WP1.E2 / THEORETICAL EVALUATION OF PROMISING SYSTEM: Solar Combisystem Concept With Water Filled Collector Loop

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/3/ Jens Peter Meyer, Innovative Systeme der Solarthermie, Bielefelder Verlag, Sonne Wind & Wärme 3/2005
/4/ markt intern `markt intern`-Innovationspreis 2005 markt intern – Nr. ISH 18/26

SUMMARY

Today most solar thermal systems in Germany are used for domestic hot water production in single or small multi-family houses. More recently a trend towards so-called solar combisystems can be observed. Solar combisystems are systems that contribute to both, domestic hot water preparation and space heating. At present solar combisystems can save approximately 20 to 30 % of the primary energy required for domestic hot water preparation and space heating in a typical single family house under average German climate conditions.

There are various designs of solar combisystems available. With regard to the store, the major difference between a combistore and a solar domestic hot water store is that in combistores the water of the space heating system is used as storage medium. The combistore is connected to the system in such a way that it can be charged simultaneously by solar energy and by a conventional fossil fuel fired boiler. The space heating loop is directly connected to the combistore. The thermal energy from the combistore is transferred to the domestic hot water line via an internal or external heat exchanger. A system based on a combistore as described above is considered as the reference system in the present report, as it represents the type of combisystem most frequently used in Germany. The evaluation of the promising system type introduced in the second part of this report is based on a comparison with this reference system.

The promising system type is a solar combisystem that works without antifreeze-fluid. An innovative freezing protection algorithm with minimal energy consumption prevents the collector loop from freezing. This is performed by circulating warm water through the collector loop. This warm water is heated up while passing the heat exchanger in the store.
The existing hot water store has not to be exchanged / replaced by a special solar store, since the heat transfer medium in the collector loop is water and not a special antifreeze-fluid. The solar loop is directly connected to the heating loop.

The main advantages compared to the reference system are that

- the system is compatible with existing heating systems,
- the existing hot water store does not have to be replaced,
- no antifreeze fluid is needed.

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Reference system

Choice and use of the reference system

In this report, the system evaluation is based on a comparison with a reference system. The reference system matches the state of the art of system technology used for (solar) water heating and space heating in Germany.
All statements in the *evaluation* section below are relative to (or in comparison with) the properties of the reference system.

Description of the reference system

Application: Primary purpose: solar domestic hot water preparation and space heating (solar combisystem)

Description: The reference system consists of a solar combistore as the key component, which uses the water of the space heating system as heat storage medium. The combistore stores the heat delivered by the solar radiation and by a conventional fossil fuel or wood fired boiler. The space heating loop is connected directly to the combistore. Domestic hot water is prepared by the combistore via an internal heat exchanger.

A boiler is not regarded as being part of the reference system and therefore it is not included in the cost indicated below. The costs of an appropriate gas or oil boiler will be approximately EURO 3000 (including VAT).
Cost (retail sales price of the reference system without installation, including VAT): Euro 10000.
Dimensioning of the reference system:
Collector aperture area: 12 m²
Store volume: 750 l

The schematic set-up of the reference solar combisystem is shown in Figure 1.

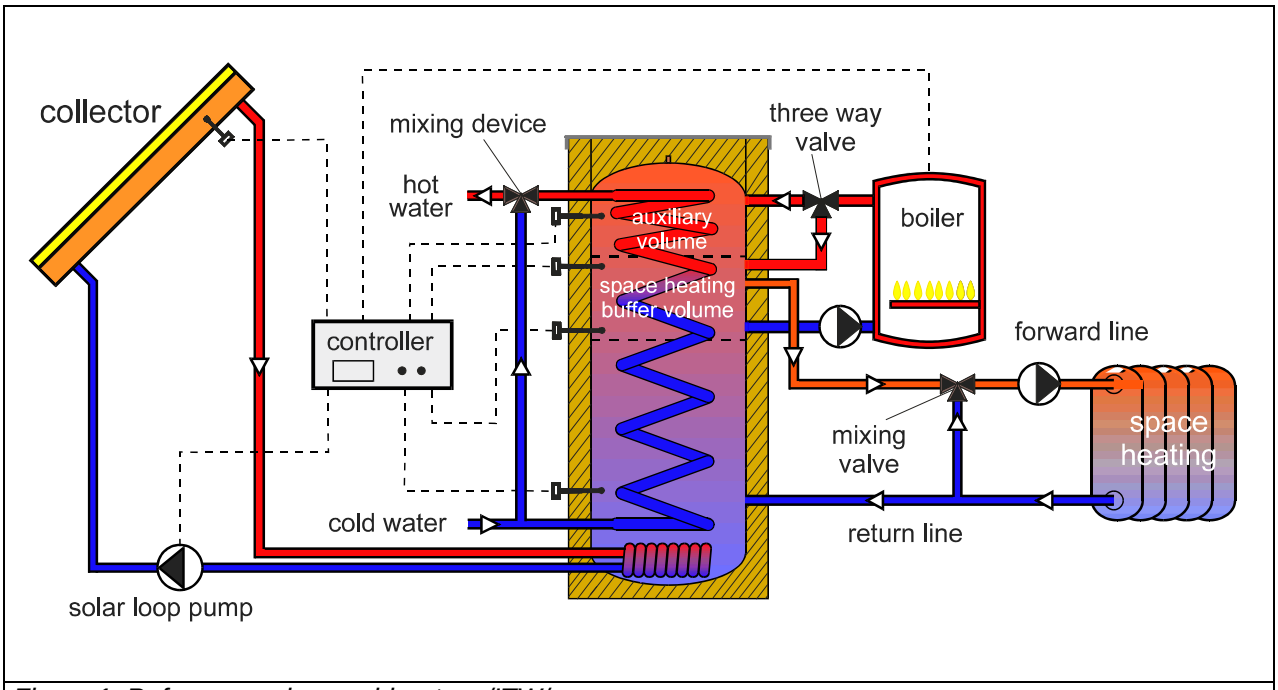

Figure 1: Reference solar combisystem /ITW/

Market: The reference system represents the state of technology in Germany in the year 2005.
Reference: The reference system is described in more detail in NEGST WP1.D1 / SUMMARY REPORT ON TODAY'S SYSTEM TECHNOLOGY, Appendix Germany

Evaluation

Description of the evaluated - solar combisystem concept with water filled collector loop and ETC particularly suitable for retrofitting

Application: Primary purpose: solar combisystem (hot water and space heating)

Description: The collector loop piping of a vacuum tube collector with CPC reflector is directly connected by trap elbows to the store of a conventional heating system. The existing hot water store doesn't have to be exchanged/replaced by a special solar store, since the heat transfer medium in the collector loop is water and not a special antifreeze-fluid. The solar loop is directly connected to the heating loop via additional pipes. The solar heat can be either transported into the DHW store or directly into the flow line of the space heating loop (version A) respectively return line of the space heating loop (version B). The choice of the appropriate version depends on the size of the thermal capacity of the boiler used. The distribution of the solar heat either to the DHW store or to the space heating loop is done by a three-way-valve in the flow line of the solar loop. Different strategies of distributing the heat are available. The collector is operated on the same or higher temperature levels as provided by the gas or oil boiler. An innovative freezing protection algorithm with minimal energy consumption prevents the collector loop from freezing. This is performed by circulating warm water from the store through the collector loop.

The detailed set-up of the innovative combisystem concept (Version A, solar input into the flow line of the space heating loop) is shown in Figure 2.

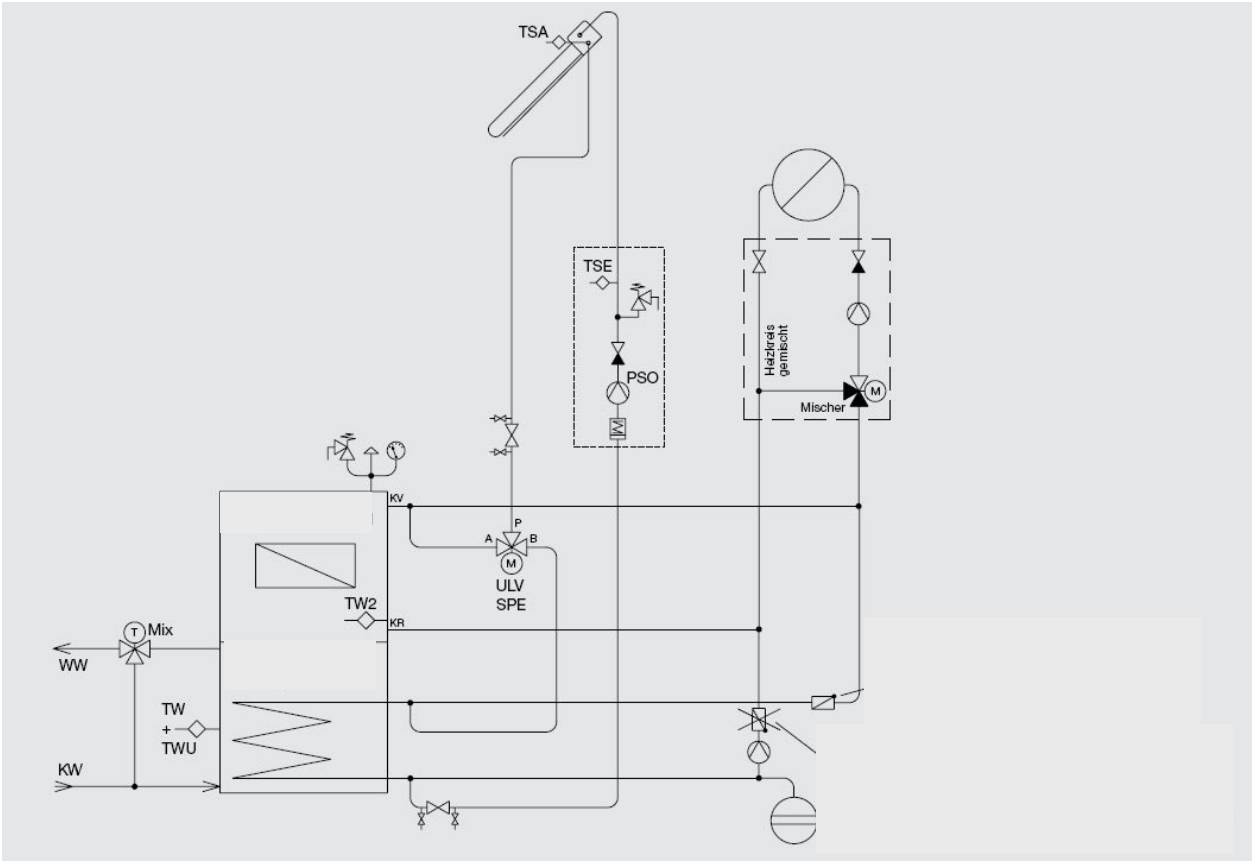

Figure 2: Solar thermal system evaluated Version A (solar input into the flow line of the space heating loop) /Paradigma/

Figure 3 shows the schematic set-up of the innovative combisystem concept with solar input into the return line of the space heating loop (Version B).

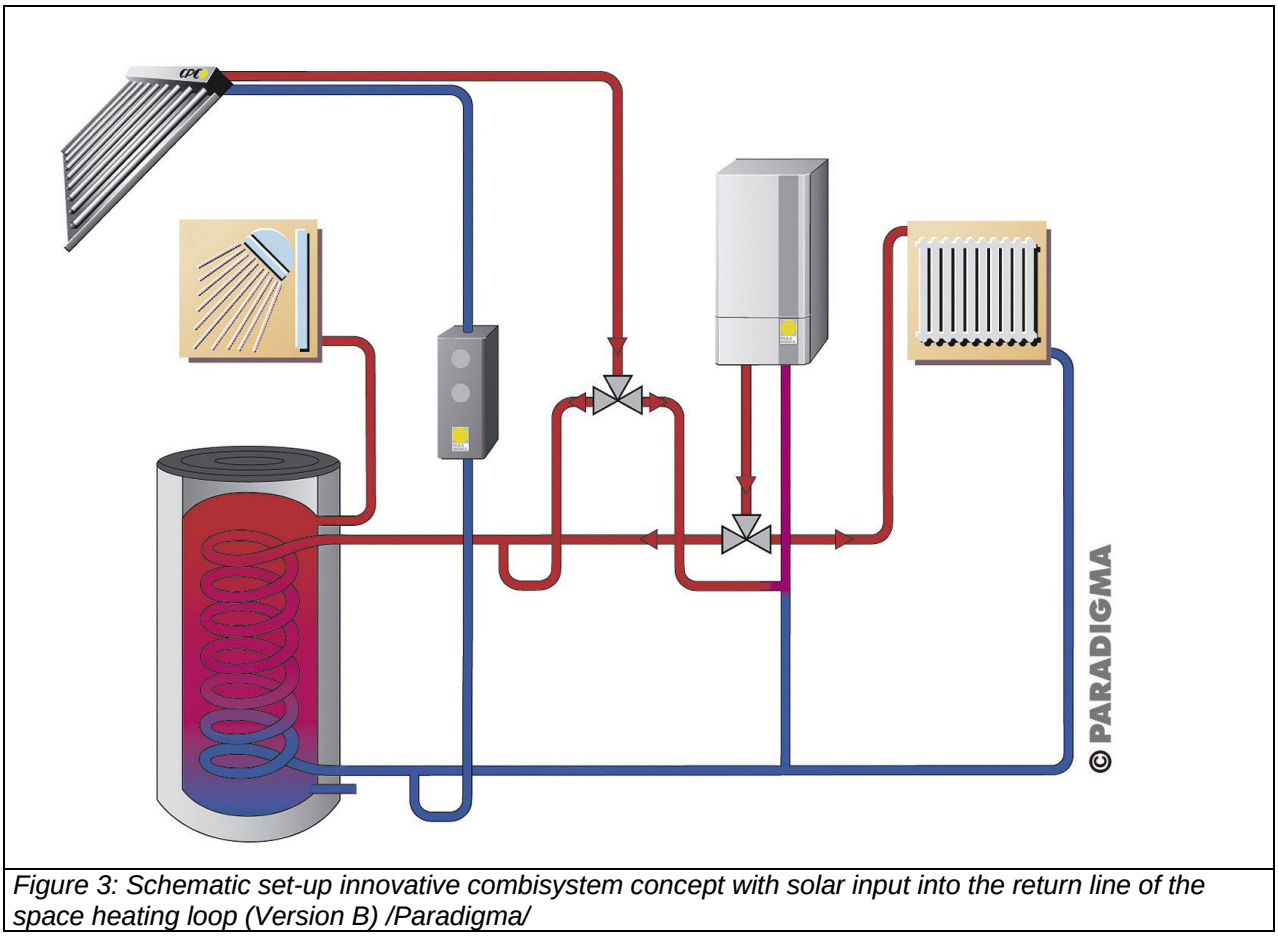

Figure 3: Schematic set-up innovative combisystem concept with solar input into the return line of the space heating loop (Version B) /Paradigma/

The detailed set-up of the innovative combisystem concept with solar input into the return line of the space heating loop (Version B) is shown in Figure 4.

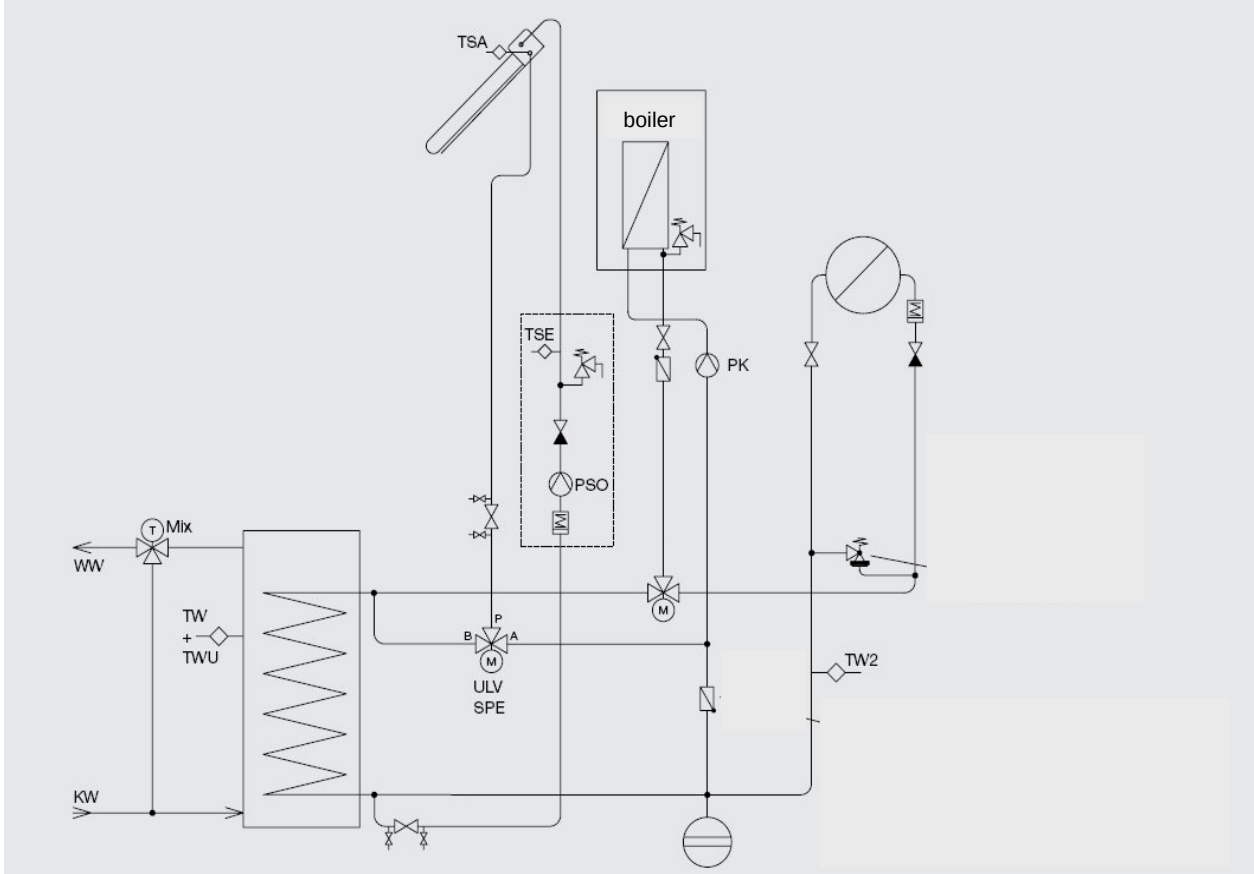

Figure 4: Solar thermal system evaluated Version B (solar input into the return line of the space heating loop) /Paradigma/

The innovative combisystem concept is sold as DHW AquaSystem with additional direct space heating by the company Paradigma, Germany.

The package comprises the components mentioned below. Please note that the names are product specific.

Package components: (in brackets values for a larger system)

- Collector 2xCPC 21(45) Star azzurro – Aperture 7.0 m² (9.0 m²)
- Installation kit for sloped roof, flat roof or front mounting
- Corrugated hose connection set for collector
- Optional DHW-store Aqua 290 (390) but existing stores with volume >= 280 l (>=360 l) can be used
- Pump unit STAqua
- Controller SystaSolar Aqua
- Mixing valve for DHW
- Hydraulic accessory equipment
- Tuning-Set with 3-way-valve for direct space heating connection

The major components of the innovative combisystem concept are shown in Figure 5.

Figure 5: components innovative combisystem concept /Paradigma/

Cost (retail sales price of the system without installation and VAT):

- Package with Collector 2 x CPC 21 Star azzurro including DHW-store: Euro 7,226
- Package with Collector 2 x CPC 21 Star azzurro without DHW-store: Euro 6,071
- Package with Collector 2 x CPC 45 Star azzurro including DHW-store: Euro 8,670
- Package with Collector 2 x CPC 45 Star azzurro without DHW-store: Euro 7,336

Advantages of the innovative combisystem:

- Existing domestic hot water (DHW) stores can be used because almost every heat store with a single heat exchanger can be retrofitted with this system, even horizontal stores
- Separate store volume on low temperature level is not necessary because the high efficient CPC Collector feeds the DHW store only with the same or even higher temperatures than the conventional boiler.
- Special combistore not necessary, since the solar heat is fed directly into the heating circuit on the level of the maximum allowed flow temperature
- If the heat delivered by the solar collector meets the actual temperature demand of the heating loop the boiler doesn't need to start, because:
  Version A: The pump of the space heating loop drives the flow in such a way, that the solar heat is directly fed into the space heating circuit. If the temperature level is sufficient, the boiler is prevented from starting since the sensor measuring the corresponding temperature is located in the flow line downstream to the connection where the solar heat is fed in.
  Version B: The solar heat is feed in the return line of the space heating loop. If the temperature of the fluid entering the boiler is sufficient, the boiler is prevented from starting.
- If the solar heat delivered by the collector loop exceeds the actual heat demand of the space heating loop the heat is stored. The way how the heat is stored depends on the version used:
  Version A: The heat is stored in the buffer volume of the boiler which is usually chared stratified
  Version B: The heat is stored In the space heating circuit and in the radiators. In this case excess heating of the radiators is only possible up to the temperature level at which the thermostatic valves at the radiators will close.
- Smaller specific store volumes are possible (>40 litres/m² collector area) than in typical solar thermal systems (60-80 litres/m² collector area) because the solar heat is used instantly with the provided high temperatures. Furthermore excess heat is stored in the buffer volume of the boiler and/or in the space heating circuit and radiators are used as store
- Except for low energy buildings, approximately the same energy savings than for the reference system can be expected, if the reference system is equipped with a flat plate collector with an aperture area of about 1,25 times the one of the CPC collector
- Immediate charging of the upper volume of vertical DHW-store with a vertically extended heat-exchanger because a significant thermal stratification is generated due to the control algorithm used for operation of the collector loop.
- No additional expansion tank for the collector loop is necessary if the expansion tank of the existing heating system is used also for the solar system
- No maintenance of the heat transfer medium is necessary, because no glycol is used in the system since the collector loop is operated with pure water.
- Standard heating system circulation pumps are used
- Electric energy consumption for the circulation pump is reduced to 50% because an innovative control algorithm reduces the annual operation time of the collector loop from about 2000 h to 800 h. Furthermore this control algorithm maximizes the transported thermal energy in the collector loop related to the amount of fluid volume circulated.
- Automatic function control with daily check of the volume flow rate, counteracting of gravity circulation and acoustic alarm in case of failures ensures correct and secure operation of the system

Disadvantage

- The innovative combisystem concept can be operated only with very high efficient CPC vacuum tube collectors. Otherwise neither the control algorithm of the collector loop nor the freeze protection algorithm is applicable.
- Heat from the store is used for freeze protection. However, under average German climate conditions this disadvantage is negligible (ca. 30 kWh thermal energy plus ca. 2 kWh electrical energy for the pump).

Cost and savings

Material and manufacturing:

- In most applications, no additional store or expansion vessel is needed, especially when the already installed components are not too old.
- Special antifreeze heat transfer medium is not necessary.
- In comparison to the reference system about 20% less collector area and therefore less material is needed for the same energy savings, because of a higher collector efficiency resulting in a larger energy output per m² collector area if the CPC collector is used.

Installation:

- The existing store does not have to be replaced. There are not many changes required in the conventional part of the heating system. It is just necessary to insert two T-pieces, one in the flow line and one in the return line of the DHW store directly near to the store. The piping of the solar circuit is connected by trap elbows to these T-pieces. The space heating loop has to be connected with the solar loop by a relatively simple third and fourth connection
- In most cases, no additional expansion tank has to be installed. The existing expansion vessel of the heating system is also used to compensate the expansion of the solar circuit, which needs a significant expansion volume only in summer during stagnation time, when the heating is switched off and therefore does not need the expansion volume.
- No separate venting for the solar circuit has to be installed, because the air is led into the heating system where usually air bleeders are installed. Entrainment of air into the solar circuit is prevented by the trap elbow connection.
- The filling and venting of the system can easily be done by connecting the solar circuit to the tap water, which usually provides enough pressure. A special pressure pump is not necessary. So the process of taking the system into operation needs less time compared to the reference system.

Maintenance:

- As the system has a function control with acoustic alarm any matter which affects the function of the system seriously is detected. Possible failures are determined by special algorithms i.e. a too low volume flow rate in the collector loop. When the acoustic alarm is activated, the installer is to be informed to check the system. If a failure is detected, the controller reacts in a way to prevent the solar system from being harmed and keeps the system in operation if possible.
- Regularly maintenance should take place during the annual maintenance of the heating system, as the innovative concept is directly connected to the heating system. Most of the maintenance like the check of the system pressure, the pressure of the expansion tank and the anodes of the store have to be done also without having a solar thermal system installed. The only necessary solar specific maintenance is to check the volume flow rate in the collector loop and a visual inspection of the collector, e. g. if the vacuum tubes and the thermal insulation of the piping is undamaged. The cost of maintenance is lower than for usual solar thermal system because the heat transfer medium doesn't have to be checked and also not to be replaced. If water is missing in the system, the system can simply be filled up by using the pressure of tap water. For systems operated with antifreeze heat transfer medium an additional pump is required for filling up the system.

Combined cost:

With regard to the sum of the costs for material, manufacturing, installation and maintenance a substantial cost reduction can be expected of the DHW AquaSystem with additional direct space heating compared to the reference system.

Performance and energy savings, including embodied energy:

The performance is expected to be similar to the performance of the reference system but with about 20% less effective collector area. The embodied energy is significant smaller as there is usually no need to replace the existing domestic hot water store by a solar combistore. This is due to the aspect that the amount of energy additionally required for the freeze protection is under average German conditions negligible and that the system is equipped with a high efficient tubular collector.

Cost performance ratio:

A substantial improvement/reduction of the cost/performance ratio compared to the reference is expected.

Additional benefits

Safety and health:

As the annual tap water temperature at the outlet of the DHW store compared to the reference is higher, the growth of legionella will be reduced.

Range of application, extra service, extra comfort, extra function:

The range of application for the innovative combisystem is fairly wide. Additional standard systems are available for DHW only and DHW and space heating with combistores (high solar fraction). Larger systems for district heating, solar cooling and process heat are under development and pilot plants are currently monitored. The innovative combisystem with additional direct space heating, version B provide an extra comfort in times when the heating (boiler and circulation pump of the heating) is still off. In these cases the circulation pump of the solar loop can deliver heat into the space heating circuit by its own. E.g. opening the thermostats in the bathroom or in a usually cold room in the cellar can offer a solar heated comfortable atmosphere free of charge and without activating the conventional heating system.

Environmental friendliness:

The CPC vacuum tube collector is built up mostly of pure materials like glass, metal, and other homogenous materials. Only a very small amount of insulation material is used and materials are not glued together. The structural components can be separated easily and used again.

The use of water as heat transfer medium avoids environmental problems which could occur in the production, during starting-up, operation, maintenance of the systems and disposal of antifreeze agents. E.g. if glycol flows into a rainwater collecting system through a leaking pipe or collector, problems can occur by growing of algae and bacteria.

Aesthetics, building integration and space requirement:

The CPC collector has an aperture/gross area ratio of more than 90% which is comparable to flat plate collectors. As the energy output is about 20% higher the system needs less space than the reference on the roof. Since there is no need for a large combistore; small boiler rooms are no obstacle for the installation of an DHW AquaSystem with additional direct space heating.

Technical integration:

The integration of the innovative combisystem concept is easy and done almost the same way as connecting a second boiler. The piping of the already existing heating system has not to be changed. With regard to the temperature levels, the innovative combisystem concept is operating like a conventional boiler.

Markets and marketing considerations

Opening-up of new and niche markets:

Usually typical solar combisystems are installed in single or multi-family houses only if the heating system is renovated. Therefore the conventional solar thermal systems only serve a niche market today. Most of the existing heating systems do not need to be renovated because they are still not old /bad enough. The consequence is that it is very unlikely that a customer decides on a solar thermal system when he has to exchange a store which is maybe only 5 years old. In many cases the available space is not large enough for the integration of a relatively large combistore. On the other hand AquaSystems make it possible to add a solar thermal system without a renovation of the heating system. The heating system can be renewed at a later stage when this it is really necessary. With this new generation of solar thermal systems a large share of the market can be served which will lead to additional market growth.

Expansion of existing market:

The above mentioned arguments are valid in the existing market as well as for newly built systems.

Special considerations and limitations

Pressurized solar thermal systems with water as heat transfer medium have been investigated by Paradigma since 2000. First AquaSystems have been testes in pilot plants since winter 2002/2003 followed by an extensive field test 2003/2004 with about 100 solar systems in 2003/2004. In the same winter extensive measurements were performed at ITW Stuttgart. A complete CPC AquaSolar DHW system was built up in an outdoor test stand and operated under realistic ambient conditions. In a later step the same system was examined in a climatic chamber with temperatures down to -25°C. The functionality and security of the system was confirmed by ITW. The energetic evaluation was done by using the simulation programme TRNSYS (ITW) and ColSim (Paradigma).

The sales of AquaSystems started in April 2004. At the end of the very strong German winter of 2004/2005 about 2000 Systems were installed. Only minor problems occurred mostly due to failures of the installer. Since April 2005 AquaSystems for additional direct space heating are available. At the end of 2005 more than 6000 AquaSystems are installed in Germany. Also in Italy these systems are sold and in France the sales have recently started. The installers are satisfied with the AquaSystems and the acceptance of the users is high. According to the manufacturer of the system actually many more solar thermal systems are sold for the operation with water in the collector loop than with a water/glycol-mixture as heat transfer medium. Even though both versions are offered parallel and at same price level.

The AquaSystem was awarded the “Innovationspreis 2005” of the installer newspaper “Markt intern”.