ storage tank) and 310 EUR/m² for a big one (500 m² collector / 30 m³ storage tank). Reference cost for the same size of heating system without solar collectors varies between 220 EUR/m² and 60 EUR/m² (cost given per m² of solar collector in the corresponding solar heating systems), so that the solar-related additional cost varies between 500 and 250 EUR/m² of solar collector.

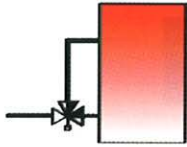


### Market distribution

This system has been marketed in Austria since 1997 and five systems, with a total collector area of 450 m², have been sold. Two companies manufacture and market this system. So far, it has only been installed in Austria. Manufacturers: Sonnenkraft GmbH, SOLID.







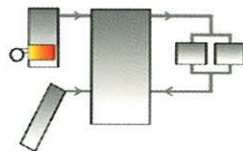
### Main features

These systems can be considered as long-term storage systems since the tank sizes may be several cubic metres. The goal is to achieve high solar fractions. Two systems are presented below. The first is already on the market, whereas the second is a prototype.

## Large Tank-in-Tank for Seasonal Heat Storage SWITZERLAND

# #20

BM(I)



### Main features

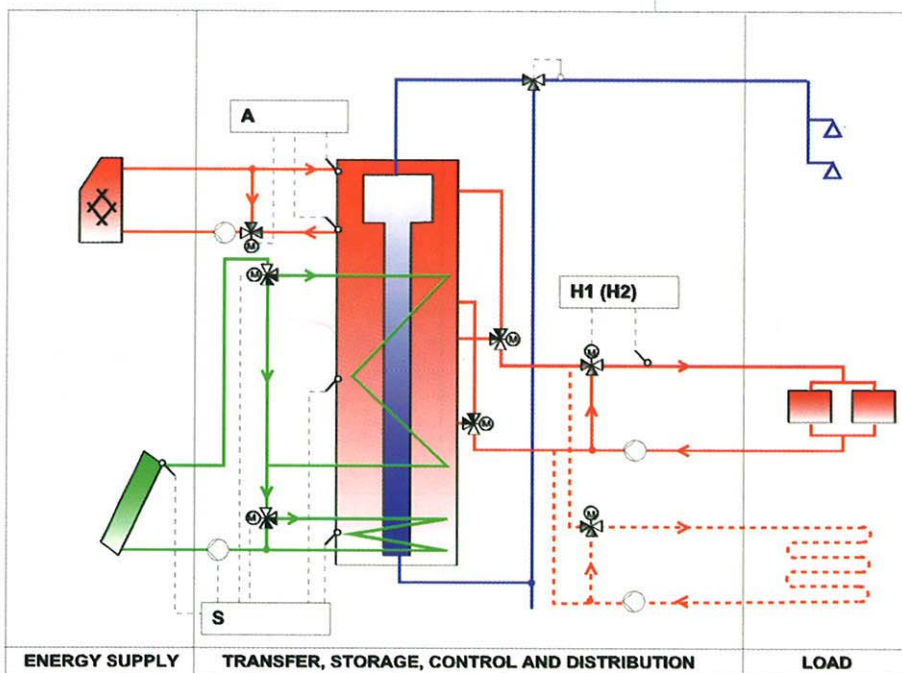
This system is very similar to the Swiss system „Small DHW Tank in Space Heating Tank“. A DHW tank with a characteristic shape is placed in the space-heating storage tank. Heat charge to and discharge from the storage tank are controlled by 3-way valves. A high solar fraction can be obtained in a single-family house with a collector area up to 100 m<sup>2</sup> and a storage volume up to 20 m<sup>3</sup>.

### Influence of the auxiliary energy source on system design and dimensioning

This system can be used either with an auxiliary boiler capable of intermittent operation (gas or oil) or with a long-running-time boiler.

### Market distribution

About 40 systems, with a mean collector area of 60 m<sup>2</sup> and a mean storage volume of 15 m<sup>3</sup>, have been installed in Switzerland. Some systems are also found in the South of Germany. The combitank is produced by one company.

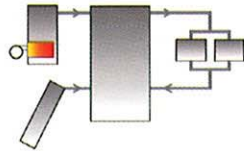




## #21

### Large Stratified Tank for Seasonal Heat Storage, Air Heating System GERMANY

BM/S(I)



#### Main features

This system, installed in a passive solar office building, can be considered as a prototype. It has 64 m<sup>2</sup> roof-integrated solar collectors and an 87 m<sup>3</sup> storage tank.

#### Heat management philosophy

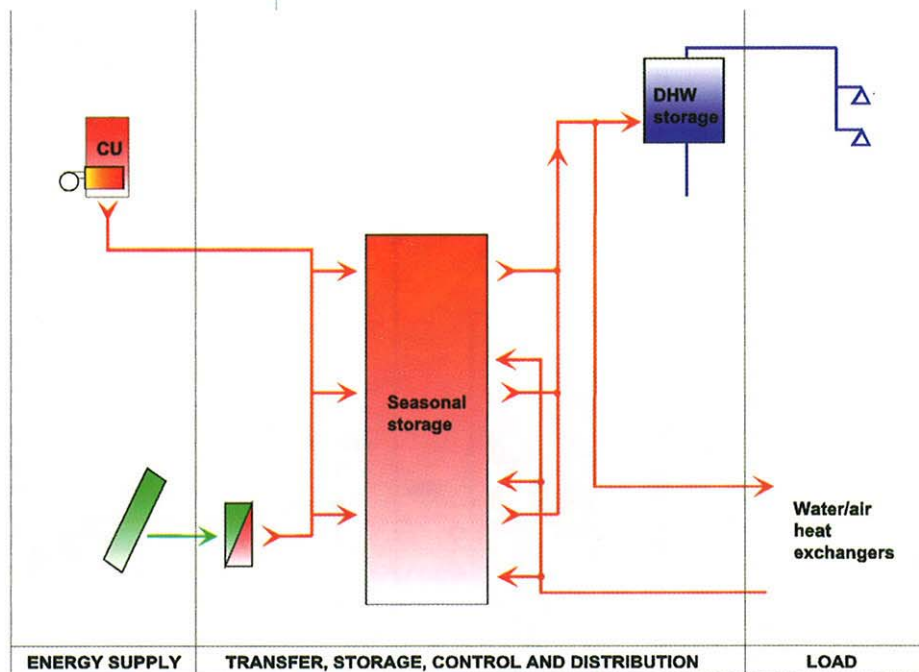
To maintain good stratification, heat can be charged to and discharged from the storage tank at different levels. The storage tank is charged by the solar collectors and a cogeneration unit (CU). The hydraulic scheme is only schematic.

#### Specific aspects

Heat for space heating is delivered by a mechanical heating and ventilating system.

#### Influence of the auxiliary energy source on system design and dimensioning

In this prototype, auxiliary energy is provided by a cogeneration unit, but a conventional boiler could also be used.





# Task Participants

## Austria

**Werner Weiss\*, Christian Fink**  
Arbeitsgemeinschaft  
ERNEUERBARE ENERGIE - AEE  
Feldgasse 19  
A-8200 Gleisdorf  
Tel.: +43 - 3112 588617  
Fax: +43 - 3112 588618  
e-mail: [w.weiss@aee.at](mailto:w.weiss@aee.at), [c.fink@aee.at](mailto:c.fink@aee.at)  
[http://www.datenwerk.at/arge\\_ee/](http://www.datenwerk.at/arge_ee/)

**Wolfgang Streicher, Richard Heimrath**  
Graz University of Technology  
Institute of Thermal Engineering  
Inffeldgasse 25  
A-8010 Graz  
Tel.: +43 - 316 - 873 706  
Fax: +43 - 316 - 873 7305  
e-mail: [streicher@iwt.tu-graz.ac.at](mailto:streicher@iwt.tu-graz.ac.at),  
[heimrath@iwt.tu-graz.ac.at](mailto:heimrath@iwt.tu-graz.ac.at)  
<http://wt.tu-graz.ac.at>

## Denmark

**Klaus Ellehauge\*, Line Louise Overgaard**  
Solar Energy Center Denmark  
Technological Institute  
DK-8000 Aarhus C  
Tel.: +45 - 72 20 13 70 (Ellehauge) /  
71 (Overgaard)  
Fax: +45 - 72 20 12 12  
e-mail: [klaus.ellehauge@teknologisk.dk](mailto:klaus.ellehauge@teknologisk.dk),  
[Line.Overgaard@teknologisk.dk](mailto:Line.Overgaard@teknologisk.dk)  
<http://www.solenergi.dk/center/>  
<http://www.teknologisk.dk/>

**Simon Furbo, Louise Jivan Shah**  
Solar Energy Center Denmark  
Technical University of Denmark  
Department of Buildings and Energy  
Build. 118  
DK-2800 Lyngby  
Tel.: +45 - 45 251857 (Furbo) / 88 (Shah)  
Fax: +45 - 45 931755  
e-mail: [sf@ibe.dtu.dk](mailto:sf@ibe.dtu.dk), [ljs@ibe.dtu.dk](mailto:ljs@ibe.dtu.dk)  
<http://www.ibe.dtu.dk>

## Finland

**Petri Konttinen\***  
Helsinki University of Technology  
Advanced Energy Systems  
P.O. Box 2200  
FIN-02015 HUT  
Tel.: +358 - 9451 3212  
Fax: +358 - 9451 3195  
e-mail: [petri.konttinen@hut.fi](mailto:petri.konttinen@hut.fi)  
<http://www.hut.fi/Units/AES/>

## France

**Thomas Letz\***  
ASDER  
P.O. Box 45  
299, rue du Granier  
F-73230 Saint Alban-Leyse  
Tel.: +33 - 479 8588 50  
Fax: +33 - 479 3324 64  
e-mail: [asder@club-internet.fr](mailto:asder@club-internet.fr)

**Philippe Papillon**  
Clipsol-Recherche  
Z.I.  
F-73100 Trevignin  
Tel.: +33 - 479 34 35 39  
Fax: +33 - 479 34 35 30  
e-mail: [clipsol@wanadoo.fr](mailto:clipsol@wanadoo.fr)

## Germany

**Harald Drück\*, Henner Kerskes**  
Stuttgart University  
ITW  
Pfaffenwaldring 6  
D-70550 Stuttgart  
Tel.: +49 - 711 685 3553 (Drück) /  
215 (Kerskes)  
Fax: +49 - 711 685 3503 / 242  
e-mail: [drueck@itw.uni-stuttgart.de](mailto:drueck@itw.uni-stuttgart.de),  
[kerskes@itw.uni-stuttgart.de](mailto:kerskes@itw.uni-stuttgart.de)  
<http://www.itw.uni-stuttgart.de/>

**Klaus Vajen, Ulrike Jordan**  
Marburg University  
Department of Physics  
D-35032 Marburg  
Tel.: +49 - 6421 282 4148  
Fax: +49 - 6421 - 282 6535  
e-mail: [vajen@physik.uni-marburg.de](mailto:vajen@physik.uni-marburg.de),  
[jordan@physik.uni-marburg.de](mailto:jordan@physik.uni-marburg.de)  
<http://www.physik.uni-marburg.de/nfp/solar/solar.html>

## Sweden

**Chris Bales\*, Klaus Lorenz**  
Högskolan Dalarna  
Solar Energy Research Center - SERC  
EKOS  
S-78188 Borlänge  
Tel.: +46 - 23 7787 11 (Bales) / 16 (Lorenz)  
Fax: +46 - 23 7787 01  
e-mail: [cba@du.se](mailto:cba@du.se), [klo@du.se](mailto:klo@du.se)  
<http://www.du.se/ekos/serc/serc.html>

**Peter Kovács**  
SP - Swedish National Testing and  
Research Institute  
P.O. Box 857  
S-501 15 Borås  
Tel.: +46 - 33 165662  
Fax: +46 - 33 131979  
e-mail: [peter.kovacs@sp.se](mailto:peter.kovacs@sp.se)  
<http://www.sp.se/energy/>

**Bengt Perers**  
Vattenfall Utveckling AB  
The Swedish National Power Board  
P.O. Box 1046  
S-61129 Nyköping  
Tel.: +46 - 155 293125  
Fax: +46 - 155 293060  
e-mail: [bengt.perers@utveckling.vattenfall.se](mailto:bengt.perers@utveckling.vattenfall.se)

## Switzerland

**Jean-C. Hadorn\***  
Swiss Research Program  
CH-1035 Bournens  
Tel.: +41 - 21 732 13 20  
Mobile: +41 79 210 57 06  
Fax: +41 - 21 732 13 20  
e-mail: [jchadorn@swissonline.ch](mailto:jchadorn@swissonline.ch)

**Jean-Marc Suter**  
Büro n+1  
P.O. Box 130  
CH-3000 Bern 16  
Tel.: +41 - 31 350 00 04  
Fax: +41 - 31 352 77 56  
e-mail: [suter@email.ch](mailto:suter@email.ch)

**Ueli Frei, Peter Vogelsanger,  
Beat Menzi**  
SPF-HSR  
P.O. Box 1475  
CH-8640 Rapperswil  
Tel.: +41 - 55 222 48 22  
Fax: +41 - 55 210 61 31  
e-mail: [ueli.frei@solarenergy.ch](mailto:ueli.frei@solarenergy.ch),  
[peter.vogelsanger@solarenergy.ch](mailto:peter.vogelsanger@solarenergy.ch),  
[beat.menzi@solarenergy.ch](mailto:beat.menzi@solarenergy.ch)  
<http://www.solarenergy.ch>

**Philippe Dind, Oliver Renoult,  
Jacques Bony**  
School of Engineering (EIVD)  
Route de Cheseaux 1  
CH-1400 Yverdon-les-Bains  
Tel.: +41 24 423 23 59 (Dind) /  
83 (Renoult, Bony)  
Fax: +41 24 425 00 50  
e-mail: [Philippe.Dind@eivd.ch](mailto:Philippe.Dind@eivd.ch),  
[renoult@eivd.ch](mailto:renoult@eivd.ch), [bony@eivd.ch](mailto:bony@eivd.ch)

## The Netherlands

**Huib Visser\***  
TNO  
Building and Construction Research  
Division Building & Systems  
P.O. Box 49  
NL-2600 AA Delft  
Visiting address:  
Schoemakerstraat 97  
NL-2628 VK Delft  
Tel.: +31 - 15 2695246  
Fax: +31 - 15 2695299  
e-mail: [h.visser@bouw.tno.nl](mailto:h.visser@bouw.tno.nl)  
<http://www.bouw.tno.nl>

## USA

**William A. Beckman\***  
University of Wisconsin  
Solar Energy Laboratory  
1500 Engineering Dr.  
USA-Madison, WI 53706  
Tel.: +1 - 608 263 1590  
Fax: +1 - 608 262 8464  
e-mail: [beckman@engr.wisc.edu](mailto:beckman@engr.wisc.edu)  
<http://www.sel.me.wisc.edu/>

\* National contact person



## Austria

### **SOLID**

Christian Holter  
Herrgottwiesgasse 188  
A-8055 Graz  
Tel.: +43 - 316 292840 0  
Fax: +43 - 316 292840 28  
e-mail: [solid@styria.com](mailto:solid@styria.com)

### **Solarteam GmbH**

Martin Bergmayr  
Jörgmayrstraße 12  
A-4111 Walding  
Tel.: +43 - 7234 83550  
Fax: +43 - 7234 835509

### **Sonnenkraft GmbH**

Peter Prasser  
Resselstrasse 9  
A-9065 Ebental  
Tel.: +43 - 463 740 958  
Fax: +43 - 463 740 958 17  
e-mail: [peter.prasser@sonnenkraft.com](mailto:peter.prasser@sonnenkraft.com)  
<http://www.sonnenkraft.com>

## Denmark

### **Batec A/S**

E. Brender  
Danmarksvej 8  
DK 4681 Herfølge  
Tel.: +45 - 56 27 5050  
Fax: +45 - 56 27 6787  
e-mail: [admin@batec.dk](mailto:admin@batec.dk)  
<http://www.batec.dk>

## Finland

### **Fortum New Technology Business**

Janne Jokinen  
P.O. Box 100  
FIN-00048 Fortum  
Tel.: +358 - 10 452 4192  
Fax: +358 - 10 452 5797  
e-mail: [Janne.Jokinen@fortum.com](mailto:Janne.Jokinen@fortum.com)  
<http://www.fortum.com>

## France

### **Clipsol**

Philippe Papillon  
Zone Industrielle  
F-73100 Trevignin  
Tel.: +33 - 479 34 35 39  
Fax: +33 - 479 34 35 30  
e-mail: [clipsol@wanadoo.fr](mailto:clipsol@wanadoo.fr)

## Germany

### **SOLVIS- Solarsysteme GmbH**

Thomas Krause  
Marienberger Straße 1  
D-38122 Braunschweig  
Tel.: +49 - 531 28906 37  
Fax: +49 - 531 28906 60  
e-mail: [tkrause@solvis-solar.de](mailto:tkrause@solvis-solar.de)  
<http://www.solvis-solar.de>

### **Consolar Energiespeicher- und Regelungssysteme GmbH**

Andreas Siegemund  
Dreieichstrasse 48  
D-60594 Frankfurt  
Tel.: +49 - 69 619911 44  
Fax: +49 - 69 619911 28  
e-mail: [andreas.siegemund@consolar.de](mailto:andreas.siegemund@consolar.de)  
<http://www.consolar.de>

## Sweden

### **Borö-Pannan AB**

Bo Ronnkvist  
Bangardsuagen 1  
S-95231 Kalix  
Tel.: +46 - 923 16680  
Fax: +46 - 923 13797  
<http://www.boroe.com>

## Switzerland

### **AGENA**

M.C. Jobin  
Le Grand Pré  
CH-1510 Moudon  
Tel.: +41 - 21 905 26 56  
Fax: +41 - 21 905 43 88  
e-mail: [maillatjobin@mcmi.ch](mailto:maillatjobin@mcmi.ch)

### **SOLTOP Schuppisser AG**

Fritz Schuppisser  
St. Gallerstrasse 7  
CH-8353 Elgg  
Tel.: +41 - 52 364 00 77  
Fax: +41 - 52 364 00 78  
e-mail: [email@soltop.ch](mailto:email@soltop.ch)

### **Jenni Energietechnik AG**

Josef Jenni  
Lochbachstrasse 22  
CH-3414 Oberburg  
Tel.: +41 - 34 422 37 77  
Fax: +41 - 34 422 37 27  
e-mail: [info@jenni.ch](mailto:info@jenni.ch)

## The Netherlands

### **ATAG Verwarming B.V.**

Erwin Janssen  
P.O. Box 105  
NL-7130 AC Lichtenvoorde

### **Daalderop B.V.**

Jeroen Noij  
P.O. Box 7  
NL-4000 AA Tiel

### **Zonne-Energie Nederland**

Paul Kratz  
De Run 5421  
NL-5504 DG Veldhoven



## Photos on Front and Back Cover



### 1 Row house, Gleisdorf, Austria

Generic system: Two stores (Parallel) (2 different versions); Collector area: 230 m<sup>2</sup>; Storage volumes: 1 x 0.1 and 6 x 0.15 m<sup>3</sup> for domestic hot water, 14 m<sup>3</sup> for space heating; Auxiliary heater: wood boiler

### 2 Multi-family house and kindergarden, Hohenau, Austria

Generic system: Two stores; Collector area: 120 m<sup>2</sup>; Storage volumes: 2 x 0.8 m<sup>3</sup> for domestic hot water, 5 m<sup>3</sup> for space heating; Auxiliary heater: wood boiler

### 3 Private house, Wolfsburg, Germany

Generic system: Two stratifiers in space heating storage tank with external load side heat exchanger for DHW; Collector area: 7.5 m<sup>2</sup>; Storage volume: 0.4 m<sup>3</sup>

### 4 Single-family house, Bortfeld, Germany

Generic system: Two stratifiers in space heating storage tank with external load side heat exchanger for DHW; Collector area: 7.5 m<sup>2</sup>; Storage volume: 0.4 m<sup>3</sup>





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