WP1.E7 / THEORETICAL EVALUATION OF PROMISING SYSTEM: Combisystem with Non-Pressurized Store and Polymer Collector

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SUMMARY

The evaluated combisystem concept was developed by the Norwegian company Solarnor AS and is referred to as the *Solarnor system concept* in this report. It includes a new type of glazed polymeric collectors. With the exception of the domestic hot water, the entire hydraulics are non-pressurized. Solarnor has designed a product, which corresponds to the system concept. In the evaluation, the Solarnor system concept was compared to a reference system, which is the state of the art combisystem in Sweden (generic system #11 in /Wei03/).

Relative to the reference system, the Solarnor system concept is characterized by:

- Low-cost polymeric collectors with moderate efficiency instead of metal-based selective collectors;
- Drain-back technology and avoidance of antifreeze additives;
- Non-pressurized heat buffer store of stainless steel instead of pressurized store; elimination of expansion vessel, simple hydraulic design, lower costs;

The lightweight, modular collector is easy to transport, handle and install. The polymeric collector is available in various dimensions and easy to adjust to given roof-/ facade shapes. The roof-/facade-integrated collector installation replaces conventional materials and contributes to cost savings. Roof-/facade-integrated installations offer more appealing architectural solutions.
Several design aspects aim to compensate for the collector's moderate efficiency: The application in solar combisystems or in systems with a large DHW demand and avoiding heat exchangers favour a low system temperature and allow the collectors to operate at a higher efficiency.
The controller of the evaluated system regulates all functions: Space heating control, solar heating system control, and energy metering function.

Reference system

Choice and use of the reference system

In the present report, the system evaluation is based on a comparison with a reference system. The reference system matches the system technology of "generic system #11", which is described in /Wei03/ and applied for combined solar water heating and space heating in Sweden and Finland. 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 (DHW) preparation and space heating (solar combisystem).

Description: The reference system corresponds to "generic system #11" in /Wei03/. The system's characteristics, which are important for the comparison to the evaluated system, are described in the following. The solar collectors are metal-based collectors in a pressurised collector loop, which is filled with water-glycol mixture. The collector loop is a pumped system. The heat buffer storage is pressurised and 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.
Cost (retail sales price of the reference system without installation): A typical system with 10 m^2 of solar collectors and a 1 500 litre storage with a wood boiler as auxiliary, costs about 12 300 EURO. A similar reference system without solar heating costs about 8 600 EURO /Wei03/.

Collector area and store volume of the reference system: 10 m^2, 1 500 l

Market: The reference system represents the state of the technology in Sweden and Finland /Wei03/.

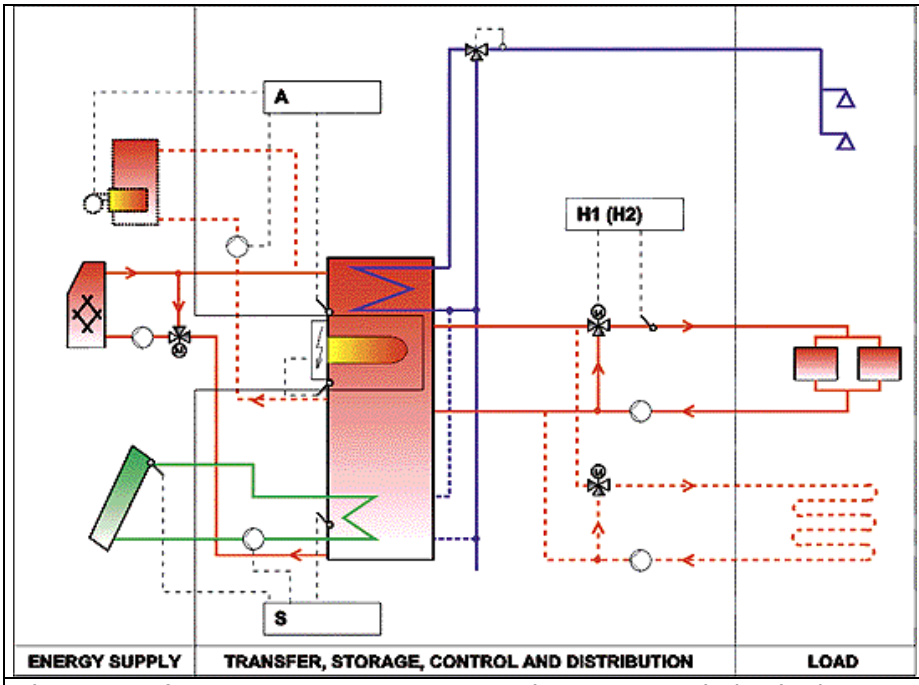


Figure 1: Reference system. Source: Generic system #11 in /Wei03/

Evaluation

Description of the evaluated system

Application: Primary purpose: Solar DHW preparation and space heating (solar combisystem) or solar DHW preparation for systems with large DHW consumption (hospitals, nursing homes, sport centres, hotels, etc.).

Background for development: The evaluated system includes a new type of solar collector and a completely reviewed design of a solar heating system, called "Solarnor concept".
The Solarnor solar heating concept is rather un-traditional and designed by starting "from scratch". The development of the Solarnor concept was driven by considering the demand side for (solar) heating systems in Central and Northern European climate, which is to provide domestic hot water of temperatures up to approximately 60ºC and to heat buildings to an indoor temperature in the range of 20-25ºC. This is basically a low-temperature heating demand and can be covered by solar collectors of moderate efficiency. The collector area of such systems normally covers a large surface of the building and it is important to consider aesthetics and the architectural integration of the collectors into the roof or facade by substituting conventional building materials. Hence, the collector materials should fulfil the demands of standard building elements. Further the modules should offer flexibility with regard to dimensions, low weight, easy handling and be cost-competitive to conventional energy sources.
A polymeric collector produced by extrusion was considered to meet these requirements better than metal collectors. The development was also strongly influenced by the Norwegian energy market where abundant and low cost hydroelectric power was accessible (approximately 0.06 EURO/kWh until 2002) and approximately 80% of the buildings in Norway were heated by direct electric heating. A considerable increase of the electricity prices the last years (presently 0.10 EURO/kWh) has moved the market toward other energy carriers. One consequence is that water based floor heating has obtained large market shares (approx. 40 %) in new residential buildings.

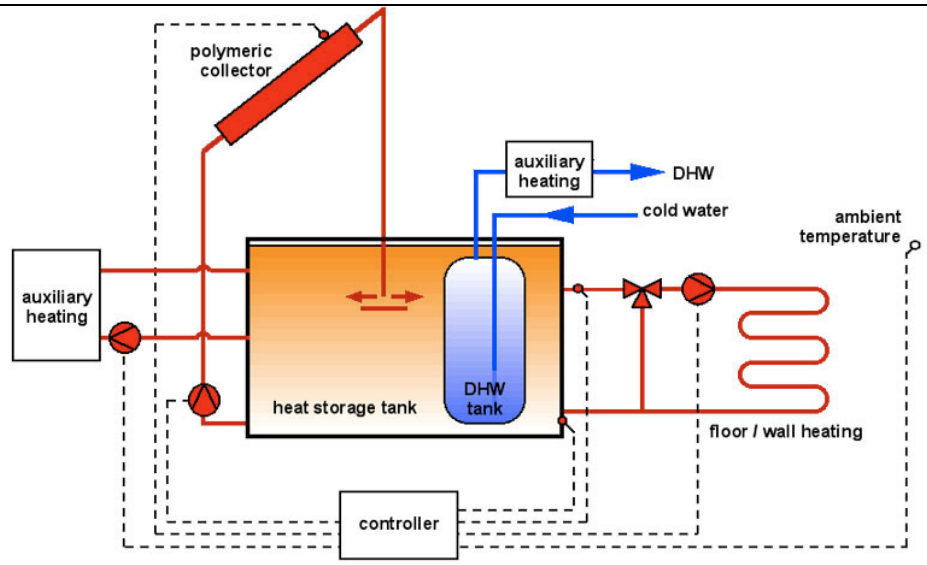
Hence, moderate collector- and system costs were playing a major role in the development of the Solarnor collector- and system concept.
A major obstacle was that water-based heating systems, which are necessary for solar heating systems, have rarely been installed in new houses since 1960. This has changed around 2000, but still a large amount of buildings is not easily accessible for retrofit with the present concept.

Description:

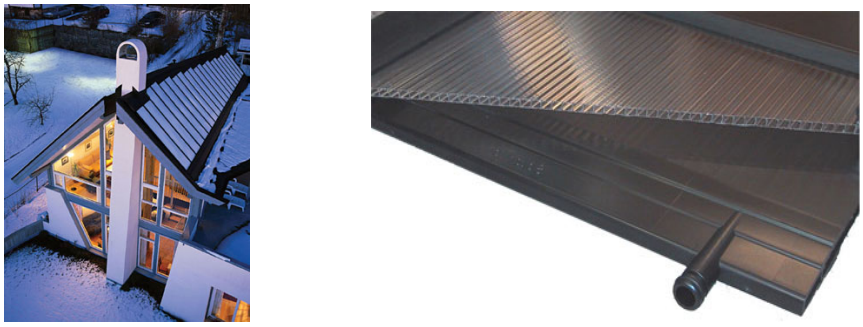
- The Solarnor system is a pumped system with drain-back technology using heating water as heat transfer liquid.
- The absorber and the collector cover consist of polymeric materials (modified NORYL®, PPE/PS blend; polycarbonate) and are sheets with an internal twin- or multi-wall structure. The collector is available in four standard lengths (2, 3, 4 and 6 m). Due to the properties of polymeric materials, the system design avoids high operation- and stagnation temperatures.
- The heat carrier's volume flow with typically 50-90 l/(m^2 h) (dependent on the absorber's length) is rather high compared to conventional low-flow metal absorbers with 30-40 l/(m^2 h). The heat carrier volume in the collector is approximately 3 l/m^2 collector area.
- The heat buffer storage is non-pressurized with typical volumes of 0.05 m^3 to 0.10 m^3 per square meter collector area. There are normally no intermediate heat exchangers between the heat storage volume, the solar loop and the heat distribution loop for space heating (e.g. floor heating loop). The hydraulic scheme is shown in Figure 2a.
- When the solar heating system is not in operation, the absorbers are filled with air and the heat carrier (water) is drained to the storage. Several collector modules are connected for parallel flow of the heat carrier (see Figure 2c).
- The Solarnor collector is modular and replaces conventional roof-/facade covers. The collector design is such that the thermal insulation of the building acts as collector insulation

where possible. Both aspects contribute to cost savings in terms of materials and installation.

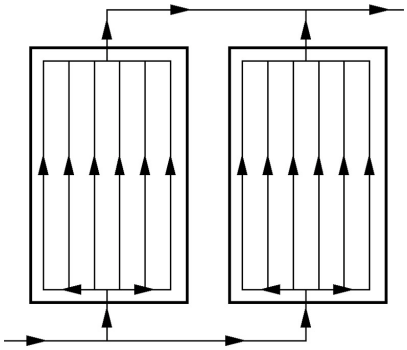
- There is only one controller (Solarnor controller), regulating the operation of the solar collector system, the auxiliary heat supply and the floor heating system; the auxiliary heat supply for DHW heating is regulated by a thermostat. The main controller is an integrated part of the heat storage tank where almost all signal connections and sensors are installed at the factory. Additionally, a remote control unit with nicely designed housing can be installed in the living room.
- All important components as shunts valves, solar pump, floor circulation pump are pre-installed in the factory, placed all on one side of the heat storage.
- Flexibility in choice of auxiliary heat supply



2a) Hydraulic scheme of a solar heating system with drain-back design and polymeric collectors.



2b) Solar combisystem with Solarnor system (left) and image of the polymeric collector (right)



2c) Flow of the heat carrier in the polymeric collector and interconnection of two modules.

Figure 2: Solar thermal system evaluated

Cost and savings

Material and manufacturing: The Solarnor solar collector is made of polymeric materials (absorber and cover sheet). The production method of the absorber and the collector cover offer a large potential for cost reduction, especially when large production volumes can be obtained (extrusion and moulding). The weight of the collector per square meter is considerably lower than for the reference system (approx. 6 kg/m^2). The low weight opens for the design of large modules (up to 6 m length) and reduces the amount of inter-connections.

The simple hydraulic scheme of the Solarnor system with drain-back concept reduces the amount of components in the system design and hence the complete system costs (no heat exchangers, expansion vessel, safety valves, antifreeze fluid, etc.).

Due to the fact that the system is a "breathing system", the heat carrier has higher oxygen content in the evaluated system than in the reference system. Hence, a certain demand on the choice of the component's material is required (preferably brass and copper). Corrosion protection is not required.

Installation: The Solarnor collector is designed for roof- or facade integrated installation. The collector easily substitutes conventional roof- or facade modules, as the width is corresponds to the standard building width of 60 cm (Norway). The installation time of a Solarnor collector roof- or facade is in the same order of magnitude as for conventional roof- or facade covers. For the collector installation, the weight of all parts is below the limit for handling by one person (also for the longest collector modules). Due to the fact that the solar collector loop is not pressurized, the on-roof or on-facade installation does not require authorized plumbers; it can be carried out by skilled roof- or facade installation experts.

The heat buffer storage includes all important installations as shunts valves, solar pump, "floor pump" are installed "in-factory" and at one side of the storage. The advantages are cost savings, easy service and avoiding installation errors at the building site.

Maintenance: The maintenance is considerably reduced due to the simple system design and reduced amount of parts and components (no antifreeze fluid, no pressurised solar- and floor heating circuits, no expansion vessel, safety valves, etc.).

Combined cost: Concerning material, manufacturing, installation and maintenance combined and individually, a considerable cost reduction is obtained.

Performance and energy savings, including embodied energy: The standard absorber in the Solarnor collector is not spectrally selective coated. This disadvantage is partly compensated by the low operational temperature in the system (floor heating). In order to obtain the same solar fraction as with high efficiency collectors, a 10 to 20 % larger collector is required.

Cost performance ratio: The increased collector area for performing the same solar fraction is more than compensated by the lower price and the reduction in used material. The result is a significant improvement in cost performance ratio compared to the reference system.

Additional benefits

Range of application, extra service, extra comfort, extra function: When installed in multi-family buildings, the controller of the Solarnor system has a built-in energy-metering function for all individual (floor heating) user-units connected to one heating central; energy metering motivates for energy conscious heating and DHW-use. Remote read-out (LON technology) of the energy meter is available for the present controller.

Environmental friendliness: No antifreeze liquid needs to be recycled. The polymeric collector materials can be fully recycled. Full life-cycle analysis shows considerably lower emissions to the environment per produced energy unit than conventional collectors (includes production, operation and recycling /Str03/, /PE98/. The heat store is made of stainless steel. The not-

pressurized storage concept opens for significant reduction in material thickness and consequently in storage material used.

Aesthetics, building integration and space requirement: The Solarnor collector is available in various standard lengths (principally in all lengths up to 6 m) and hence very flexible to integrate in existing building shapes. The heat storage is normally larger than in the reference system, but due to the rectangular-shaped design, easy to be set-up in corners or niches. The low height of the storage allows a set-up in the low-value areas of a house, e.g. basements with low height (max. height of 1.5 m including service operations required).

Technical integration: Due to the whole-system approach, it is rather difficult to include individual parts of the present Solarnor system e.g. in the reference system. The controller exists as individual product (control of floor heating systems, energy metering in multi-family buildings with floor heating where all users are connected to one heating central, read-out of energy metering with LON technology).

Markets and marketing considerations

Opening-up of new and niche markets: It is assumed that the present market is dominated by customers which have a special interest in solar/ renewable energy. These customers are able and willing to pay the still rather high investments for a conventional solar heating system of the "reference type". The Solarnor system would like to address a market without subsidies

Example of recent development in Norway where a new market is addressed and a large degree of pre-fabrication and standardisation is introduced: A large Norwegian "type house" producer (Systemhus AS, Bodø) has as the first "type house" company in Norway included solar thermal heating as a standard the "type house" KARAKTER. In Norway 82% of the new installed private houses are type-houses (2001). Type-houses are pre-designed houses for living, mostly of wooden construction. The concept of KARAKTER has been awarded for the innovative design in 2003 (Boligprodusentenes Nyskapingspris 2003).
In Norway, the installed systems are almost exclusively polymeric solar collectors with water as heat carrier in the solar loop.

Expansion of existing market: It is assumed that the Solarnor system concept has good potential to expand in existing market outside Norway, due to its simplicity, innovativeness, cost competitiveness without subsidies. It is lightweight and easy to install. However prejudices as "plastics as low value material" need to be overcome, installers of conventional systems need to be skilled. The most attractive solution seems to transfer the installation of the roof- and facade installation of the collectors to roof- and facade installing companies.

Special considerations and limitations

The polymeric collector concept by Solarnor is available in the market in its present design since 2002. Performance tests and monitoring studies carried out in laboratory scale and in the field confirm the predicted energy performance.
The life time of polymeric materials is considered to be shorter than the life time of conventional metal-based collectors with solar glass as collector cover. There are measurements on polycarbonate collector covers available and on-going, e.g. /Köh03/. Measurements on PPE/PS absorbers are on-going and will be among others be a topic in the new IEA-SHCP Task "Polymeric materials for solar thermal applications" /Köh05/.
Special installation requirements for drain-back systems have to be followed regarding the montage of those pipes, which are exposed to freezing conditions **(slope of approx. 1 %).** Further the choice of pumps with regard to the material is important (brass or stainless steel).

Acknowledgements

Continuous support by Solarnor AS is acknowledged.

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