SOLAR COMBISYSTEMS

Task 26

Industry Workshop

Oslo, Norway, April 8, 2002

Compiled by Werner Weiss

INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

Industry Workshop

Task 26 - Solar Combisystems

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Solar Heating & Cooling Programme

Soria Moria Conference Centre, Oslo, April 8, 2002

13:00 h	**WELCOME ADDRESS** ***John Rekstad and Fritjof Salvesen***
13:10 h	**Task 26, missions and achievements** ***Werner Weiss, AEE INTEC, Gleisdorf, Austria***
	Solar energy in the energy political context of Norway
13:30 h	**Solar energy – a political issue?** ***Rolf Jarle Åberg, Norwegian Solar Energy Society, Norway***
13:50 h	**Solar energy in the Norwegian energy policy** ***Brit Skjelbred, Deputy Minister of Oil and Energy, Norway***
14:10 h	Discussion
	Solar Combisystems with gas as auxiliary energy source
14:30 h	**Combination of solar and natural gas in Dutch products** ***Huib Visser, TNO, Delft, The Netherlands***
14:50 h	**Solar Heating with a storage-integrated condensing gas burner** ***Thomas Krause, SOLVIS Energiesysteme GmbH, Germany***
15:15 h	**Influence of different combistore concepts on the overall system performance** ***Harald Drück, University of Stuttgart, Germany***
15:40 h	Discussion
16:00 h	**COFFEE / TEA BREAK**
	Architectural aspects of active solar heating systems
16:30 h	**Facade integrated collectors – constructions, building physics and results of two monitored systems** ***Irene Bergmann, AEE INTEC, Gleisdorf, Austria***
16:50 h	**Architectural integration of solar energy** ***Per Monsen, GASA Architects, Norway***
17:15 h	**The Norwegian solar energy industry** ***Alf Bjørseth, REC, Norway***
17:35 h	Discussion
18:00 h	**END**

Contents

SOLAR COMBISYSTEMS FOR A SUSTAINABLE ENERGY FUTURE

Werner Weiß

AEE INTEC
Arbeitsgemeinschaft ERNEUERBARE ENERGIE
Institut für Nachhaltige Technologien
Institute for Sustainable Technologies
A-8200 Gleisdorf, Feldgasse 19
Tel.:+43-3112-5886, Fax: +43-3112-5886-18
E-mail: w.weiss@aee.at, Internet: http://www.aee.at

The increase in the use of solar collectors in recent years for domestic hot water preparation has shown that solar heating systems are a mature and reliable technology. Every day, thousands of systems world-wide demonstrate the possibilities of this ecologically harmless energy source. Motivated by the confirmed success of these systems for hot water production, an increasing number of homebuilders are considering solar energy for space heating as well.

Combining solar heating systems with short-term heat storage and high standards of thermal insulation allows the heating requirements of a single- or multi-family dwelling to be met at acceptable costs. Compared with systems using seasonal storage (the costs of which are currently not affordable for single-family houses), this combination provides a cost-effective system with high efficiency.

The demand for solar heating systems for combined domestic hot water preparation and space heating is growing rapidly in several countries. In some countries, such as Austria, Denmark, Germany and Switzerland, solar combisystems have a noteworthy share of the market.

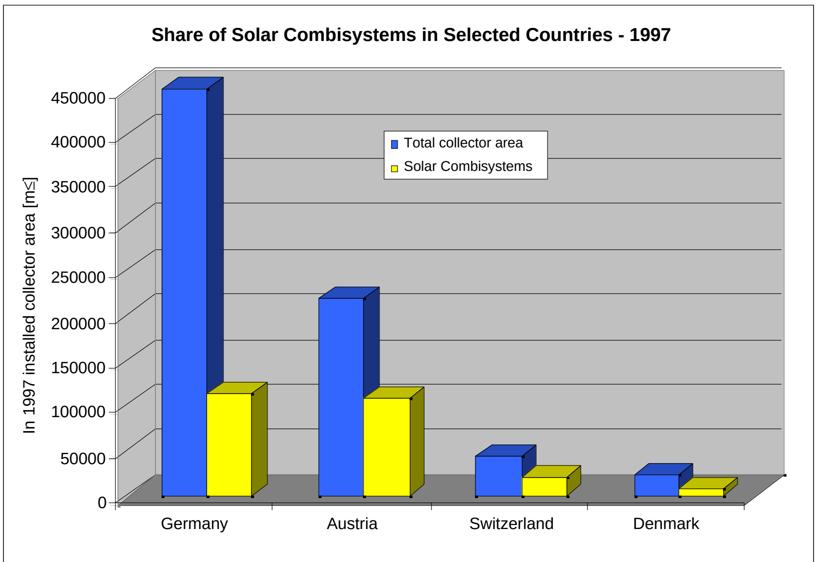

Fig. 1: In 1997 installed collector areas and share of collectors for solar combisystems in selected countries.

Solar heating systems for combined domestic hot water preparation and space heating, so-called "solar combisystems" are essentially the same as solar water heaters when considering the collectors and the transport of the produced heat to the storage device. There is, however, one major difference - the installed collector area is generally larger for combisystems, as there are two different heat consumers to supply. Furthermore, in a combisystem there are at least two energy sources to supply heat to these two heat consumers - the solar collectors and the auxiliary energy source. The auxiliary energy source can be biomass, gas, oil or electricity.

Solar combisystems are more complex than solar domestic hot water systems as there are more interactions with extra subsystems. And, these interactions profoundly affect the overall performance of the solar part of the system. The general complexity of solar combisystems has led to a large number of widely differing system designs, which do not necessarily reflect local climate or local practice. Several systems, for example, could be and soon will be sold all over Europe. Collaborative work in analyzing and optimizing combisystems is therefore an important activity. Since December 1998, 26 experts from 9 European countries and the USA and 11 solar industries, have been working together in the Solar Heating and Cooling Program Task 26, ***Solar Combisystems.*** The objective of this Task is to further develop and optimize solar combisystems for detached single-family houses, groups of single-family houses and multi-family houses.

Why solar space heating?

The enrichment of gases inducing a greenhouse effect 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 of this impending change in the climate can for the most part be attributed to the use of energy, in particular, the combustion of fossil fuels and the associated emission of CO_2.

Today, the world's energy supply is based primarily on 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 2/3 into biomass and 1/3 into hydropower.

The effective protection of the climate which makes provisions for the future will, according to many experts, demand at least a 50% reduction in the world-wide anthropogenic emission of greenhouse gases in the next 50 years.

As a result of the climate conferences of the last decade and the discussion about sustainable development, the European Commission has laid down its goals with respect to future development in the field of renewable sources of energy in the White Paper[1] «Energy for the Future: Renewable Sources of Energy». In the Commission's "White Paper" the following is mentioned as a strategic goal: "... to increase the market share of renewable sources of energy to 12% by the year 2010." The yearly increase in the installed collector area named in the White Paper in the member states is estimated at 20%. Thus, solar heating systems in operation in the year 2010 would correspond to an overall installed collector area of 100 million m^2.

If the direct use of solar energy for heating purposes via solar collectors, as shown in the sustainable energy scenarios, is to make a relevant 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.

A realistic approach would be to assume that in the next ten years, about 20% of the collector area yearly installed in middle and northern latitudes 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 per year around 120,000 solar combisystems with 1.9 million m^2 of collectors need to be installed.

[1]Bulletin from the Commission Regarding Energy for the Future: Renewable Sources of Energy, White Paper for a Community Strategy and a Plan of Action

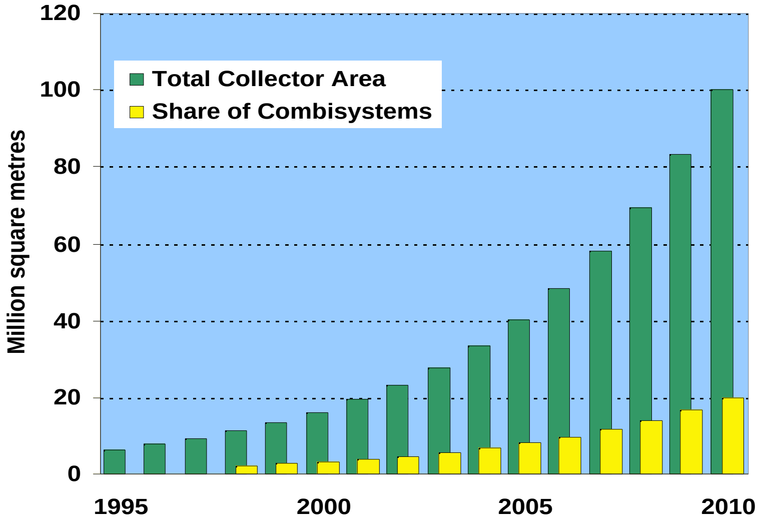

Fig. 2: Objectives for the installed collector area until 2010 in the European Union's member countries.

Conditions and pre-requisites for solar space heating

Currently installed systems clearly show that solar space heating is possible even under mid- and northern climatic conditions. However, before a solar combisystem is installed, due attention must be paid to the conditions and other requirements.

Solar energy availability

In high 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. In comparison to hot water supply, the heating load is dependent on the outside temperature. Measurements of solar irradiation and temperature in the transitional periods (September - October and March - May) clearly show that solar irradiation availability is relatively high at the beginning and end of the space heating season. Even on winter days, energy demand and solar irradiation are partially related.

Figure 3 shows the solar irradiation on a horizontal plane at Zürich, Switzerland. It can be seen that, under this latitude, there are not only strong seasonal variations in radiation throughout the year, but solar radiation also quite widely changes on a daily, or even hourly basis.

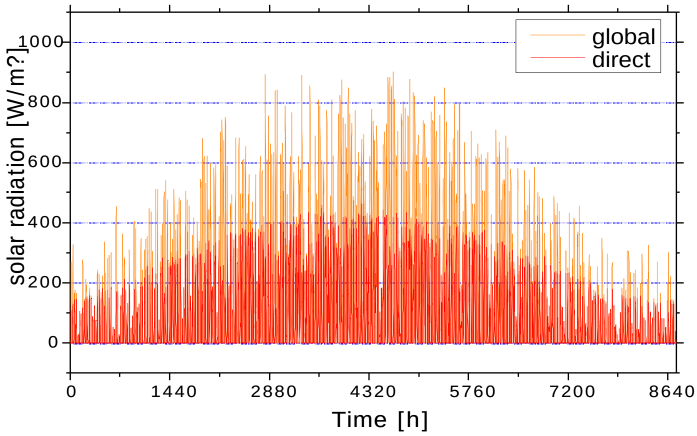

Fig. 3: Solar irradiation on a horizontal plane at Zürich, Switzerland

In order to make efficient use of the available solar energy supply, it is therefore necessary to even out these fluctuations, by means of storage systems, to be able to supply hot water continuously and to guarantee a constant room temperature.

Fig. 4: French house equipped with a direct solar floor system (Source: Clipsol, France)

System designs

The solar contribution, that is, the part of the heating demand met by solar energy, varies from 10% for some systems up to 100% for others, depending on the size of the solar collector, the storage volume, the hot water consumption, the heat load of the building, and the climate.

As mentioned before, there is a large variety of system concepts on the European market. The different system concepts can partly be put down 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 gas or electrical energy are primarily used as auxiliary energy. In the Netherlands, for example, a typical solar combisystem consist of 4-6 m^2 of solar collector and a 300 liters storage tank. The share of the heating demand met by solar energy is therefore correspondingly small.

Fig. 5: Dutch solar combisystem (Source: ATAG, The Netherlands)

In countries such as Switzerland, Austria and Sweden, where solar combisystems are typically coupled with a biomass boiler, larger systems with high fractional energy savings are encountered. A typical system for a single-family house consists of 15 – 30 m^2 of collector area and a 1 - 3 m^2 of storage tank. The share of the heating demand met by solar energy is between 20% - 60%.

Fig. 6: Solar combisystem for a single-family house in Germany (Source: SOLVIS, Germany)

Requirements for the hydraulic layout

Requirements for the hydraulic layout of solar combisystems can be summarized as follows (Streicher, 2000):

- deliver solar energy to heat store(s) with as low heat loss as possible;
- distribute all the heat needed to hot water and space heating demand;
- reserve sufficient store volume for auxiliary heating taking into account minimum running time for the specific heater;
- low investment costs;
- low space demand; and
- easy and failure safe installation.

Furthermore, specific properties of components influence the operation of the other components. As mentioned before, heat demand and annual and daily load distribution are of major importance for system dimensions.

Generally, the heat store is the heart of a solar combisystem. Solar heat is stored in the lower part of the store and, if applicable, auxiliary heat in the upper part. The collector hydraulics influences the height of the collector loop outlet to the store. For high-flow collectors, this connection can be quite low. On the other hand, this connection should be higher or even better variable (stratifier) for low-flow collectors and the heat store should be prepared to enhance thermal stratification.

For combisystems with indirect integrated auxiliary heating, the inlet pipe from the heater is connected at the top. The height of the outlet depends on the peak hot-water demand, the outlet pipes to the heat distribution system and the volume needed for solar energy. The minimum operation time for the heater also determines the auxiliary volume.

Requirements are stricter for wood furnaces than for gas boilers. Another factor is the type of the heat distribution system, for example, connection from high-temperature radiators to the store should be higher than from a low-temperature heat distribution system.

This indicates that system design largely depends on national building traditions, auxiliary energy source and user behavior.

Examples of system layout

Figures 7 – 9 show designs from different countries and manufacturers. The system in Figure 7 is a typical early design with a large number of components. The system can be very efficient, but is also more difficult to install.

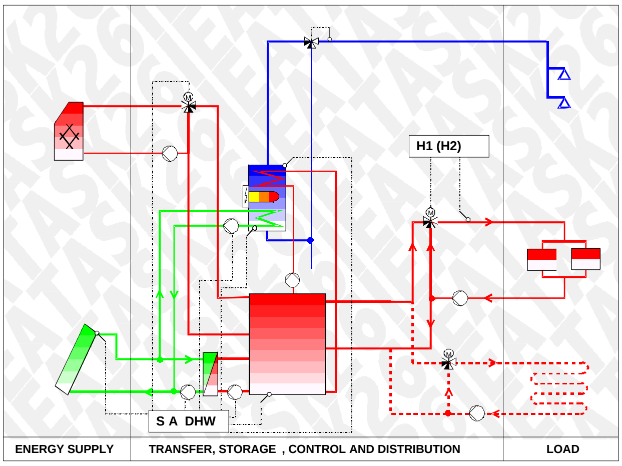

Fig. 7: Two-stores combisystem with fixed-power auxiliary heater (Austria)

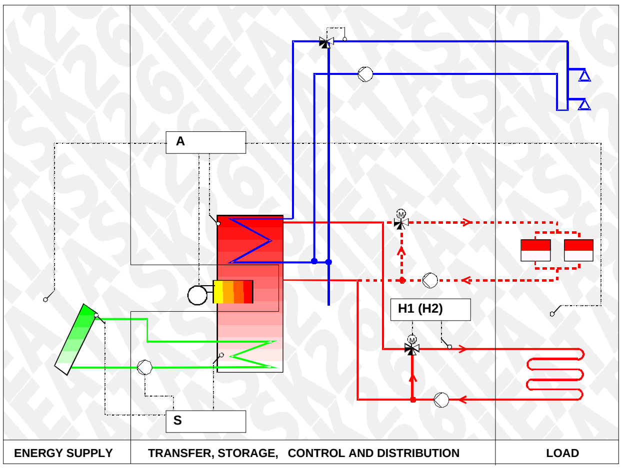

Fig. 8: Solar combisystem with integrated gas or oil burner (Finland)

In the system layout presented in Figure 8, most functions have been integrated in the heat store, even the gas or oil burner. Figure 9 shows a solar combisystem with direct floor heating. The thermal mass of the floor heating system is used as heat store. Auxiliary heating is coupled in series. A special control is used for distribution of the solar heat between floor and hot water.

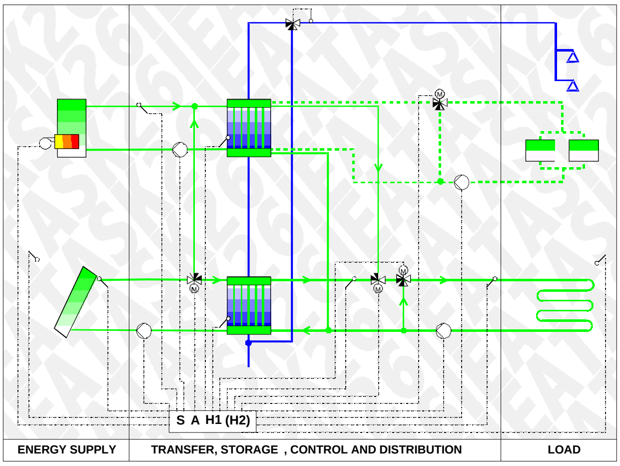

Fig. 9: Direct solar floor combisystem (France)

More information on system layouts can be found in the report, Overview of Solar Combisystems 2000 which can be found on the Task 26 homepage at http://www.iea-shc.org/task26

The systems described above are designed for single- or two-family houses. But there are also systems in operation which are designed for multi-family houses and terraced houses. These systems also have shown promising results during the last years.

In Gleisdorf, Austria a system was installed in 1998 for an office building and 6 terraced houses. The collectors – spread on three construction parts – with an extension of 230 m^2 were integrated into the roofs of the winter gardens and cover 80% of the hot water and 60% of the space heating demand of the whole year. The remaining energy is provided by a biomass boiler. A local heating network connects the individual houses to the central 14 m^3 storage tank.

The efficiency of a solar heating system is also determined by the temperature level of the heat release. For this reason the buildings were equipped with special low-temperature wall heating systems. The medium fluid temperature of low-temperature wall heating system is 35°C during the heating period.

Fig.10. 60% of the space heating demand of this terraced houses are covered by solar energy (Source: AEE INTEC, Austria)

Support for System Development

Both mathematical models and test methods support the assessment and optimization of solar combisystems.

Computer programs

There are several computer programs on the market for the thermal performance calculation of solar combisystems: Polysun, TSOL and SHWwin. All are transient simulation programs with time steps of a few minutes and feature database support for components and systems. Heat loads can also be defined in great detail. Possible system layouts are, however, restricted and differ from one program to the other. More information on these programs can be found in (Streicher, 2000).

A more general computer program is TRNSYS., Solar combisystems can be composed from TRNSYS modules. Within SHC Task 26, about half of the solar combisystems from the 2000 overview are being modeled using TRNSYS so that optimization of these system concepts can be calculated.

For solar combisystems with a relatively small collector area (2 – 5 kW heat load), optimum heat store volume appears to be 50 – 200 liters per kW heat load. The optimum tilt angle is between 30^o and 75^o. Orientation is best between 30^o east and 45^o west.

Test methods

Emphasis in solar combisystem test method development is now in the so-called “Direct Characterization” (DC) test procedure where a 6 days test simulates the system operation during summer, winter and spring/autumn. Performance indicator from testing is processed in a simple way to deliver annual performance prediction, but only for the conditions during the test, being average values for the whole year. Extrapolation into other climates and heat demands than used in the test is not possible.

The CTSS (Component Testing – System Simulation) method, available from European Standardization of solar hot water systems, is more complex. Components are tested separately in this method and component models are used to determine component specifications. Combination of component models into a numerical model for the whole system gives the annual performance and enables extrapolation.

The DC method is under investigation in Task 26. CTSS serves for comparison. There is a liaison between SHC Task 26 and CEN Technical Committee 312 ‘Solar Energy’.

Conclusions

The attention that is being given to solar combisystems is justified as these products will certainly hold a sound share of the market in the future. In recent years, combisystems have changed from complex designs into compact products. And, although there are still many different system designs to choose from, the computer programs being used to optimize system designs and the test methods being used to assess and compare products are supporting the market development of reliable systems.

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Further Information: http://www.iea-shc.org/

SOLAR ENERGY – A POLITICAL ISSUE?
NORWEGIAN PERSPECTIVES AND INTERNATIONAL TRENDS

Dr. Rolf Jarle Aaberg
Norwegian Solar Energy Society
c/o Institute for Energy Technology, Box 40, 2027 Kjeller, Norway
Tel: +47 63 80 62 33
Fax: +47 63 81 29 05
E-mail: solenergi@solenergi.no
http://www.solenergi.no

Abstract

Solar energy policies have developed quite differently in various countries. It is observed that countries with attractive financial incentives or strong regulations have developed the most viable markets. A portfolio of integrated incentives is known to be more efficient than single support mechanisms. One observes that solar energy policies are developing from market introduction programmes to marked growth programmes. As the market grows in volume and competitiveness solar energy policies should develop in the direction for market maintenance schemes. This paper describes how renewable energy certificate systems can be a viable framework for market growth and market maintenance for solar heating and cooling technologies. Renewable energy certificate policies have been developed in a number of countries. Although, the tradable "green" certificate policies at present are focusing on renewable power there is a great potential for renewable heat certificates as well. However, the success of any solar energy market development strategy depends on the integration of solar energy in the long term energy policy.

1. Introduction

The global solar energy market is growing at an impressive rate. During the year 2000 world production of photovoltaic (PV) cells increased by 44%. European production rose from 38.6 to 61.6 MWp Austria, the Netherlands, and in particular Germany, are dominating the European market. The European PV market is still expected to grow as British and Italian programmes for grid connected PV power are commencing. Estimates of the European solar thermal market shows that the accumulated collector area in 2000 was over 11 million m^2. More than 1 million m^2 were installed that year, a growth of almost 25% from 1999 [1]. From a Norwegian perspective it is interesting to observe that the markets in neighbouring countries are in progress as well. At present, about 200 000 and 350 000 m^2 of solar heaters are installed in Sweden and Denmark, respectively. For comparison Norway only has about 7000 m^2. It is obvious that such differences are due to different solar energy policies rather than variations solar resources.

The massive growth in installed solar energy capacity is mainly taking place in countries with efficient policies and support programmes. This is shown in various studies. According to [2] an integrated blend of fiscal measures, subsidies, regulatory measures and administrative initiatives characterises the counties with the strongest market development.

One further observes that solar energy policies are developing from market introduction programmes to marked growth programmes. Market introduction programmes are typically based on investment subsidies. More advanced schemes such as tax deductions, VAT exemption, feed in tariffs, large scale purchase programmes and information and education campaigns seems necessary in order to bring the technology from a market introduction stage into a steady market growth regime.

Solar energy technologies are gaining competitiveness in many national or local markets. One expects that market support mechanisms will change from subsidies in a market introduction schemes and more in the direction of market 'maintenance' schemes. Various policy initiatives may fit into such 'maintenance' schemes, for example legal requirements in building standards or like the Danish obligation for solar thermal energy installations in buildings outside district heating areas [3]. In general the market 'maintenance' schemes should acknowledge and reflect the environmental benefit of the technology.

One possibly important mechanism for the future is green energy certificates. A number of countries and international organisations are developing certificate schemes where the environmental benefit is marketed separately to energy. The energy itself is traded and consumed locally against common tariffs; while the environmental surplus value is reflected in certificates, which are issued by certified bodies. These 'green' certificates can be traded, with their value determined by open market forces. This enables market participants of all sizes to participate in the renewable energy market [4].

To date most renewable energy certificate systems are focusing on electricity. However, in the following a proposal for including heat production in tradable certificate programmes is discussed. Renewable heat certificates should be developed to include even small scale units such as domestic solar boilers. The discussion below refers specifically to obligatory certificate markets as in renewable energy portfolio standards, but the principle is applicable to any tradable certificate system.

2. Renewable heat certificates

Almost all renewable energy certificate systems are support mechanisms for wind power, hydro power and power production from waste and biomass. Although solar power is included in most certificate systems, it is a paradox that solar heating and cooling and other environmentally friendly thermal technologies (i.e. biomass boilers, heat pumps etc.) are generally excluded. It has been explained that a reason for this is the difficulty of measuring certified amounts of energy in the absence of a power grid. However, in principal the certificate system the value of the certificate is traded in completely separate market, detached from the physical energy transfer. As long as the renewable heat production and consumption can be verified there is no reason for excluding certain technologies.

The effect of introducing heat production in the obligatory certificate trading system is shown in figure 1. The idea is that all renewable heat production from commercial as well as non-commercial heat units generates tradable certificates along with their energy production. Since heat production is much more common in small scale systems than power production a system as shown in figure 1 will open a range of new possibilities for the consumers to participate in and take advantage of the certificate trading.

In a compulsory certificate market, any energy consumer who has a renewable heat boiler can sell his surplus certificates to a certificate exchange institution. In this way the incentive to install solar thermal systems, heat pumps or various biomass boilers will be encouraged. Even if the heat is utilised for heating purposes at the production site, the added value of the renewable energy is returned to the owner of the boiler. The excess certificates issued on behalf of one small scale heat producer should be bought by energy consumers who don't have the opportunity to produce their own renewable energy.

An important aspect of the system in figure 2 is that the consumer has various ways of meeting his renewable energy obligation. Either by producing the energy himself and selling the excess certificates, by buying commercial renewable energy and certificates, or by buying the certificates only. This is an efficient way to renewable energy portfolio targets. At the same time the obligation is more acceptable to the energy market, as it represents both an obligation and a business opportunity.

Small scale energy producers may not be able to trade their own certificates. In order to bring the certificates to the market the local grid utility or another professional institution may issue certificates on behalf of the producer and reimburse him for certificates in excess of the renewable energy portfolio. The opinion that heat is more difficult to handle in a tradable certificate system is thus largely groundless.

The certificates generated from power and heat production should be exchangeable to ensure that small scale heat producers don't have to buy mandatory power certificates in addition to producing their own renewable heat. Otherwise one may encounter a situation where a renewable electricity certificates market is limiting the development of the renewable heat market. In a long term perspective an integrated compulsory green certificate market for both heat and power can contribute to a balanced development for rational use of both energy forms.

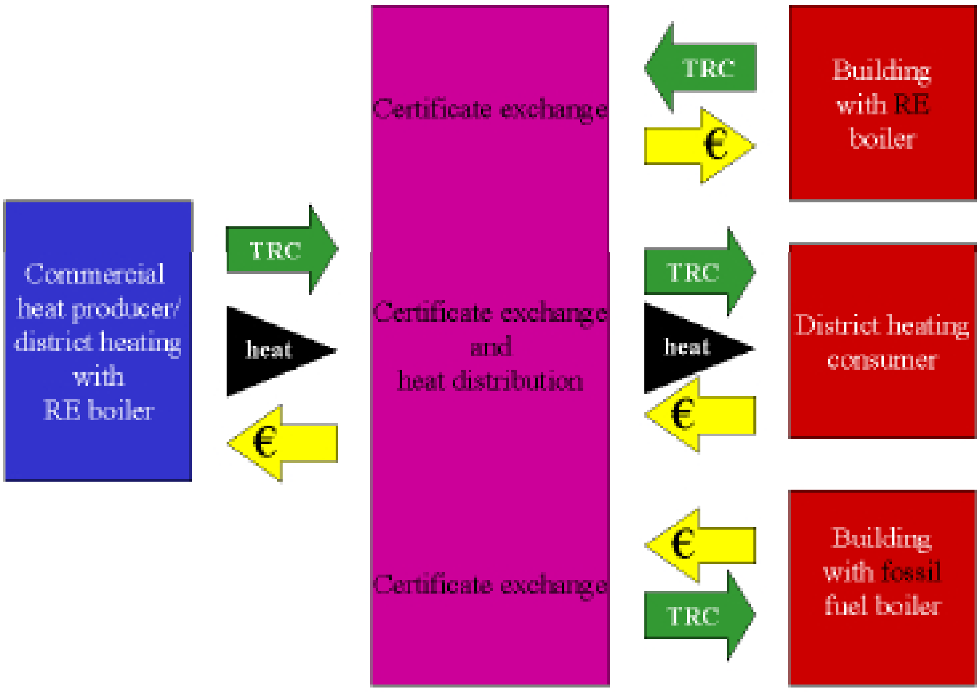

Fig. 1: An illustration of how renewable heat production in commercial large scale boilers and non-commercial small scale boilers generates heat certificates to be traded on a compulsory certificate market (TRC = tradable renewable certificate, € = payments).

An essential part of any tradable certificate system is that both production and use of energy is accounted for in order to verify the validity of each certificate. In principle it is no problem to keep accounts of heat in the same way as power. District heating plants already keep records of their various primary energy inputs and their customers have meters. Even solar thermal boilers may have energy meters integrated in the control system. However, it may be impractical to install meters in all kinds of small boilers. Some owners may even be tempted to dissipate off excess heat just to earn the certificates. For small non-commercial heating units a better and fraud proof scheme would be to issue certificates based on the nominal average capacity or load of the installed system. The owner would then only have to produce documentation that the system is being operated as intended in order to earn his certificates.

4. Summary

The above is a short introduction to the principle of including heat in renewable energy certificate systems. A number of details such as where to place the obligation (on the producer or the consumer) and the design of the interface between the certificate market and small consumers and producers. Nevertheless, the above discussion shows that solar heating and cooling technologies may be well and efficiently integrated in market oriented energy policy frameworks. Although, political initiatives and decisions will still be very important in order to develop and maintain sound markets for solar technologies. Certificate systems alone are not able to achieve this.

References:

[1] EurObserv'ER, in Renewable Energy Journal, No. 11, November 2001

[2] Active Solar Thermal Industry Group, www.astig.org

[3] www.solenergi.dk

[4] RECS, Renewable Energy Certificate System, www.recs.org

SOLAR ENERGY IN THE NORWEGIAN ENERGY POLICY

Brit Skjelbred
Deputy Minister of Petroleum and Energy
Ministery of Petroleum and Energy
P.O. Box 8148 Dep, N-0033 Oslo
Norway
Tel:+ 47 22 24 90 90
Fax:+ 47 22 24 95 65
E-mail: bt@oed.dep.no , postmottak@oed.dep.no

Delegates and participants,

It is a pleasure for me to be invited to this industry workshop that is organised in connection with the Solar Combisystems task. I hope you all have had, and will have, some interesting and enjoyable days here in Oslo. Looking back at the cold and dark season we've just left it is a pleasure to feel that the sun is starting to warm us up again, pushing the winter away, and underlining the fact that even in Norway energy from the sun can be exploited.

In this short speech I will address the solar energy in the Norwegian energy policy, starting with a general picture of the energy situation in Norway today.

Norway is blessed with an abundant supply of energy. We are also the country in the OECD which has the greatest share of renewable energy in our energy supply system. About half of our domestic energy consumption derives from renewable energy sources. Hydropower accounts for 99 per cent of the electricity generated in Norway.

In recent years the electricity consumption has increased more than the supply of new production capacity. From 1990 up to 2000 our yearly consumption of electricity increased by 18 TWh, while the production capacity in the same period increased by only 3,9 TWh. This has led to Norway turning from a net exporter to a net importer of power in years with average precipitation. Today the average production capability of the hydropower plants is about 1.19 TWh/year, while the consumption is 125 TWh.

This is a development which calls for action. We have to bring about a shift in our energy system. To cope with this challenging situation, the Storting (of the Norwegian Parliament) on 27 March in 2001 approved the establishment of a new public enterprise for promoting energy savings, new renewables and environmentally friendly natural gas solutions. The name of the new enterprise is Enova and it is situated in the city of Trondheim - in the middle of Norway. Enova has been operating from 1 January 2002. Enova is owned by the Government of Norway, represented by the Ministry of Petroleum and Energy.

Before Enova, measures aimed at initiating energy efficiency and new renewables were divided among the Norwegian Water and Energy Directorate (NVE) and the grid companies (through Demand Side Management Programs). The establishment of Enova aims to secure a more cost-effective use of public funding so that energy saving and new renewables may have a real impact on the Norwegian energy balance.

A central task for Enova will be to reach the energy objectives that were approved by the Storting in the spring of 2000. These are:

- to limit energy use considerably more than would be the case if developments were allowed to continue unchecked
- to increase annual use of central heating based on new renewable energy sources, heat pumps and waste heat by 4 TWh/year by the year 2010
- to construct wind generators with a production capacity of 3 TWh/year by the year 2010.

To achieve these objectives, the Storting has indicated grants within a framework of up to NOK 5 billion (approximately 650 million Euro) over a ten-year period. The funding will come from a levy on the distribution tariffs and from ordinary grants over the State budget. For 2002 Enova is receiving approximately 60 million Euro. Enova will use this funding to finance programmes and initiatives that are in line with the objectives. Investment support is granted to wind energy projects and to projects that will increase the use of central heating based on new renewable energy sources, heat pumps and waste heat.

In addition to the investment support, the Government has established other measures and incentives to speed up the introduction of new renewables in Norway. Investments in most new renewable energy technologies, including solar energy systems, is given exemptions for investment taxes, and production from wind energy is supported corresponding to half the consumer tax on electric power per kWh produced.

The Government does also wish to encourage a more effective use of energy in buildings. In a white paper on climate, issued just before Easter, the following initiatives are brought forward, among others:

- a national action plan for central beating based on new renewable energy sources, beat pumps and waste heat,
- a support grant for heat pumps in private households, which comes in addition to the already existing grants for official and business buildings,
- possible new regulations in the planning and building act, making it possible for the authorities to demand certain energy solutions through town and country planning procedures, as well as giving specific demands as to the use of energy in new buildings and a shift of energy systems in existing ones.

I think that the last measure may be interesting as supplementary to the IEA project on Sustainable Solar Housing, in which 1 know that Norway takes an active part. It is important that different measures are viewed together, so that the public may have the benefit of simplification, coordination and cooperation between the different actors.

Moreover, research and development is an important and integrated part of our energy policy. There are two main objectives behind the authorities, support for energy R&D firstly, the funding is intended to maintain the prominent position held by Norwegian energy related industry enterprises and others can use in their long term strategies. Secondly, such support is intended to promote the development of new energy technologies and innovative solutions and thus create a more efficient and environmentally sound energy supply system. A strong focus on research and development is important to be able to meet the challenges we are facing in the energy sector today.

There is no specific goal directed at introducing solar energy to a greater extent in the Norwegian energy system. Solar energy projects will be considered by Enova along with other energy projects within the framework of a long-term and environmentally friendly shift in the energy system.

Today solar energy does not play an important role in Norway. However, the potential to increase our use of solar energy is large. What contributes most to the energy supply when it comes to solar energy is passive solar heating. Today, solar radiation that shines through windows and heats up the interior parts of a building, is estimated to cover 10-15 percent of the heating requirements of the building. This corresponds to about 3-4 TWh/year. And, even in the harsh Norwegian climate, intelligent design with passive solar heating can be sufficient to cover 25 percent of the heating requirements.

When 1 was studying to become an architect, my class had an excursion to Italy. I remember a professor of architecture in Venice asking us what we did in Norway to avoid the sun shining into our houses. That was a rather new way of looking at it from our point of view. We have not so much sun as to make it a thing to be avoided. As you may have noticed, Norwegian houses are often built with large window panes, letting as much of the sun in as possible. And that may in turn make it convenient to design houses that makes the most of passive solar heating.

But active solar heating systems is also used in Norway. It is calculated that about 6000 m^2 solar collectors are installed in Norway for room and/or water beating, giving approximately 1,5 GWh/year. Between 5 and 10 percent of the yearly solar radiation on a single family home in a Nordic climate could cover the total annual heat demand. However, most of the energy is available in the summer, while most of the beat demand occurs during the winter. In order to build houses in higher latitudes with a high solar fraction, seasonal storage which is loaded during the summer is needed. This is of course familiar to you, so I will leave it there. My point is just that even for Norway, active solar heating systems have potentials.

When it comes to electricity from solar cells, or photovoltaic (PV) systems, Norway is already a large user - believe it or not. Situated between latitudes 58 and 71 north, Norway has limited hours of daylight in the winter, and parts of the country enjoy midnight sun during the summer. This, together with relatively low electricity prices because of our large hydropower resources, makes the natural conditions for PV utilisation not particularly favourable.

But despite this situation, small I-V systems have become very popular in Norway, especially among owners of cottages and recreational homes far from the electricity grid, but also on lighthouses along our coast. For such applications the electricity is mainly used for lightening, and represents in many cases a cost-effective alternative to grid connection, diesel, etc. As a result, as many as approximately 80 000 solar cell systems have been installed in Norway. In total they amount to nearly 4 MW. In addition, there is an interesting potential for building integrated solar systems, for instance in commercial buildings.

Before 1 finish, 1 will underline the importance of international energy technology co- operation. Countries differ significantly with respect to their points of departure, their energy structures and their flexibility in designing an effective policy response to reach the Kyoto-targets. We have, however, one incontestable common challenge which all countries should work together to solve. Both markets and governments have a role to play in meeting technological challenges in the medium and long term. I would like to emphasise international cooperation and networking across borders between governments, commercial actors and the research communities as keys for future progress to be made.

The IEA has been an important vehicle for policy analysis and the source of increased understanding of the effectiveness and realism of different policy options. It has also become a catalyst for developing networks of international co-operation in energy technologies through the implementing agreements. 1 hope that the IEA will continue its efforts to increase the awareness and understanding of the energy dimension of ongoing processes.

Having a relatively small energy R&D community in Norway, it is our policy to focus our activity on topics which are of particular interest to us, and where energy research can contribute to our overall energy policy. To get a total picture of what is going on in the energy R&D field world-wide, it is important to be kept informed and updated on energy R&D activities in different countries.

For Norway, then, it is of vital importance to have an international network to turn to for information and to participate in international energy co-operating agreements and projects. It is also important to contribute to solve energy problems on a global scale by communicating to other countries information on R&D activities in Norway. Exchange of information on energy technologies is a cost-effective way to strengthen our competence and knowledge in the energy sector.

I hope this presentation has given you a picture of Norway's energy policy, including the role of the solar energy in this respect, and 1 wish you all an interesting workshop and some pleasant days in sunny Norway.

Thank you for your attention.

COMBINATION OF SOLAR AND NATURAL GAS IN DUTCH PRODUCTS

Huib Visser
TNO Building and Construction Research
P.O. Box 49, 2600 AA Delft
The Netherlands
Tel: +31 15 269 52 46
Fax: +31 15 269 52 99
E-mail: H.Visser@bouw.tno.nl
http://www.bouw.tno.nl

Abstract

Thermal solar systems depend on the environment where the products evolved. Availability of primary energy source, traditions and regulations determine the direction of development. This presentation involves the two solar combisystems on the Dutch market being an example of that.

1. Interaction between energy market, regulations and product development

'Incredibly cheap and ridiculously small', that's what you often hear abroad when people talk about Dutch solar thermal systems for domestic use. Typical sizes for a solar domestic hot water system are 2.7 m^2 for collector area and 120 liters for heat store volume. For solar combisystems, it is generally not more than twice these sizes. Prices including installation work are about 2000 € and 3000 € respectively, i.e. additionally with respect to comparable more conventional systems. Hence, they are right. - Are they? International projects, also Task 26 'Solar Combisystems'of the IEA Solar Heating and Cooling programme, make very clear that there is no unambiguous truth. The choice of system concepts and dimensions within these concepts strongly depend on local conditions, both regulations and traditions.

If the Dutch would not have found large quantities of natural gas in the 1960's, energy distribution infrastructure would be very different. Major energy source for hot water preparation and space heating in the Netherlands is natural gas. In most households, both functionalities have been combined in one rather compact apparatus installed in the attic of the house. Dutch houses are relatively small and attics are often used as living area. Sizes of the system should be as small as possible. As gas is available at any time and price of the gas does not depend on the time of use, there is also no need from this point of view to store heat. Hence, systems can be small. Compare in this respect the wood fired and electrically heated systems in other countries, where heat stores are a necessity from a technical, comfort and/or cost point of view.

Up into the 1990's, solar thermal systems were exclusively produced by solar manufacturers. Combination of solar energy and auxiliary always involved two separate systems. Nowadays, cooperation between solar industry and boiler manufacturers is quite common and solar and auxiliary part have often been integrated into one apparatus. The integration brought together optimum space requirements with a higher comfort level due to the larger volume of hot water available. For the Dutch solar combisystems, floor area needed is hardly any more than needed for a conventional heating system and this is nicely compensated with the extra comfort. Current solar combisystems can be taken apart into two major pieces in order to be able to transport the system easily into the attic for installation. There, the two parts are put together and the whole system is ready for further installation, which is easy because of all complex parts are already inside the casing.

Regulations have their influence on system concepts as well. Regulations in the past for quality of drinking water only admitted additives in the collector fluid if separation with tap water would be double. In order to prevent bad heat transfer, single wall heat exchanger was combined with plain water in the collector circuit. This required elaboration of a foolproof drain back concept that lasted for several years to be properly developed ([1]).

2. Description of Dutch solar combisystems

There are two major manufacturers in the Netherlands producing solar combisystems, i.e. Atag Verwarming and Daalderop. Both products have been described below. More information can be found in [2] and [3].

ATAG S-HR SolarGasCombi^II system

This solar combisystem combines the well-known ATAG condensing boiler with experiences gained in an earlier generation. Figure 1 shows the hydraulic scheme of the system and Figure 2 presents pictures of the device with and without casing.

The condensing boiler is connected inside the device to the 200 litres heat store. Solar collectors are coupled to the coil heat exchanger in the lower part of the tank. For space heating, the boiler control unit regulates the mixing valve for optimal use of the heat exchanger in the middle of the tank. Solar heat is extracted from the heat store if space heating return temperature is lower than the heat store temperature at the heat exchanger level. If necessary, the mixing valve mixes the space heating water to the required (low) temperature. This is very useful in the case of low temperature heating and/or use of the integrated outdoor temperature control. If the amount of available solar heat is insufficient the condensing boiler will heat the flow to the required temperature. Modulation ratio for the burner is 1:6. For domestic hot water, the upper coil in the tank is used to heat the stored water to the required temperature. Boiler is available in 15, 24 and 35 kW.

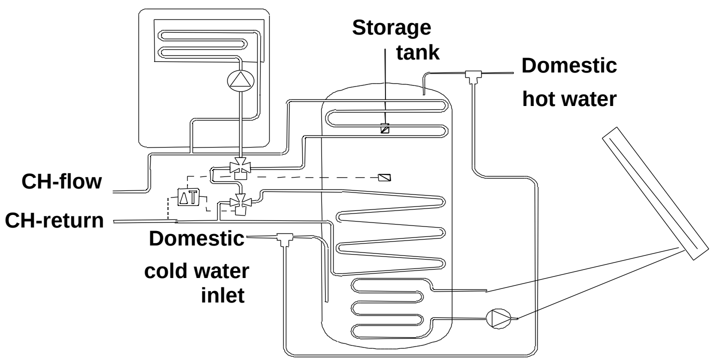

Figure 1: Hydraulic scheme of the ATAG S-HR SolarGasCombi^II.

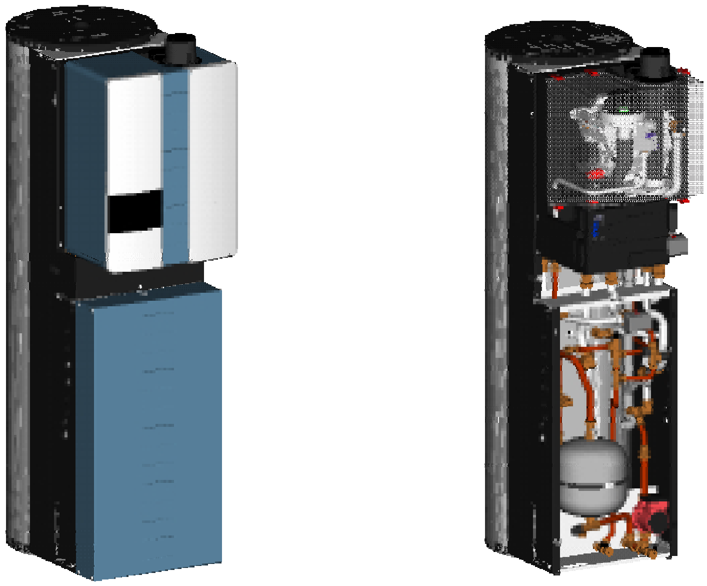

Figure 2: The ATAG S-HR SolarGasCombi[II].

Daalderop MultiSolar system

Also this product combines well-known Daalderop techniques with solar energy use. Figure 3 gives the hydraulic scheme and a picture of the MultiSolar.

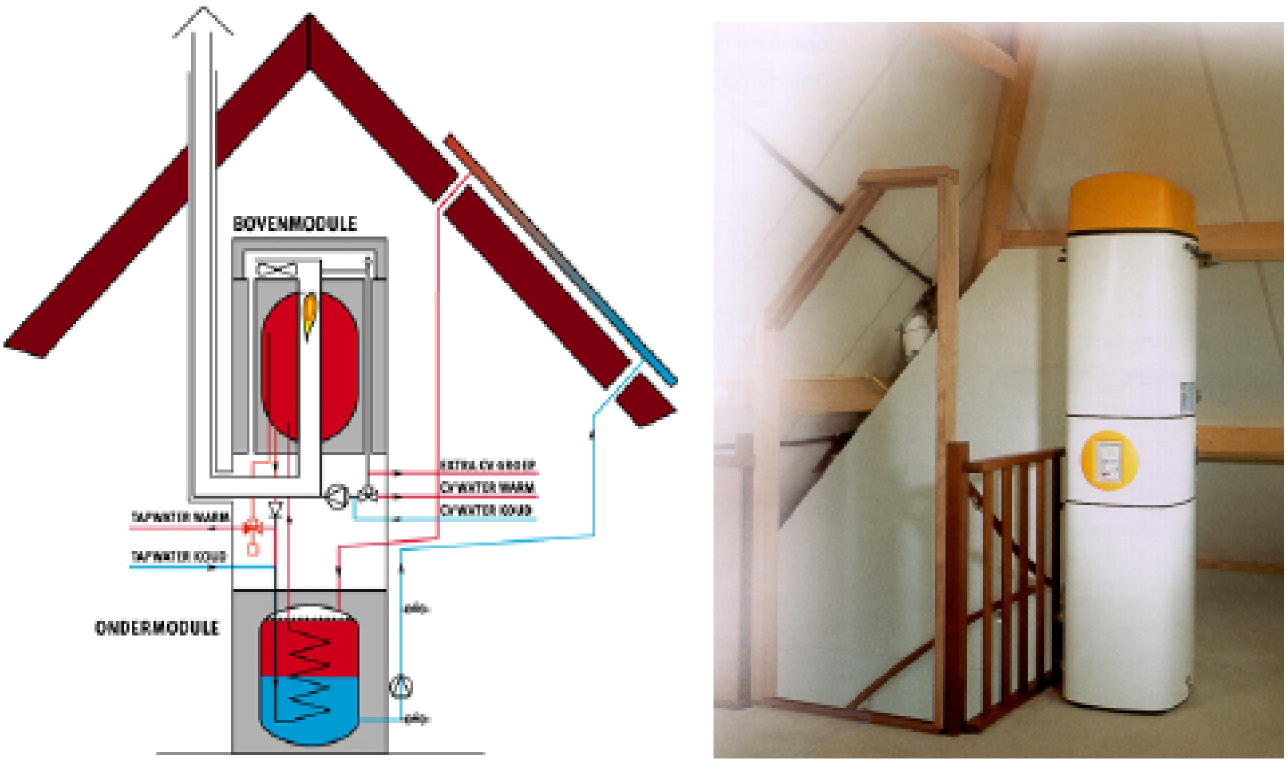

Figure 3: Hydraulic scheme and picture of the Daalderop MultiSolar.

The upper module consists of a condensing boiler with a heat store volume of 80 litres, a heating water circuit and a low NO_x modulating burner. The 5 litres copper heat exchanger in the lower module contains tap water and is connected to the boiler in the upper module. During hot water draw-off, tap water flows through the heat exchanger into the boiler. The 80 litres heat store is kept at a minimum of 60°C and will not cool down as long as temperature in the top of the lower module is higher than about 65°C. In that case and if there is no tap water draw-off, a thermosiphon flow will start. Colder water in the upper module is exchanged by warmer water from the heat exchanger in the lower module. Temperature in the upper module can rise up to about 90°C.

The 80 litre copper store with tap water has a double-walled separation from the space heating water. The burner has been placed in an aluminium heat exchanger where flue gasses are cooled down by space heating water that flows through channels in the heat exchanger. If the burner is switched on, space heating water circulates internally and reaches a supply temperature up to 90°C. Heat transfer through the double-walled separation to the tap water is 17 kW. Boiler is available in 24 and 32 kW.

If there is a space heating demand, the MultiSolar will first start to pump for a very short time and the burner only ignites if the supply temperature is below its setpoint, i.e. between 60°C and 90°C or as calculated from outdoor and return temperatures if there is a weather dependant control. If return temperature of the space heating circuit is lower than the boiler temperature, there will be a heat flow from the boiler to the space heating circuit. With this additional heat, flow temperature for space heating will be raised. As long as flow temperature is higher than its setpoint, burner ignition is suppressed.

Hence, MultiSolar utilises solar energy directly for consumption water and indirectly for space heating. Heating systems with a low flow and return temperatures will therefore receive a larger contribution of solar energy.

Features for both Dutch solar combisystems

Both systems are easy to handle and install because of the 2 colli system, i.e. the upper part with the condensing boiler and the heat store with the other components. All necessary components are included, i.e. controls, drain-back, mixing valve for space heating, filter, water safety valves and controls, etc. The system is easy to understand by the installer because of the well known condensing boiler. Dutch space heating GASKEUR-label, class HR107, is applicable for condensing boilers of both manufacturers. The same applies for the label for low CO and NO_x. The relatively low/specification ratio is achieved by the use of standard products and/or standard machines for making these products.

3. Considerations for the future

It seems that solar combisystems fit closer to the traditional gas apparatus than solar domestic hot water systems: Dutch often ask 'Why does this solar boiler not deliver heat to the space heating?' Hence, traditional aspects may be important in selling renewable energy.

More important are governmental regulations, especially on energy performance of buildings ([4]). Low energy requirements urge architects and project developers to think more thorough about application of energy saving measures and use of renewable energy. This already is an important selling point for solar thermal systems in the Netherlands. Requirements on reduction of energy consumption may lead to a different dimensioning of systems: even Dutch systems may become larger.

For well-insulated houses, contribution of solar energy to space heating is restricted. It can only grow significantly, if seasonal heat storage is applied. Whether developments of Dutch products will go into this direction can be questioned and surely has to do with the cost aspect.

References:

[1] J. Noij, Drain back in small systems. Proceedings Industry Workshop IEA-SHC Task 26, April 2001, Delft, The Netherlands.

[2] J.J.M. Luttikholt. A new generation of solar combisystems ATAG S-HR SolarGas-Commbi II. Proceedings Industry Workshop IEA-SHC Task 26, April 2001, Delft, The Netherlands.

[3] E. van den Tillaart. Daalderop solar systems for domestic appliance: MonoSolar and MultiSolar. Proceedings Industry Workshop IEA-SHC Task 26, April 2001, Delft, The Netherlands.

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SOLAR HEATING WITH A STORAGE-INTEGRATED CONDENSING GAS BURNER

Thomas Krause, Dagmar Jähnig
SOLVIS GmbH & Co. KG
Marienberger Str. 1
D-38122 Braunschweig, Germany
Tel: +49-531-28906- 737, -748
Fax: +49-531-28906-60
E-mail: tkrause@solvis-solar.de, djaehnig@solvis-solar.de,
Internet: www.solvis.de

1 It's Time for Solar Heating

Solar Combisystems (domestic hot water and space heating) are a good method to save energy and minimise CO_2-emissions. The market position of these systems will become much stronger if investment and installation costs can be reduced.

2 Integration of the Gas Condensing Burner into the Storage Tank

Most combisystems consist of two separate components: a buffer store and a boiler. That means that there are still two components to be adjusted which can cause several problems for the hydraulic system and the controller.
The next step is to optimise these two components. The goal is to get maximum integration of the solar system into the standard heating system. This integration has to be done in a way that ensures that the solar system can operate at the same high efficiency as in a separate system. Special consideration has to be given to the efficiency of the collector, mainly given by the inlet temperature into the collector, and the insulation of the storage tank, which is usually much better in a solar system than in a conventional boiler.

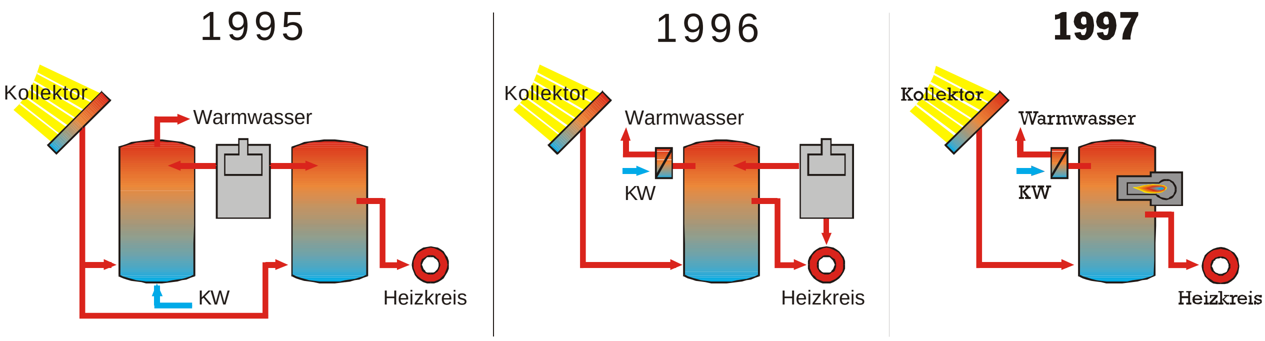


Figure 1: Complete integration of all components into one device

The main aspects for the position of the integrated burner are:

- Ideal position of the combustion chamber is just at the height of the border between heating buffer and domestic hot water buffer to allow maximum solar use.
- The exhaust gas is led down through the colder part of the storage tank to improve condensation and to stop thermal convection.

- A burner concept that minimises emissions combined with an optimised heat transfer surface of the combustion chamber.

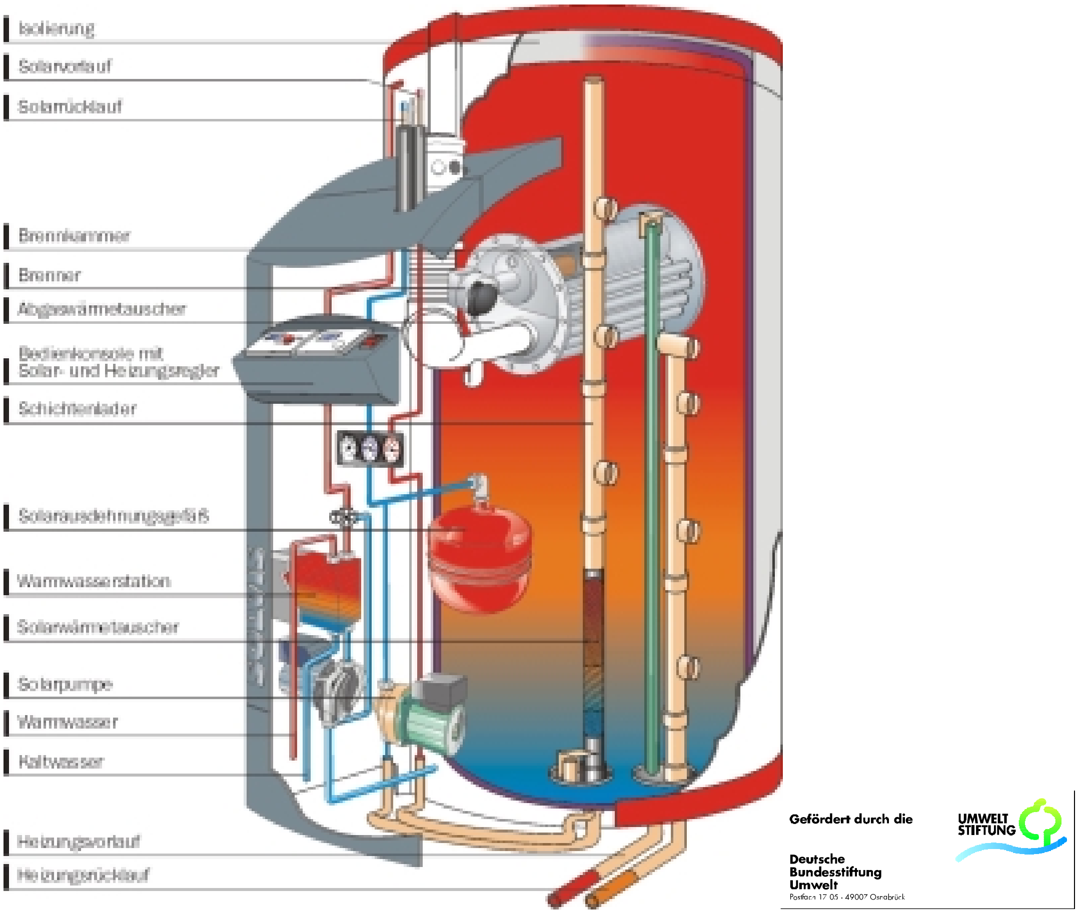


Figure 2: Cross section of the SolvisMax

2.1 Simplified Hydraulic Scheme

The basic idea of this concept is the stratified storage tank working as an energy manager. Each energy source (solar or gas) is stored in the temperature layer inside the tank that corresponds to the temperature of the energy source. This avoids mixing of temperature layers.

It is equally important to draw the outgoing flows (space heating loop or domestic hot water preparation) from the correct temperature layer to avoid mixing and inject the return flows from the consumers in the temperature layer of the returning medium.

The number of pipe connections to be made by the plumber is reduced from 17 to 8!

The fact that all inlet and outlet pipes run through the cold bottom part of the tank insulation is also very important for reducing the heat losses.

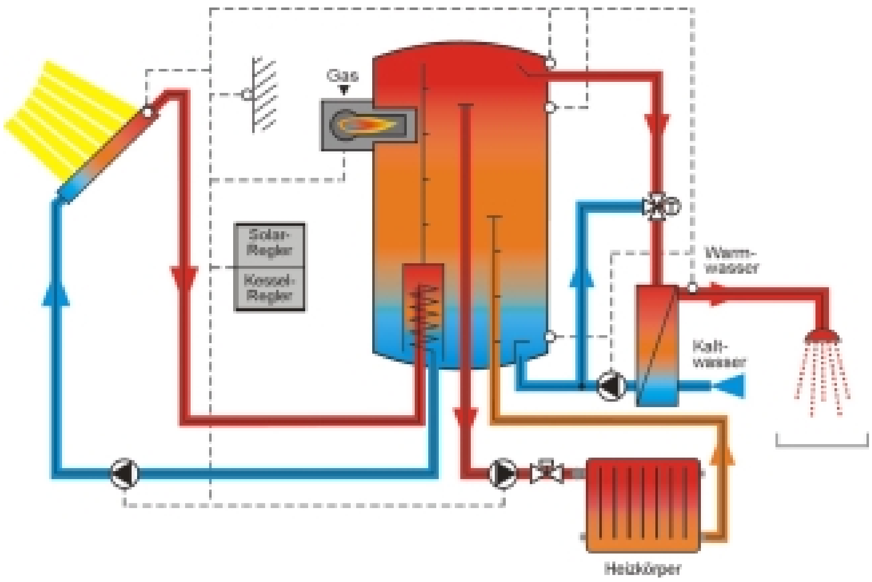


Figure 3: Hydraulic scheme of the SolvisMax

2.2 New Controller Possibilities

In the conventional configuration with two separate components there are generally a lot of small controller problems as they are not designed to work together. Sometimes a third controller is added and the original controllers of the two devices are not used at all. In the integrated approach, the whole control philosophy is contained in one device. This way, it is much easier to make sure that the system functions correctly, installing the system also becomes easier. In addition, it offers new options to optimise the system.

2.3 Less Space Required

Building a new house costs approximately 1000 to 2000 Euro per square meter. Integrating the boiler inside the storage tank saves you around 1 m^2 of floor space!

2.4 Less Weight

This integration reduces the weight from 250 kg to 160 kg. Obviously, this has ecological aspects but it will also reduce investment costs.

Figure 4 shows these aspects of integration.

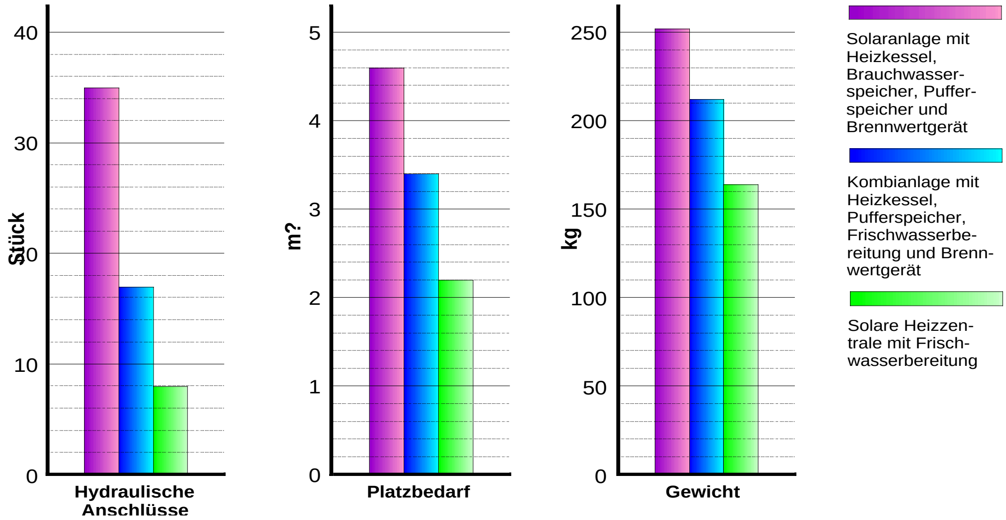


Figure 4: Reducing the number of pipe connections, the required floor space and the weight of the systems

3 Elements of the Concept

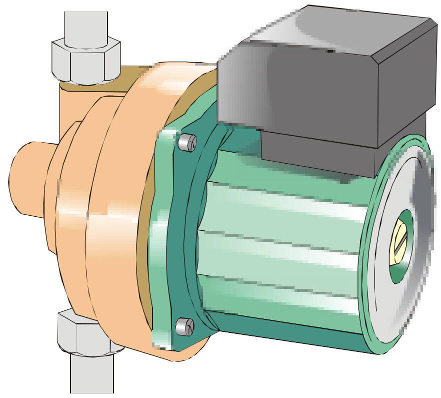
3.1 Low-Flow Solar Loop

In a low-flow system, the volumetric flow rate within the collector loop allows the fluid to reach operating temperature in a single circulation though the collector. This means, that the standard volumetric flow rate has to be reduced from about 40 l/(hr*m^2) to 8-12 l/(hr*m^2). This leads to several advantages. A low-flow system can only perform well, if all components work well together. As in every system, the weakest part defines the limit. Up to now, only few low-flow component are on the market for small solar systems.

3.1.1 Cost Reduction

Less material: Using the low-flow technology, the costs for material used in the system can be reduced. Because the flow rates are smaller, all components can be dimensioned smaller. This is mostly true for the piping between the collector and the storage tank, but also for other components.

Simplified Filling of the System: Standard solar systems need a special pump for filling the collector loop with the fluid (the height of the building cannot be overcome by a standard solar pump). Low-flow systems often use smaller diameter pipes – therefore (even though the flow rates are lower) they have a higher pressure drop. Manufacturers have started to develop a new low-flow pump which can deliver the required flow rate at the required pump head. These pumps can be used for filling the system with fluid– that means that the installation process is much easier, the plumber saves time and the additional pump for filling. Caused by the small inner diameter of the tubes, air can be forced through the whole loop, so the air vent on the roof at the highest point of the circle is not used anymore. This aspect is especially interesting knowing how many problems are caused by the air vent on the roof if it is not separated from the loop after filling the system.



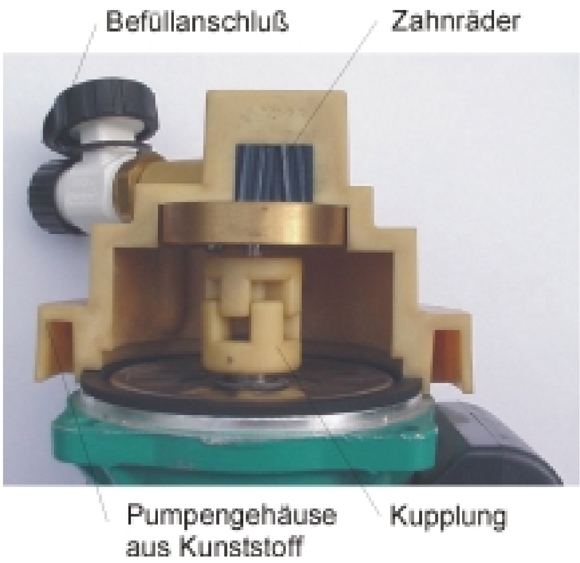


Figure 5: Low-Flow-Pump

3.1.2 Higher Performance in Combination with a Stratifier

Figure 6 shows the principle of a stratified charging – that means avoiding to mix the temperatures inside the storage tank.

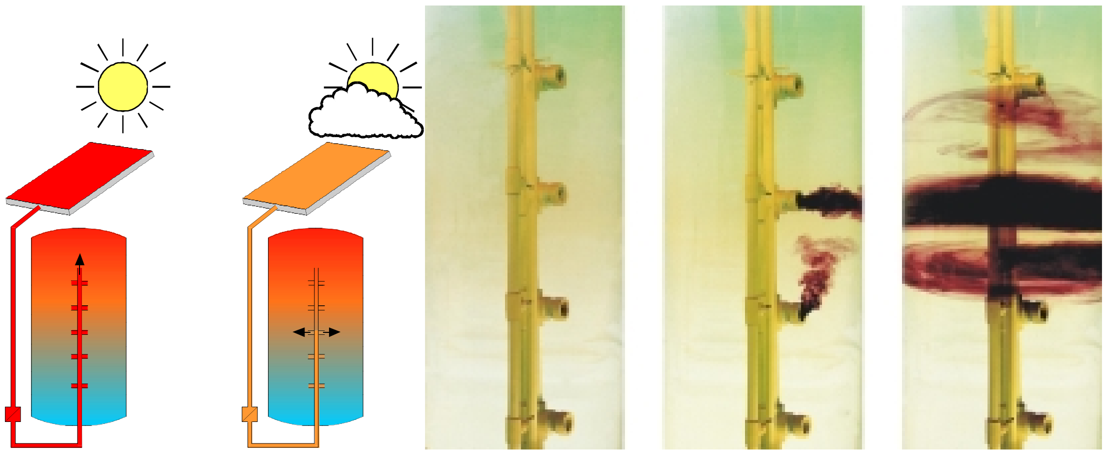
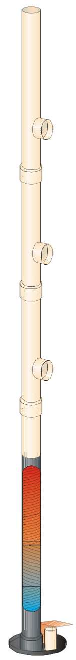


Figure 6: Optimised stratification by the SOLVIS-stratifier



On a sunny day the storage tank is loaded from the top with the required temperature. If clouds are reducing the radiation and therefore the outlet temperature of the collector is lower than before, the stratifier is putting this water in the level below, which has the same temperature as the solar heated fluid. This is achieved by the density differences between the water inside the stratifier and outside in the tank, i.e. there is no active control mechanism.

3.2 Hygienic Domestic Hot Water Preparation Without Mixing the Storage Tank

If you want to use only one storage medium, you have to decide if you are using a domestic hot water tank or a buffer tank filled with water from the heating loop. Most of the solutions prefer the second option, especially because there are less problems with lime deposits and corrosion. There are several possibilities to prepare domestic hot water. One that is becoming increasingly popular is the preparation by means of a flat plate heat exchanger. The domestic hot water is heated when a water draw occurs by a single pass through the heat exchanger. This method ensures germ-free water and also a very good water draw performance if the system is well designed. The Solvis concept offers up to 48 kW at a flow rate of 1200 l/h and can cool the water returning to the buffer store to very low temperatures (5- 8 degrees above mains temperature). Therefore, the return pipe can be led directly into the bottom of the tank (with an impact plate as protection against mixing).

Figure 7: Cross section through a flat plate heat exchanger

3.3 Minimising the Energy Used by the Heating Loop Pump

Because we sell the complete heating system for a building, we can take influence also on the heating loop pump. Currently there are two possibilities available to reduce the power (a new motor generation with a higher efficiency will reduce the energy consumption even further):

— We recommend a high temperature difference within the heating loop, that means to use large radiator surfaces. This reduces the necessary volumetric flow rate and therefore the electricity consumption.

— By using electronic pumps which reduce their power automatically when detecting an increase of the pressure drop inside the loop (caused by closing valves), you can save up to 40% in energy consumption.

3.4 Optimised Combustion Technology

An important factor for the efficiency of a condensing burner is the dew point of the exhaust gas. This point depends on the type of gas and the amount of excess air. Figure 8 shows how the excess air influences the dew point.

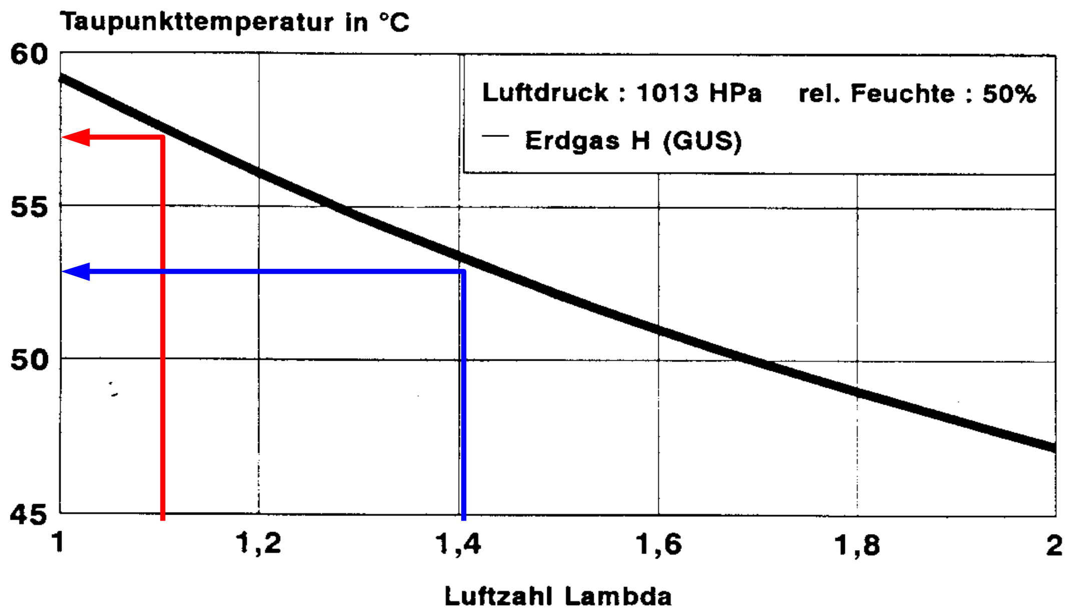
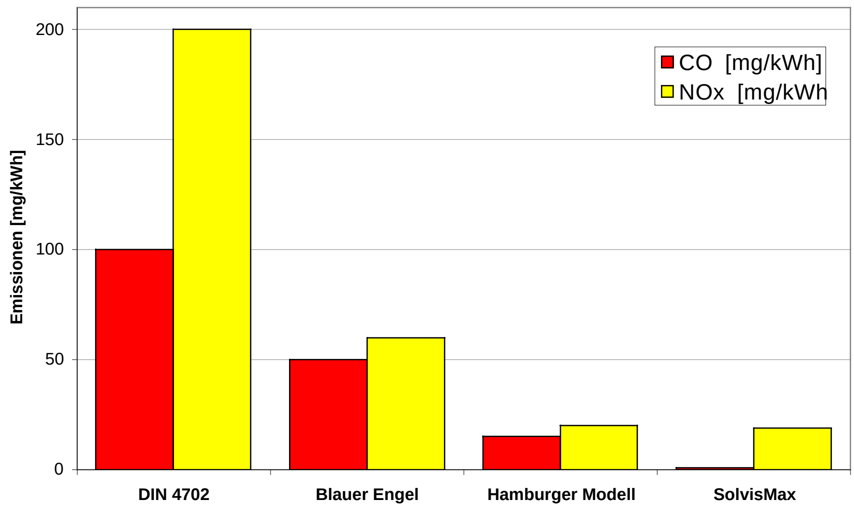


Figure 8: Dependency of the excess air „lambda“ on the dew point temperature [Jannemann, Kompendium Gas-Brennwerttechnik, 2. Auflage 1996]

SolvisMax works with a lambda value of 1.15, which causes condensing to start at exhaust gas temperatures lower than 57 °C. Other devices needs to cool the exhaust gas below 53 °C before condensing starts.



The design of the combustion chamber, optimised excess air conditions and a well designed burner surface lead to low surface temperatures even at full load and therefore very low emission values.

Figure 9: Comparison of different boiler standards with the SolvisMax

4 Thermograph Investigations

The next pictures show that the combustion chamber is integrated at the correct height of the storage tank: The lower part is not heated by the auxiliary burner. You can see quite well the clear stratification also within the area of the combustion chamber.

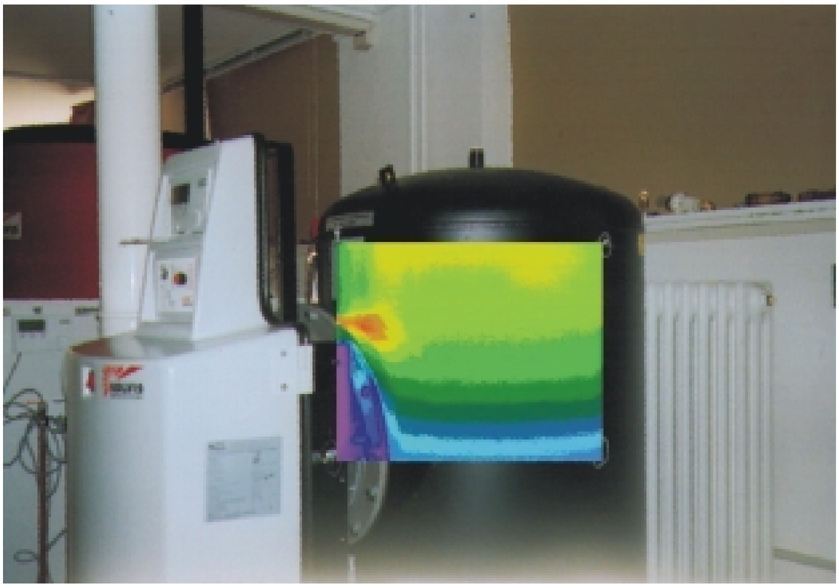


Figure 10: Thermograph picture of the SolvisMax

The next examination was done to optimise the insulation of the combustion chamber. Several openings cannot be avoided like the gas and air inlet, the exhaust gas and condensing water outlet, wires and a small window to watch the flame. That means the insulation cannot be perfect – compared to solar storage tanks without integrated burner. The left picture shows the first version of the insulation, the right one the optimised solution.

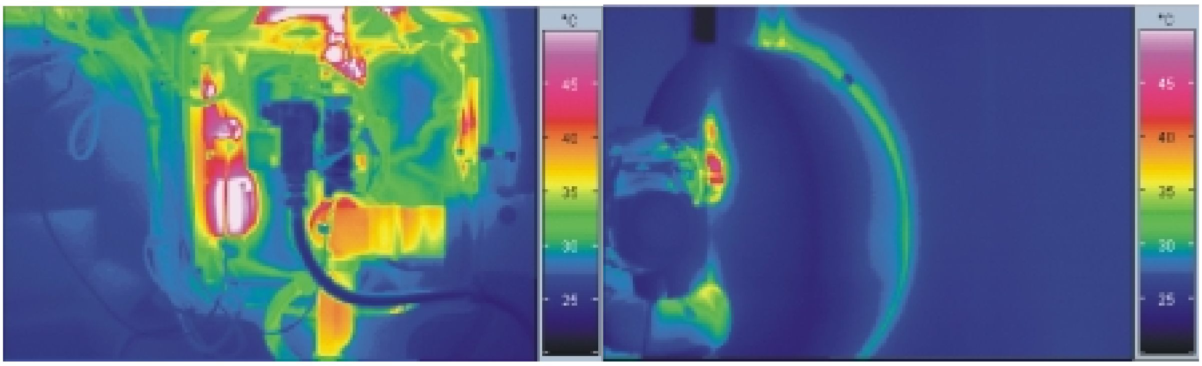


Figure 11: Optimising the insulation of the SolvisMax burner

5 Field Testing of Two SolvisMax Systems

Two SolvisMax systems were monitored under realistic conditions in co-operation with the “Institut für Gebäude- und Solartechnik (IGS)“ at the Technical University of Braunschweig. The “Institut für Thermodynamik und Wärmetechnik (ITW)“ of the “Universität Stuttgart“ has written a TRNSYS model of the SolvisMax as part of this project.

The monitoring period was one year. The descriptions of the systems are given in the table below.

Table: Descriptions of the systems

	System 1	System 2
Type of Building	Four family house, built in low energy standard	Single family house, built in low energy standard
Location	D – 38 173 Evessen	D – 38 329 Wittmar
Standard-Heating-Load (DIN 4701)	15 kW	7 kW
Type of collector, area	flat plate collector, 10 m^2	flat plate collector, 7,5 m^2
Storage volume	750 l	400 l

5.1 The "Low-Flow" Heating-Loop

Low temperature heating loops usually work with a temperature difference within the loop of only about 10 Kelvin. To improve the condensing efficiency and the collector efficiency (depends on the return temperature) it is better to work with 20 Kelvin.

In Germany, the annual distribution of the control function for the temperatures in the heating loop is supposed to show that

- only 10% of the year the boiler works at an ambient temperature lower than –5°C and therefore at boiler temperatures higher than 50°C.
- only 10% of the year the ambient temperature is higher than 12°C, so that the boiler temperature is less than 30°C.
- therefore, the boiler works 80% of his operating time at temperatures between 30°C and 50°C.

We have verified this for the two monitored systems:

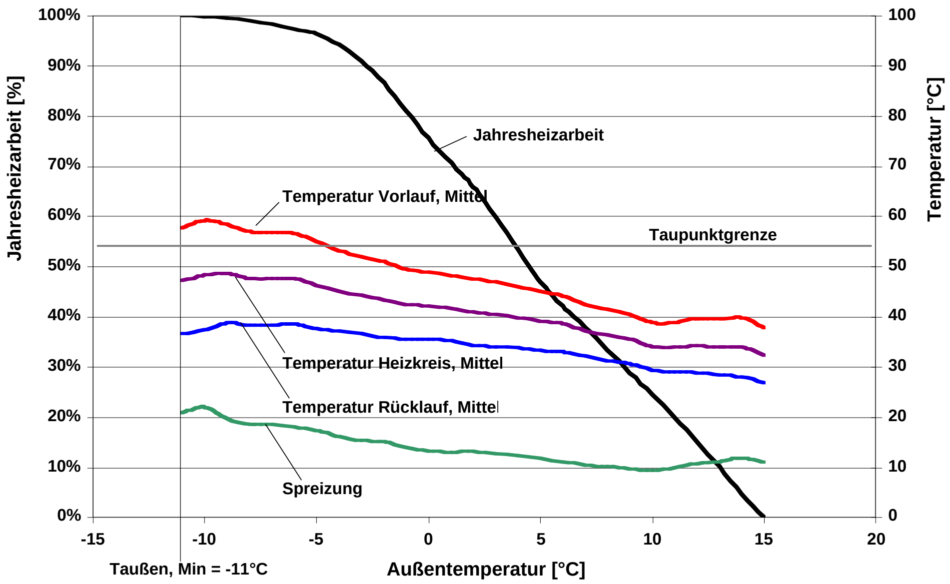


Figure 12: Heating loop control function for a monitored SolvisMax system

Indeed, the system works within these temperatures! Figure 12 shows, that the system is designed for forward/return temperatures of 60/40°C. The return temperature to the boiler is below 40°C all year, that means the difference between the return temperature and the dew point of the exhaust gas is at least 15 K. The exhaust gas is cooled to temperatures of about 5-10 K above the return temperature, therefore, the efficiency of the condensing burner is very high.

Figure 13 shows the measured temperature of the exhaust gas: One curve shows the temperatures when the boiler operates at maximum power for domestic hot water preparation, the other one the temperatures when running for space heating. It is below 55°C in both cases during the whole year!

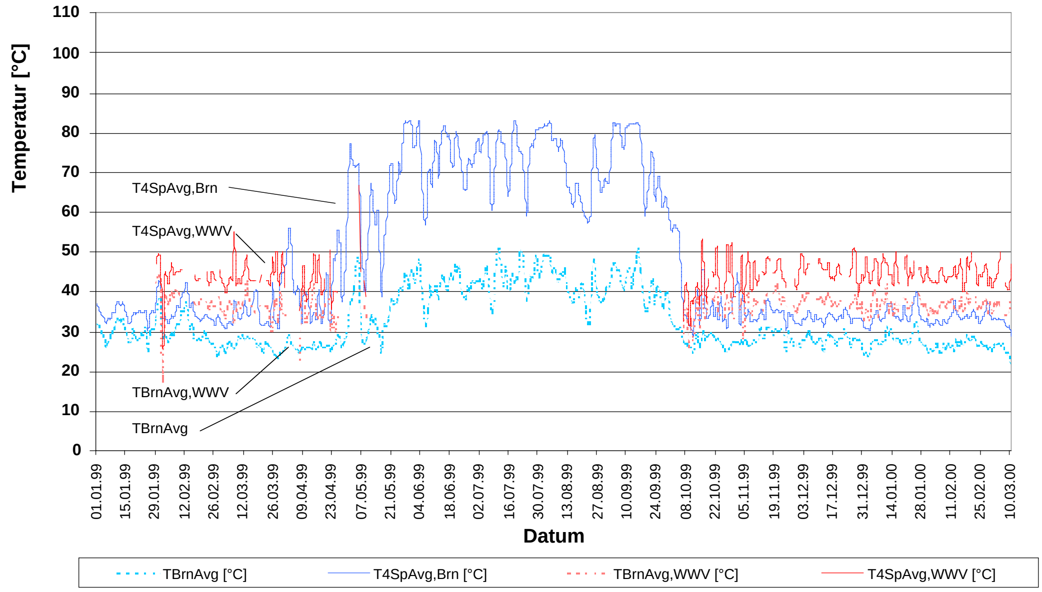


Figure 13: Exhaust gas and storage temperatures for a monitored system

5.2 Cycling of the Burner in Field Tests

Reducing emissions is not only possible by replacing fossil energy by solar energy, but also by reducing the cycling of the burner: The emissions, produced by starting and stopping of the burner, can have such high peaks, that they can get values up to five times higher than during the stationary period. (Figure 14).

Figure 14: Boiler emissions / Sources: [Buderus], [Pfeiffer]

To reduce cycling modulating burners have been developed, which can produce exactly the power that is needed by the heating system. But nowadays the power, which is necessary to satisfy the domestic hot water comfort (15 kW or more), is much higher than the power to heat a house in spring or autumn (can be as little as 1 kW). Therefore, even a modulating burner has to be switched on and off in these periods.

Using a buffer store, the cycling can be reduced even more. Considering, that about 70% of the annual heating power is used in times with ambient temperatures above 0°C, explains why some heating systems start about 25,000 up to 37,000 times per year (Source: Buderus).

Solvis has taken the statistics from 44 systems running in the field:

Statistics of 44 SolvisMax systems	
Number of considered systems for statistics	37 of 44
Sum of the operating time of the considered systems	699,456 hours (29144 days)
Sum of operating time of the considered burners	132,412 hours
Sum of all burner starts of the considered systems	364,182 starts
Average value of the monitored period of each system	788 days (ca. 2.2 years)

The average value of starts of the considered SolvisMax systems was 4636, some systems have had only about 2100 starts per year.

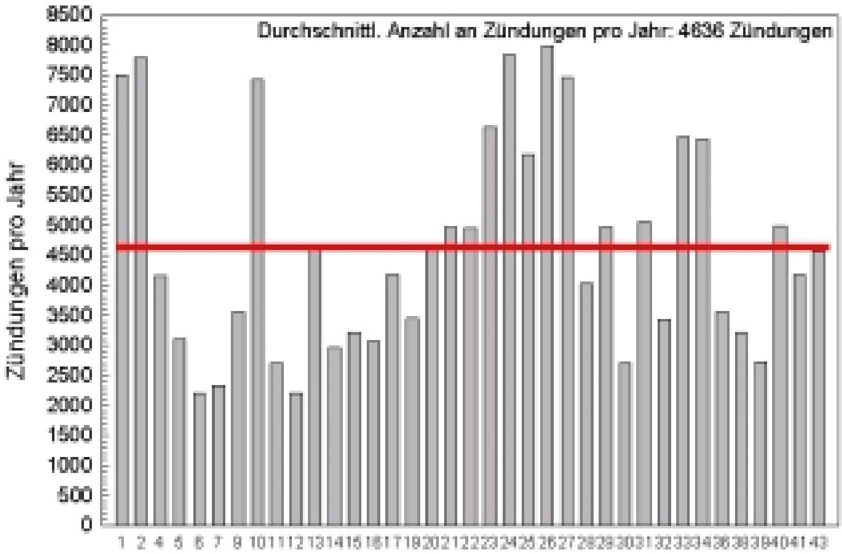


Figure 15: Number of burner starts per year

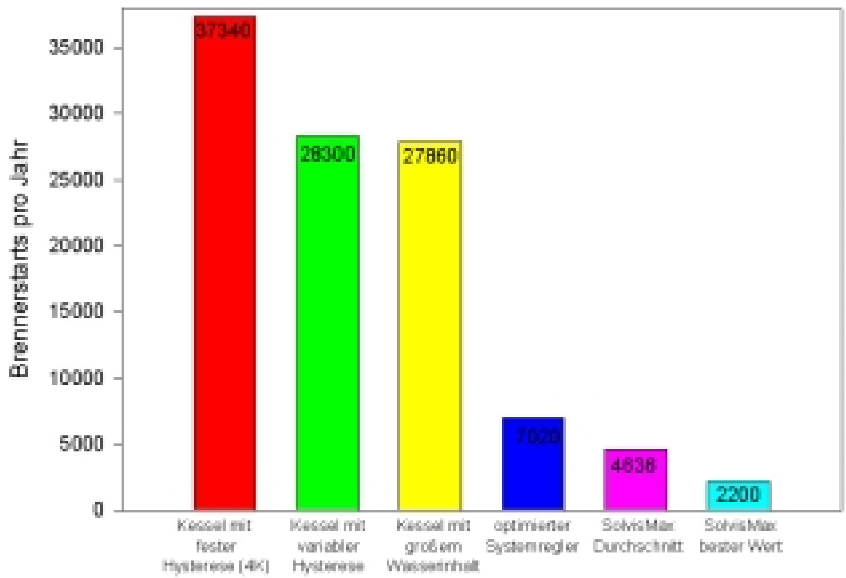


Figure 16: Comparison of burner starts

5.3 Burner Surface Test

The life time of the burner surface was tested in the Solvis laboratory. After 16,300 hours of operation without any maintenance or problems the test was stopped and the surface compared with a new one in the manufacturer's laboratory. The running time corresponds to 10 years normal life (with 1626 operating hours per year as the average running time per year).

It was found that under these testing conditions the burner could run about 3 to 4 times longer! (Report of the manufacturer of the surface, examined from 14 to 17 April 2000).In the left picture, there is a new burner surface, on the right side the examined burner after 16,300 hours. The flame is more uniform, because longer fibres of the new surface have been burned.

Figure 17: Burner surfaces (new and after 16,300 hours of operation)

6 Optimised Burner Annual Efficiency

Annual boiler efficiencies of the solar optimized integrated gas condensing boiler SolvisMax Gas were simulated using the transient simulation program TRNSYS for different space heating loads and also for domestic water heating mode only. The results were validated through laboratory tests. The annual boiler efficiency of the SolvisMax varies from 106% for space heating mode only to 93% for domestic water heating mode only. These efficiencies include the stand-by losses of the system.

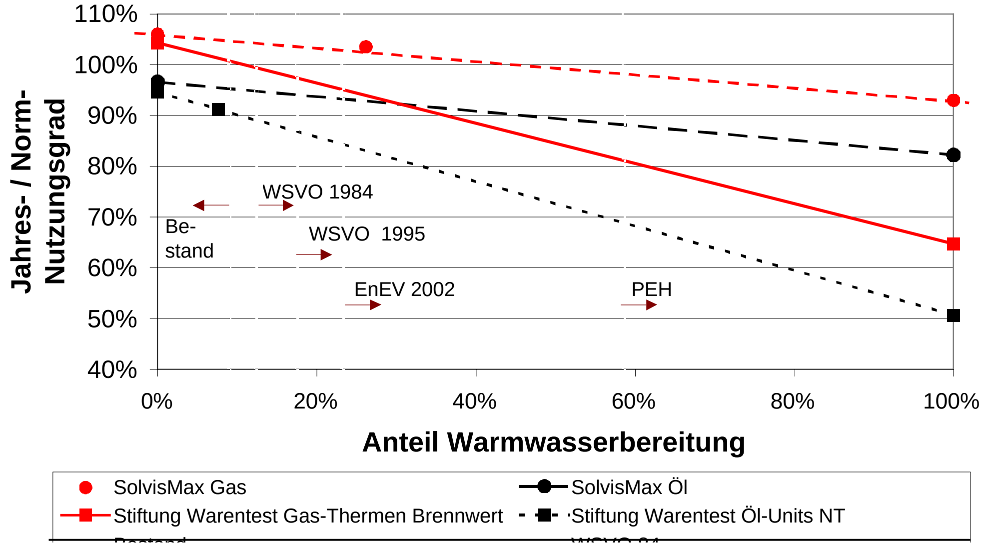


Figure 18: Influence of the operation mode (space heating or domestic hot water preparation) on the annual efficiency of the burner

Figure 18 shows how much better the integrated burner of the SolvisMax performs in hot water preparation mode compared to standard, non-integrated systems tested by "Stiftung Warentest" in 1998. The main reason for this is that the surrounding temperature of the lower portion of the combustion chamber is kept as cold as possible. This means that the exhaust gas temperature is kept at a minimum which leads to very good condensing conditions.

7 Responsibility for the Whole System

Solar energy contributes its share to save energy. Developing a complete solar heating system gives the chance to:

- adjust the system so that all components work well together.
- take responsibility for the whole system: Everything is manufactured by one producer. This helps the installer by giving him the security that there is only one manufacturer responsible for the whole system.
- reduce the time needed for installing the system, as everything fits together.
- look for further cost reductions in the future.

There are more than 2500 systems now running in Europe.

Heating with the sun is no longer utopia! The solar plant is becoming a part of the heating system.

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INFLUENCE OF DIFFERENT COMBISTORE CONCEPTS ON THE OVERALL SYSTEM PERFORMANCE

Harald Drück

Institut für Thermodynamik und Wärmetechnik (ITW)
Prof. Dr.-Ing. habil. H. Müller-Steinhagen
Universität Stuttgart
Pfaffenwaldring 6,
D-70550 Stuttgart, Germany
Tel.: +49 711 685 3536,
Fax.: +49 711 685 3503
E-mail: drueck@itw.uni-stuttgart.de Internet: http://www.itw.uni-stuttgart.de

Abstract

Four hot water stores for combined domestic hot water preparation and space heating, so-called solar combistores, were investigated in detail. The thermal performance of these combistores was determined on the basis of ENV 12977-3.

In this article the principle structure of this test method is described. The schematic setup of four particular combistores is explained and the test results are presented. In order to investigate the influence of thermal stratification inside the store, six, with regard to charging and discharging different store concepts have been defined.

The thermal behaviour of the four combistores and the six store concepts in a solar heating system has been investigated and compared by means of system simulations. The results obtained for the different stores and store concepts are presented and discussed.

1. Introduction

Systems for combined domestic hot water preparation and space heating have an increasing market share in many European countries. In Germany approximately one third of the solar heating systems sold for one family houses and multiple family dwellings are combisystems. For those systems the heat store is the key component, since it is used as a short-term store for solar energy and as a buffer store for the fuel or wood boiler.

2. Store Test Method

The test method for combistores has been further developed from the test procedure for solar domestic hot water stores, which was presented at EuroSun 96 [1] and is now available as ENV 12977-3. The objective of store testing, as described in this standard, is the determination of parameters which can be used in combination with an appropriate numerical model, for the detailed description of the dynamic thermal behaviour of the store.

The test method can be subdivided into the three following steps:

- Performing the appropriate test sequences according to ENV 12977-3 with the store being connected to the test stand. During the operation of the store temperatures and volume flow rates at the inlet and outlet as well as the ambient temperature are measured and recorded.
- Identification of parameters that are required in order to describe the thermal behaviour of the store in combination with an appropriate numerical model.
- Verification of the determined parameters by 're-simulation' of a verification sequence.

3. Investigated Combistores

From the approximately 25 combistores already tested at ITW, four typical ones were chosen for the following comparison (see Figure 1). The stores are thermally charged via an immersed heat exchanger. The domestic hot water preparation is also performed via an immersed heat exchanger (except for store B). For thermal insulation prefabricated pieces of foam are used. They are mounted after the store has been set up.

The peculiarities of the stores are described in the following:

Store A: For stratified charging a pipe with horizontal outlets is mounted above the solar loop heat exchanger. Due to the relatively large openings at the bottom of the stratification device the flow rate on the secondary side (inside the store) is two to three times as large as the flow rate through the solar loop heat exchanger.

For the preparation of domestic hot water a smooth tube heat exchanger made from copper is mounted on the inside surface of the store. The part of the store used as the auxiliary part for domestic hot water preparation is separated from the space heating part by a horizontal plate. This plate shall reduce the degradation of thermal stratification due to a reduction of the vertical heat transfer.

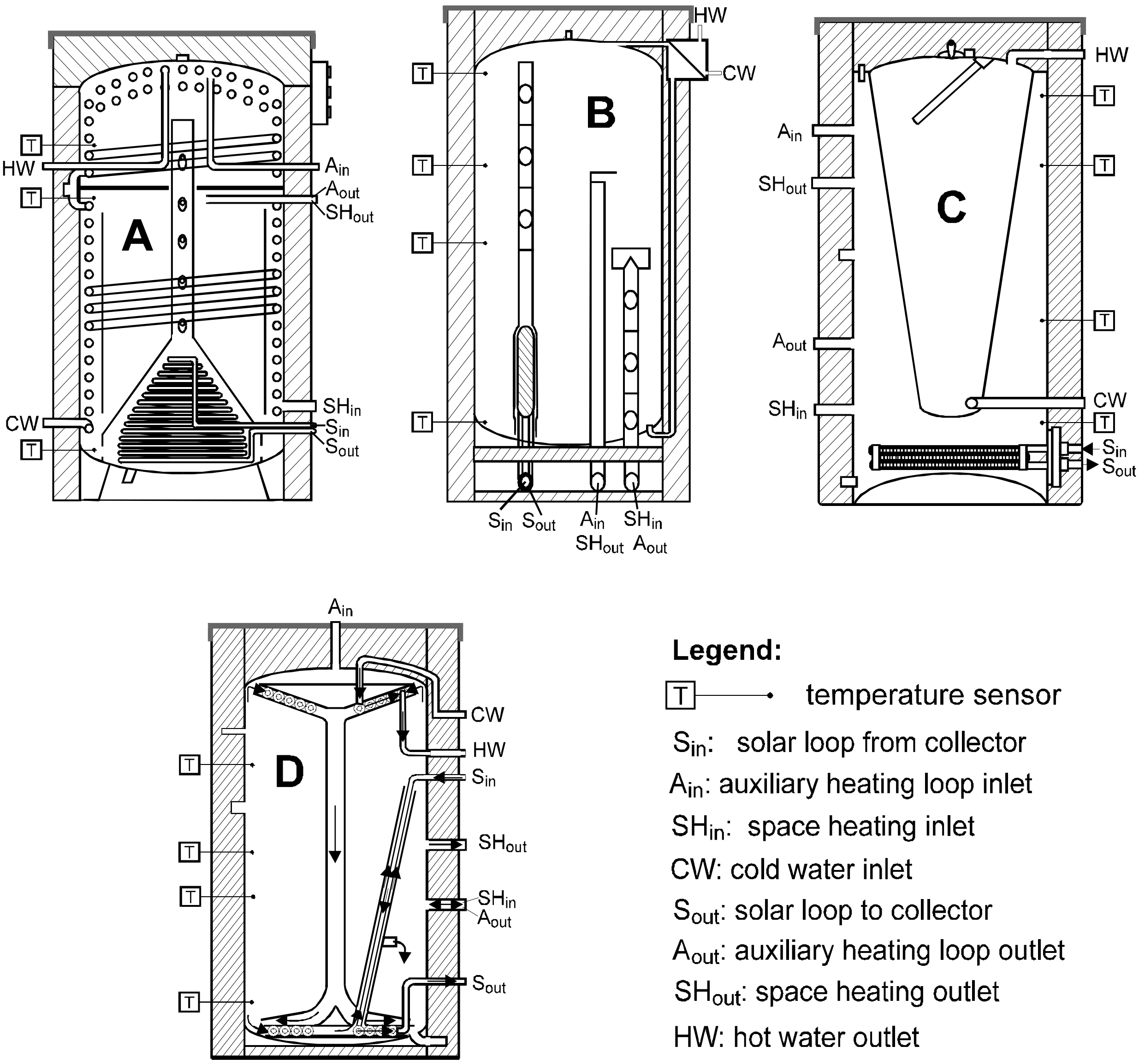

Figure 1: Schematic setup of the four investigated combistores

Store B: For stratified charging a pipe with horizontal openings being equipped with flaps is placed above the solar loop heat exchanger. In order to provide the high temperatures, which are required for building up a good stratification, this store has to be connected to a system where the collector loop works according to the low-flow principle. The water returning from the space heating loop is also supplied to the store via a pipe with horizontal openings equipped with flaps. The domestic hot water is prepared by means of a plate heat exchanger which is mounted outside the tank within the thermal insulation of the store.

Store C: This store is a so called 'tank-in-tank-store' since there is a second, smaller tank inside the main store containing the domestic hot water. The thermal energy is transferred to the domestic hot water via the surrounding water of the space heating loop. The solar energy is supplied to the store via a horizontally mounted finned tube heat exchanger made from copper.

Store D: The solar loop heat exchanger as well as the domestic hot water heat exchanger of this store are equipped with devices for stratified charging and discharging, respectively. In order to provide the high temperatures which are required for building up a good stratification, this store has to be connected to a low-flow system.

4. Comparison of the four combistores

As a result of store testing, several parameters are determined which are required to describe the thermal behaviour of the store in combination with the numerical model 'MULTIPORT'. Some of these parameters, e. g. the heat loss capacity rate, can be compared with each other and assessed in a direct way. Other parameters, such as the vertical positions of the connections for direct charging and discharging as well as the positions of the temperature sensors are also important for the thermal behaviour of the store, since these parameters determine e. g. the volume of the auxiliary heated part or the buffer volume. However, these parameters cannot be compared or assessed in a direct way.

Figure 2 shows the domestic hot water draw-off profiles of the four combistores as well as the temperatures measured at the individual positions of the temperature sensors.

These tests were performed as follows:

- Charging the <u>complete</u> store with an inlet temperature of 60^{o}C until the outlet temperature at the bottom of the store exceeds 55^{o}C.
- Discharging via the domestic hot water loop with a flow rate of 600 l/h and an inlet temperature of 20^{o}C until the hot water outlet temperature drops below 30^{o}C.

In order to compare and assess the different draw-off profiles the following two effects have to be taken into account:

- Thermal stratification inside the store.
- Difference between the domestic hot water outlet temperature and the temperatures inside the store.

The draw-off profiles of the four stores presented in Figure 2 show, that the thermal stratification during discharge is nearly perfect for store B. Comparing the stratification during discharge for the stores with an internal heat exchanger for domestic hot water preparation (stores A, C, D) the stratification is the best for store D. However, the temperature difference between the domestic hot water outlet temperature and the temperature inside the store is also the largest one.

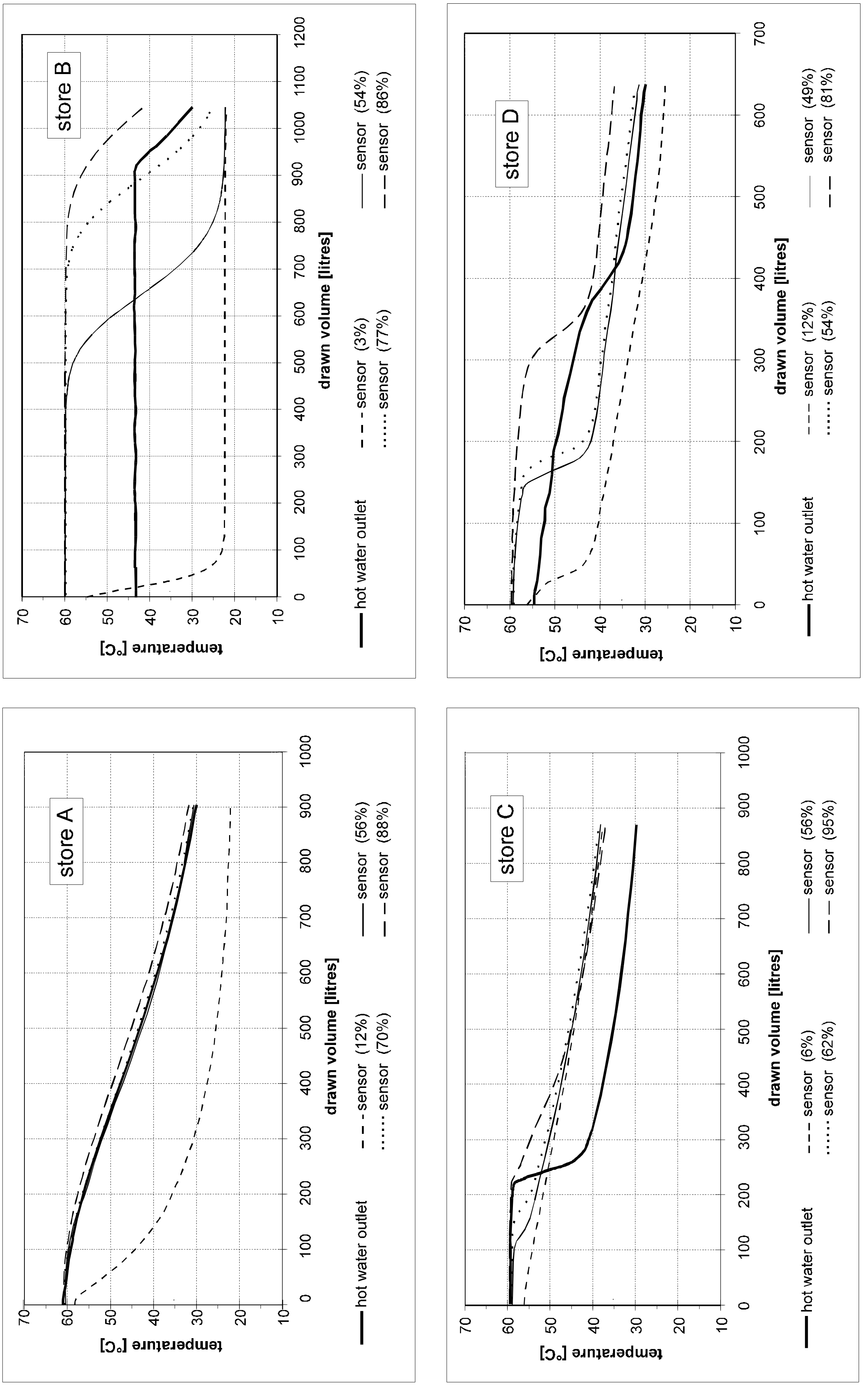

Figure 2: Hot water outlet temperature and store temperatures during the discharge of the completely charged stores (vertical position of the temperature sensors in [%] of the height of the store)

Considering the store as a whole, a complete comparison of the stores can only be carried out by means of system simulation. Therefore the different stores are included in a 'standard combisystem' with 10 m^2 flat plate collector area. With respect to space heating this system is a preheating system, with the boundary conditions described in [2].

The performance of the combistores is assessed by using the predicted yearly fractional energy savings. This quantity specifies the percentage of energy that can be saved by using a solar combisystem instead of a conventional system for space heating and domestic hot water preparation.

In order to cover the domestic hot water load during days without solar input, a certain amount of energy has to be stored in the auxiliary part. Since the performance of a combistore depends on the energy stored in the auxiliary part, the set temperature for auxiliary heating $T_{aux,set}$ was adjusted in such a way that the domestic hot water load could just be covered. Auxiliary heating was performed with a flow rate of 450 l/h and an inlet temperature that is 5 K above $T_{aux,set}$.

Table 1 shows the effective store volume V_s, the effective vertical thermal conductivity λ_{eff}, the volume heated by auxiliary energy for domestic hot water preparation $V_{HW,aux}$ and the overall heat loss capacity rate $(UA)_{s,a}$ as the most important parameters determined from the test of the store. Furthermore the obtained auxiliary heating set temperatures $T_{aux,set}$ are listed. In order to take into account the influence of the flow rate in the collector loop, the fractional energy savings f_{sav} are predicted for both high-flow (50 l/(hm^2)) and low-flow (12 l/(hm^2)) operation of the collector loop.

For stores A to D the maximum deviation of f_{sav} is 2.5 % (absolute), which corresponds to approximately 470 kWh or approximately 12 % relative difference in f_{sav}. However, these are the results determined for the stores which are physically existing.

store	V_s [litre]	λ_{eff} [W/(mK)]	$V_{HW,aux}$ [litre]	$(UA)_{s,a}$ [W/K]	$T_{aux,set}$ [°C]	high-flow f_{sav} [%]	low-flow f_{sav} [%]
A	693	1.80	208	3.43	54	20.8	20.0
B	769	1.01	231	2.53	49	20.2	20.8
C	755	1.71	128	3.59	43	20.2	19.2
D	549	1.06	104	3.48	52	18.3	18.3

Table 1: Test results and predicted fractional energy savings for the four stores tested

In order to investigate the influence of the store design itself (e. g. positions of the connections, stratification devices), additional simulations were carried out using a uniform $(UA)_{s,a}$-value of 2.5 W/K and a store volume of approximately 750 litres for all four stores. The results of these simulations (store A* to D*) are listed in Table 2. Now the maximum difference in f_{sav} is halved. However, there is still a difference of 1.3 % (absolute).

For store A* f_{sav} increases by 0.2% (absolute) and for store C* by 0.8 % (absolute) due to a smaller $(UA)_{s,a}$-value resulting in lower heat losses. For store B* a homogeneous $(UA)_{s,a}$-value of 2.5 W/K results in a decrease of f_{sav} by 0.3 % (absolute). This is due to the fact that for the store tested, the heat loss capacity rate was not uniformly distributed over the surface of the store since the insulation at the top and the mantle was thicker than the one at the bottom. The overall $(UA)_{s,a}$ -value of this store was determined to 2.5 W/K. Hence a homogeneous $(UA)_{s,a}$ -value of 2.5 W/K causes higher heat losses.

store	V_s [litre]	λ_{eff} [W/(mK)]	$V_{HW,aux}$ [litre]	$(UA)_{s,a}$ [W/K]	$T_{aux,set}$ [°C]	high-flow f_{sav} [%]	low-flow f_{sav} [%]
A*	693	1.80	208	2.50	54	21.0	20.2
B*	750	1.01	225	2.50	49	19.9	20.5
C*	755	1.71	128	2.50	43	21.0	20.1
D*	750	1.06	143	2.50	50	19.7	19.7

Table 2: Predicted fractional energy savings with a $(UA)_{s,a}$ = 2.5 W/K and V_s ≈ 750 litres.

Regarding store D* there is a total increase of f_{sav} by 1.4 % due to a lower $(UA)_{s,a}$-value and a larger store volume (1 % is due to the lower $(UA)_{s,a}$ -value and 0.4 % due to the larger store volume). However, the use of this store still leads to the lowest value of f_{sav}. This can be explained by the positions of the connections for the space heating loop and the auxiliary heating loop outlet (A_{out}). For an optimal configuration of these connections the performance increases by approximately 1 % (absolute).

It is well known that good low-flow concepts as well as small auxiliary volumes and low auxiliary heating set temperatures are leading to higher fractional energy savings. But why is it store A* with almost the largest auxiliary volume and the highest set temperature that performs quite good under highflow conditions?

The reason is the large heat transfer capacity rate (under high-flow conditions) and the effective working stratification device of the solar loop heat exchanger. However, further simulations showed that for low-flow operation f_{sav} could reach approximately 21.3 % if the heat transfer capacity rate of the solar loop heat exchanger did not decrease by a factor of two for low-flow conditions and if the stratification device was optimised.

5. Comparison of different store concepts

The presented comparison of the real existing stores and store designs leads to the general question of the influence on thermal stratification on the system performance. In order to answer this question theoretically, six different store concepts were investigated by means of numerical simulations /3/.

The boundary conditions used were the same as described in the previous sections. All store parameters were kept constant, except the ones which directly influence the thermal stratification. Hence the ways of solar charging, domestic hot water preparation and space heating were varied.

The **domestic hot water preparation** can either be performed by means of an external heat exchanger which is considered as ideally stratified or by means of a 'tank-in-tank-store'.

Both ways of domestic hot water preparation are principally shown in Figure 1, store B and store C.

With regard to the thermal stratification during **discharging of the store for space heating** purposes, also two ways have to be distinguished. Either the return pipe from the space heating loop is directly fed into the store or through a stratification device, which is considered as ideally working. An example of such a stratification device is shown in Figure 1, store B.

The **solar charging** of the store can be performed via an immersed or an external heat exchanger. If the immersed heat exchanger is equipped with a stratification device, solar charging is considered as ideally stratified. If no stratification device is used, it is assumed that solar charging takes place in a mixed way. In Figure 1 solar loop heat exchangers with (store A, B, and D) and without stratification device (store C) are shown.

If an external heat exchanger is used, the secondary side outlet from the heat exchanger can either be connected to the lower part of the store, which leads to a mixed way of charging. Another possibility is to have several connections at different heights of the store and to use that connection at which the temperature inside the store is more or less similar to the temperature of the fluid coming from the heat exchanger. In the present study an external heat exchanger in combination with two connections at the store for “stratified” charging was investigated in combination with a matched-flow operation strategy of the collector loop.

Based on the different ways of charging and discharging the store, six different combistore concepts were defined. These concepts can be characterised as follows:

store	domestic hot water preparation	space heating return line	solar charging	collector loop flow rate
S1	tank-in-tank	without stratifier	mixed	high-flow
S2	external hx	with stratifier	stratified	low-flow
S3	external hx	without stratifier	mixed	low-flow
S4	external hx	without stratifier	stratified	high-flow
S5	external hx	without stratifier	mixed	high-flow
S6	external hx	without stratifier	external hx 2 connections	matched-flow

Table 3: Investigated store concepts (hx = heat exchanger)

The results of the annual performance prediction are shown in Figure 3. The relative deviation of the fractional energy savings is based on the results determined for Store S1. It can be seen, that the best result (+ 7% relative) is obtained for Store S2. This could be expected, since this is the store with the maximum of thermal stratification. However, it should be noticed that this result is based on the assumption that charging and discharging takes place in an ideally stratified way. If this can really be achieved during practical operation conditions is still an open question.

With regard to the influence of the collector loop flowrate a comparison between S2 and S3 shows, that stratified solar charging influences the system performance by approximately 5% (relative) if the collector is operated in the low-flow mode. Furthermore, with regard to S5 it can be seen that it is better to operate the collector loop with high-flow, if no device for stratified charging is used. The result determined for S4 shows that the advantage of stratified solar charging is quite small, if the collector loop is operated with a high flowrate.

From the results described above it can be concluded that the operation of the collector loop in the low-flow mode only leads to an increase of the thermal system performance if the solar loop heat exchanger is equipped with a stratification device.

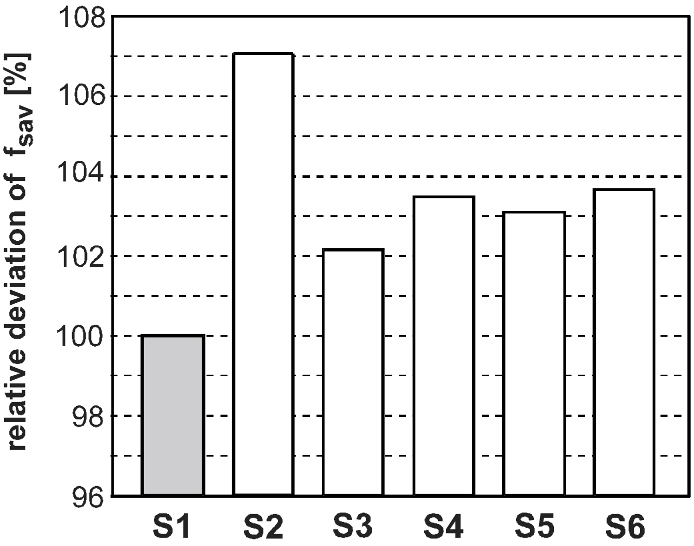

Figure 3: Deviation of predicted fractional energy savings for the different store concepts

A look at the fractional energy savings determined for S6 principally verifies this result with an increase of f_{sav} by 3.7% (relative, compared to S1), since as well the two connections for charging as the matched-flow operation are steps towards an ideally stratified low-flow system.

6. Conclusions

Four combistores were tested and their performance in combination with a standard solar combisystem was compared. It can be concluded that the most important parameters for a well performing combistore are low heat losses due to a good thermal insulation and a well dimensioned (as small as possible with respect to hot water comfort) auxiliary volume in combination with a low set temperature due to a high heat transfer capacity rate of the heat exchanger used for domestic hot water preparation.

In order to keep the collector inlet temperature as low as possible, the heat transfer capacity rate of the solar loop heat exchanger should be large (approximately 80 W/K per m^2 collector area). Furthermore the connections for the auxiliary and the space heating loop should be in the appropriate positions.

The comparison of the six different combistore concepts showed that the maximum increase in system performance that can be expected from a theoretically ideally stratified store is 7% (relative). If this fact is considered in comparison with the results determined from the comparison of the four combistores it can be concluded that the use of certain stratification devices is only appropriate if the store is already optimised with regard to the heat losses and the volume and temperature level required for the auxiliary part.

Acknowledgements

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FACADE INTEGRATED COLLECTORS – CONSTRUCTIONS, BUILDING PHYSICS AND THE RESULTS OF TWO MONITORED SYSTEMS

Irene Bergmann
AEE INTEC
Arbeitsgemeinschaft ERNEUERBARE ENERGIE
Institut für Nachhaltige Technologien
Institute for Sustainable Technologies
A-8200 Gleisdorf, Feldgasse 19
Tel.:+43-3112-5886, Fax: +43-3112-5886-18
E-mail: i.bergmann@aee.at, Internet: http://www.aee.at

In the main solar thermal systems are used to prepare hot water in small-scale plants. When it comes to applications in the field of solar space heating, large-scale plants in urban building projects, hotels and solar district heating networks, there are not always roof areas available which are sufficiently suitable for the installation of solar collectors. When installing these on existing roofs or joining them to flat roofs, the plants often form a foreign body since they are not an integral part of the architecture. For this reason solar plants are still rejected by some architects and town planners.

For a wide market penetration it is, therefore, necessary to develop collector systems which can be integrated in façades. As the development of façade systems for photovoltaic modules has shown, these open up a large and new market segment.

Figure 1: With the help of a façade-integrated collector it is possible to bring the sun into the façade by means of both energy and design. Source: Sonnenkraft.

As part of IEA SHC Task 26, Solar Combisystems, and of an Austrian national project (financed by the Austrian Ministry for Transport, Innovation and Technology) two systems with façade- integrated collectors were measured by the AEE INTEC to evaluate the systems' thermal and humidity behavior. One test façade has been erected on a light weight wall construction and one on a brick wall to record the different behavior of the system collector/wall in different constructions.

The results showed the different problems in the different systems: whereas the main question in massive wall constructions is the fixing of the collector without thermal bridges, it is the removal of the humidity in light weight wall constructions.

The results of this project are used by the two solar engineering companies participating in this project as a basis for the production of test façades and subsequently for the transfer to manufacturing and series production.

System-, structural- as well as building physical basis theories have been elaborated. They served as a basis for constructional and aesthetically attractive solutions for the production of façade-integrated solar collectors without thermal separation.

1. Direct Façade Integration

In this context a collector element directly integrated in the façade is understood by a façade-integrated solar collector in which heat insulation is a component both of the building as well as of the collector. There is no thermal separation between the collector and the wall in the form of rear ventilation.

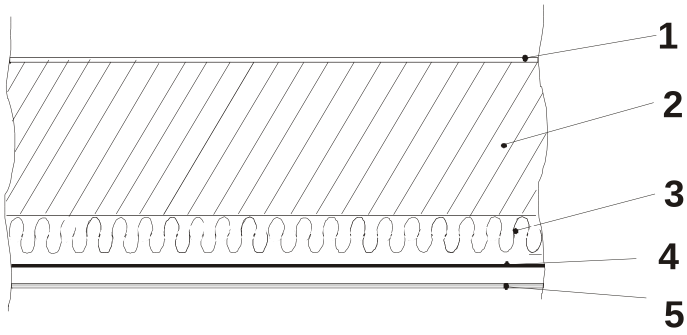

Figure 2: Cross section of a wall with a façade-integrated collector without rear ventilation. 1: interior finish, 2: wall, 3: insulation, 4: absorber, 5: glazing

The collector which comprises a fluid-cooling absorber, a glass disk, glass bearer profiles, sealings and covering sheet metals, therefore, assumes different functions:

- function as a thermal flat plate collector
- improvement of the heat insulation in the building
- protection against atmospheric conditions
- a structural design element for the façade

In accordance with this the advantages of façade-integrated collectors are:

- cost savings as a result of the joint use of building components
- as a replacement for the conventional façade
- suitable both for new buildings and for the renovation of old buildings

Therefore façade collectors are an integral part of the architecture as well as being an energy converter.

Another advantage of façade collectors is the possibility of a high level of pre-manufacturing, as is shown in figure 3. Pre-manufacturing shortens the working hours on the building site, which leads to a reduction in costs. On the other side it prevents the collectors from getting dirty or wet during the installation.

Figure 3: Construction of a hotel in Austria with façade-integrated collectors. A high level of pre-manufacturing is possible

Simulations showed that the façade integrated collector has a positive effect on the reduction of heat losses in the wall. Also in periods with low irradiation, when the collector loop pump is switched off, the collector functions as a "passive solar" element. It has been found that the U-value of a wall with a façade collector is reduced by up to 90% during cold winter days with a high irradiation and up to 45% during days with a low irradiation, because the temperature of the outer layer of the wall – the collector – is higher than the ambient temperature outside.

2. The architects demand

Façade collectors can be used as an element for the design of buildings. By varying the surface grid dimensions, the kind and color of the cover strip of the glazing and the color of the absorber the look of the façade can be changed. To determine the demand from architects a survey among architects and town planners has been carried out.

The survey should clear up the following questions from the point of view of the architects: the priority use of façade-integrated collectors, the color of the absorber, the standardization of the grid dimensions of absorbers and the design of the cover strip of the glazing.

86% of the architects are of the opinion that the future use of façade integrated collectors is in new buildings, the rest believe in using these in the renovation of old buildings. The differences in the two uses are obvious: When renovating the planner has to consider the boundary conditions of an existing building, whereas in new buildings the planner has more freedom in design. Figure 4 shows the successful thermal renovation of a youth hostel in Austria. The integration of collectors in the façade of a new building is demonstrated in figure 5.

Figure 4: Solar thermal system with 112 m^2 façade-integrated collector area for the hot water preparation for a youth hostel in Dornbirn, Austria. The façade integrated collectors were installed within the framework of the thermal renovation of the building.

Figure 5: Solar thermal system with a 22.7 m^2 façade-integrated collector area for the hot water preparation and space heating for a new single family house.

Regarding the shape and color of the absorber it turned out that the architects wish to be free when it comes to the design. Only 15% are satisfied with black and declared the wish to use different colors – even when the yield of the collector is lowered (see figure 6). There are already some examples of solar thermal collectors installed in Austria with colored absorbers. The biggest system has a collector area of 120 m^2 with a bright blue absorber and is a solar combisystem for hot water preparation and space heating for a restaurant in the Alps in the Tyrol in Austria.

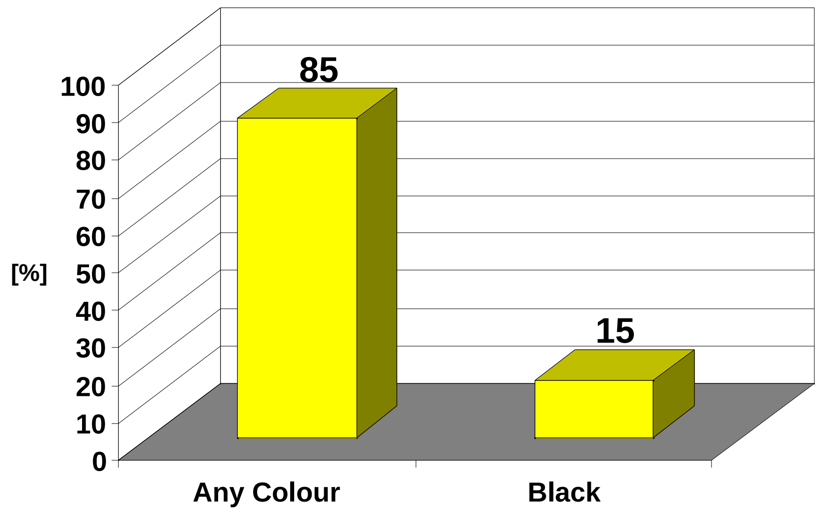

Figure 6: Survey amongst architects: Preferred color of the absorber. 85% of the architects would prefer different colors besides black (taking a lower collector yield into account)

As Figure 7 shows only 29% of the architects think it is sufficient to provide standard dimensioned collectors. Most of them wish to adapt the dimensions of the collector to the modular dimension of the building or would even prefer to be able to choose any dimension they want. This is a clear task for the manufacturers.

Cover strips for the glazing of the collector form an important instrument of design for façade collectors. 92% of the architects are of the opinion that the available cover strips do not quite correspond with demands. This is also something which manufacturers will have to address.

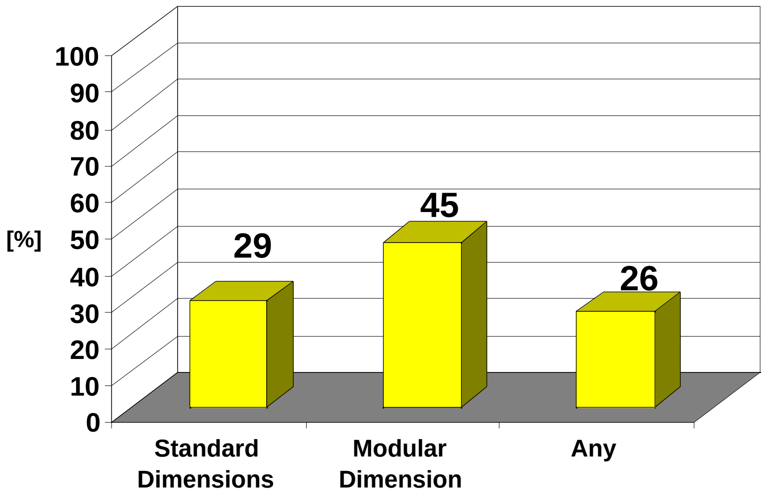

Figure 7: Survey amongst architects: preferred dimensions of the collector. Only 29% of the architects questioned were satisfied with standard dimensions.

As a consequence of the architectural integration of solar thermal collectors in the façade, standard collector sizes are not or only very rarely possible. The architect determines the surface grid of the façade !!! In most cases the surface grid does not correspond to the size of the absorber. A large absorber can be divided optically with the help of cover strips.

Another consequence of the architectural integration is that co-operation is necessary between the architect, the MVAC-engineer and the façade engineering company at a very early stage of a project, as there is a need for façade design know-how.

3. Dimensioning

In central Europe the yearly irradiation in the façade is about 30% less than the irradiation on a surface with a 45° tilted angle. A characteristic of collectors in the façade is the regular profile of the irradiation with small peaks in the spring and autumn (see figure 8). This leads to a more or less balanced collector yield all over the year.

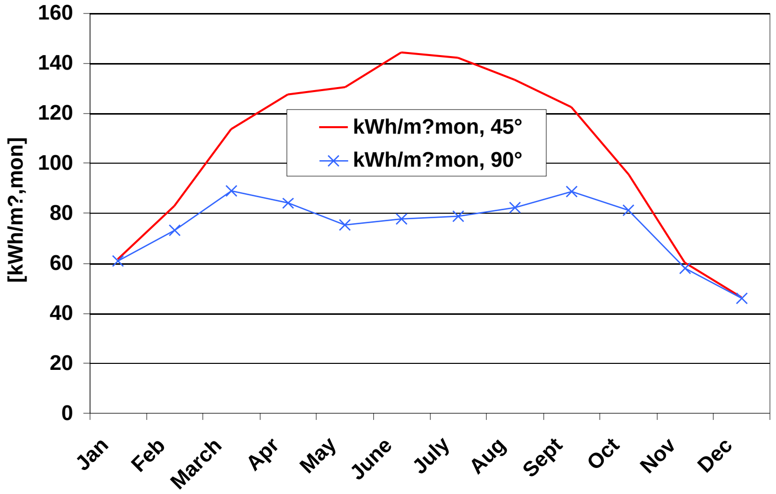

Figure 8: Irradiation on a surface with a 45° and a surface with a 90° tilt angle, Graz, Austria

In addition to the irradiation on the collector area, the energy demand has to be looked at – which is the hot water and space heating demand in the case of solar combisystems. Whereas the hot water demand is more or less constant over the year the space heating demand varies very much depending on the season. However most of the energy for space heating is needed when the irradiation is lowest.

Solar combisystems for hot water preparation and space heating often have large collector areas. Collector areas of 15 to 30 m^2 for the energy supply of a single family house are not unusual in Austria. This leads to high solar fractions but on the other hand it may also lead to stagnation problems during the summer time. Depending on the location of the house, the standard of insulation in the building, the passive solar gains, the air tightness of the house and the room temperature, which is preferred by the inhabitants, the heating season in central Europe ends between March and May. During the summer time, when there is no energy demand for space heating, more energy is available due to higher irradiation. This leads to the stagnation of the solar thermal collectors.

The profile of irradiation in the façade meets the need of combisystems quite well: during the heating season the irradiation in the façade and in a 45° tilted surface are quite similar. During the summer the advantage is on the side of the collector in the façade because the danger of overheating of the solar thermal system is significantly reduced due to less irradiation in the façade. On the other hand the relatively large collector area of a combisystem is big enough to prepare the hot water.

3.1 Simulations

Simulations were carried out to obtain the collector yield of façade collectors compared to collectors with a tilt angle of 45°. The calculations have been done for a combisystem and for a domestic hot water (DHW) system. The combisystem should provide the heat for space heating and hot water and the DHW system should provide only the hot water for a single family house with four inhabitants (space heating demand: 14,500 kWh, DHW demand: 2,700 kWh). The assumed combisystem had a 2,000 l stratifying space heating storage tank and a 300 l DHW storage tank. The DHW system had a 300 l DHW storage tank. The collector area has been varied to simulate different solar fractions from 20% to 60%.

Figure 9 shows the results of the simulations. The higher the solar fraction of a combisystem is, the less additional collector area is needed in the façade to reach the same solar fraction as in a system with a tilt angle of the collectors of 45°.

For example if the solar fraction of a combisystem is 60% the needed collector area in the façade is only about 20% larger than for a system with collectors, which have a tilt angle of 45°. If the solar fraction is 20% the extra collector area is about 55% larger for the façade-integrated collector to reach the same solar fraction.

It is just the other way around if we compare systems which are used exclusively for hot water preparation. The additional collector area in the façade grows with the growing solar fraction.

In central Europe façade collectors have their main advantages when used for combisystems for hot water preparation and space heating, which is caused by irradiation in the façade as described above.

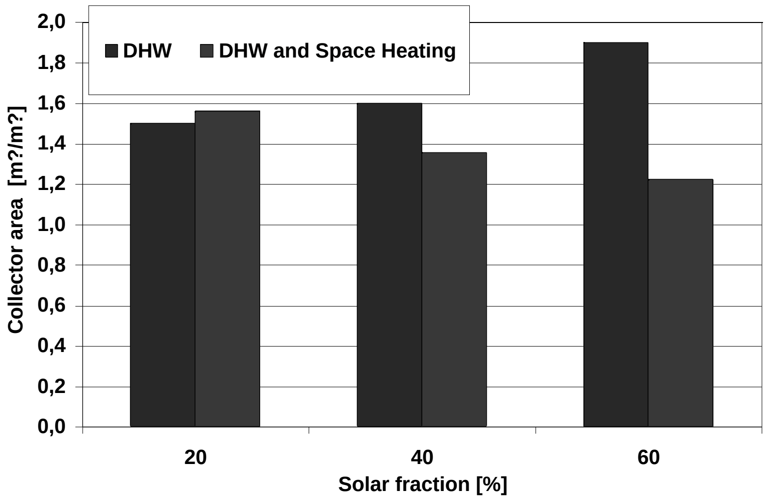

Figure 9: Collector area in the façade compared to a collector area with a 45° tilt angle for different solar fractions for a DHW-system and a combisystem for a single family house

What has not been taken into account in these simulations is the fact that the U-value of the collector improves by mounting it vertically. This results from the reduction of the heat losses caused by the convection of air between the absorber and the glazing (see chapter 4). If there is no air gap for ventilation between the collector and the building the insulation of the building also serves to insulate the collector. This improves the U-value of the collector even more. Therefore, the real additional collector area in the façade is less than the calculated values from the simulation above, which is another advantage for façade-integrated collectors.

3.2 Reflection

The radiation in a surface is composed of the direct and diffuse radiation and the reflection of the radiation from the ground and the surrounding (see equation 1). This reflection depends very much on the material. The reflection from a light façade of a building is about three times higher than the reflection from grass or pebbles. If there is snow or ice the reflection from the ground is up to four times higher than from grass.

$$I_g = I_S \cdot R_S + I_d \cdot \frac{(1+\cos S)}{2} + (I_S + I_d) \cdot \frac{(1-\cos S)}{2} \cdot re \qquad \text{equ.1}$$

I_g	[W/m^2]	Total irradiation on the collector area
I_S	[W/m^2]	Direct irradiation on the horizontal surface
R_S	[-]	Conversion coefficient from a horizontal to a tilted surface
I_d	[W/m^2]	Diffuse irradiation on the horizontal surface
S	[°]	Tilt angle
re	[-]	Reflection coefficient

The reflection of the solar radiation from the ground on the collector increases the collector yield. The influence of the reflection grows with a steeper tilt angle of the collector. The reflection is, therefore, an important point of influence when it comes to the façade integration of solar collectors. Simulations showed that during the heating season the irradiation in the façade is higher than in a surface with a 45° tilt angle due to the reflection of snow (see figure 10).

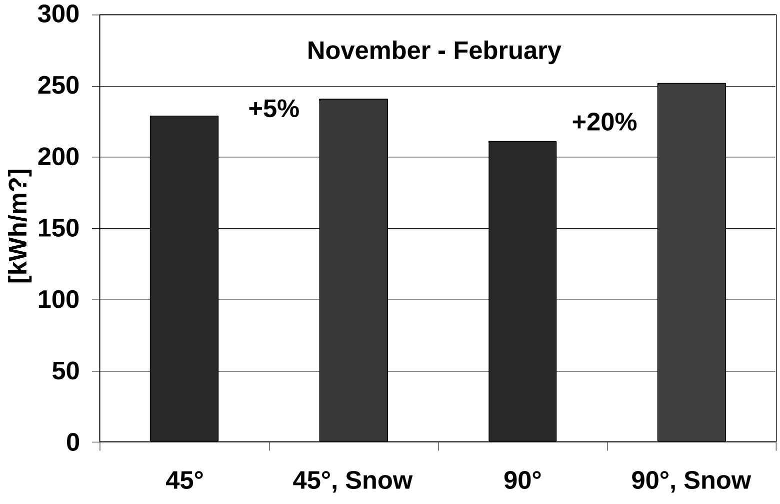

Figure 10: Increase in irradiation in a surface with 45° and 90° tilt angle caused by the reflection of the snow on the ground from November to February; Graz, Austria

4. U-value of the collector

To determine the influence of the tilt angle on the collector on the efficiency curve, simulations were carried out. First a collector with 45° and a collector with 90° tilt angle with 40 mm insulation were compared.

The transportation of heat between the absorber and the glazing caused by the convection of air decreases as the tilt angle increases. This leads to a reduction of the U-value of the collector and a higher collector efficiency of vertical collectors at higher temperatures /3/.

Moreover the efficiency curve of a vertical collector with 160 mm of back side insulation (corresponding to the insulation layer of a well insulated house) was calculated to simulate a façade-integrated collector without an air gap for ventilation. This leads to the minimization of the heat losses at the back of the collector and again improves the U-value.

The results of these calculations are shown in figure 11 and table 1.

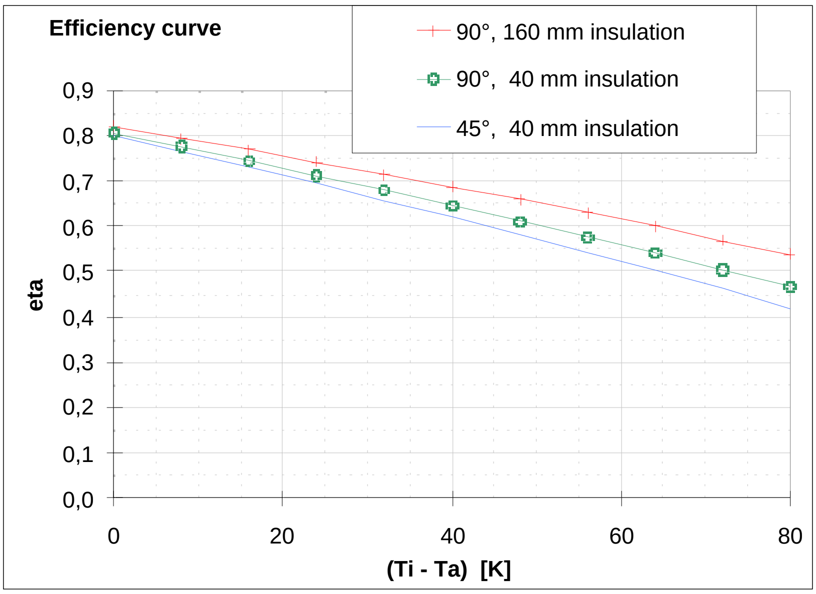

Figure 11: Influence of the tilt angle on the efficiency curve, irradiation 800 [W/m^2]; wind 0 [m/s], selective coated collector

Table 1: Influence of the tilt angle on the characteristic values of the efficiency of a selective coated collector

Tilt angle	alpha	epsilon	Insulation	η_0	k1	k2
			[mm]	[-]	[W/m_K]	[W/m_K_]
45°	0,95	0,05	40	0,800	3,37	0,005
90°	0,95	0,05	40	0,807	3,05	0,004
90°	0,95	0,05	160	0,820	2,48	0,004

5. Test façades

As mentioned above two systems with façade-integrated collectors were monitored by the AEE INTEC to evaluate the thermal and humidity behavior of the system “collector/wall”. One test façade was erected on a timber frame construction and one on a brick wall to record the different behavior of the system collector/wall in different constructions.

5.1 Test façade on a timber frame construction

Figure 12 shows the test façade, which was mounted on the timber frame wall. The total collector area is 55 m^2. The collector consists of three collector fields with 18.3 m^2 each. The fields were pre-manufactured and mounted with the help of a crane in March 2001.

The wooden back wall of the collector was fixed to the timber frames with steel angles. Then the insulation of the building, which is made of rock wool, was installed. Only about 10 steel angles for the fixation were arranged for each 18.3 m^2 collector field. This type of fixing has almost no effect on thermal bridges.

The solar thermal system consists of a 3570 l stratifying space heating storage tank and 500 l DHW storage tank. The backup is provided by a pellet oven. Therefore, the house is heated 100% with renewable energy.

Figure 12: Two family house with a 55 m^2 collector area in the south façade

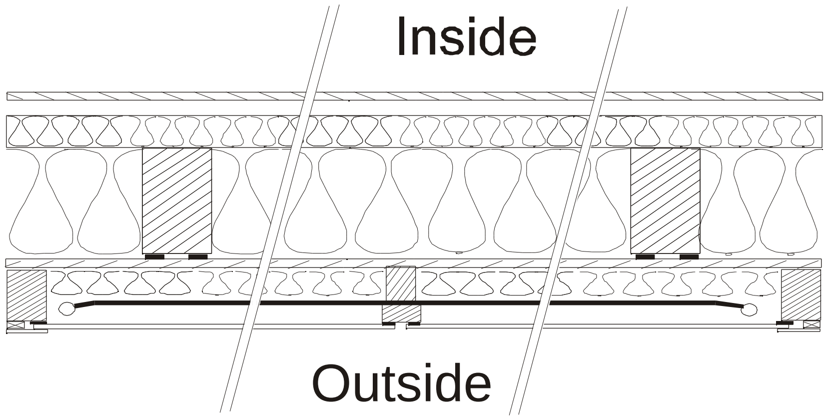

Figure 13: Cross section of the timber frame wall with the attached façade collector. Collector insulation: 40 mm rock wool; insulation of building: 160 mm rock wool; inner plumbing layer: 50 mm wood fiber board.

Measuring instruments were installed in every layer of the wall to record the temperature and humidity profile of the wall and the collector. The measurements started in March 2001. The inhabitants moved in June 2001 and the solar thermal system was initiated at the same time.

The monitoring results showed that it is necessary to take care of dry construction material from the beginning. Moreover the trapping of the timber wall between two vapor tight layers – the collector at the outside and a vapor barrier at the inside - has to be avoided. This would lead to the destruction of the wood in a very short period of time because of the growth of mould fungus. To ensure the drying of the timber construction it must be possible to dry out the inside of the building. If a vapor barrier is used it must be relatively open for vapor.

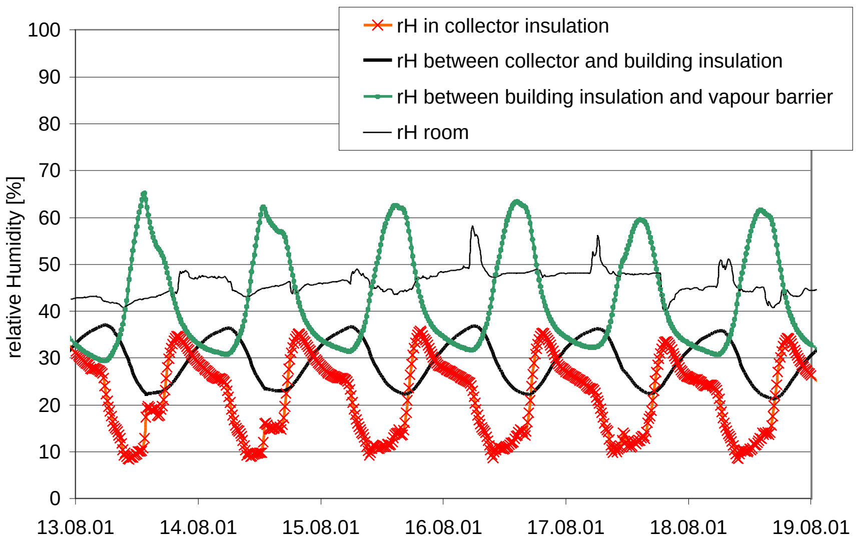

Figure 14: Relative humidity in the timber frame construction from August 13 to August 19, 2001

At the beginning of the monitoring high relative humidities were detected in the wall. This was caused by the high humidity of the wood used for the wall construction and insulation material. Figure 15 gives monthly mean values for relative humidity in the layer between the building insulation and the vapor barrier. The measurements show that the relative humidity decreased significantly during the period of the measurements from March 2001 to January 2002.

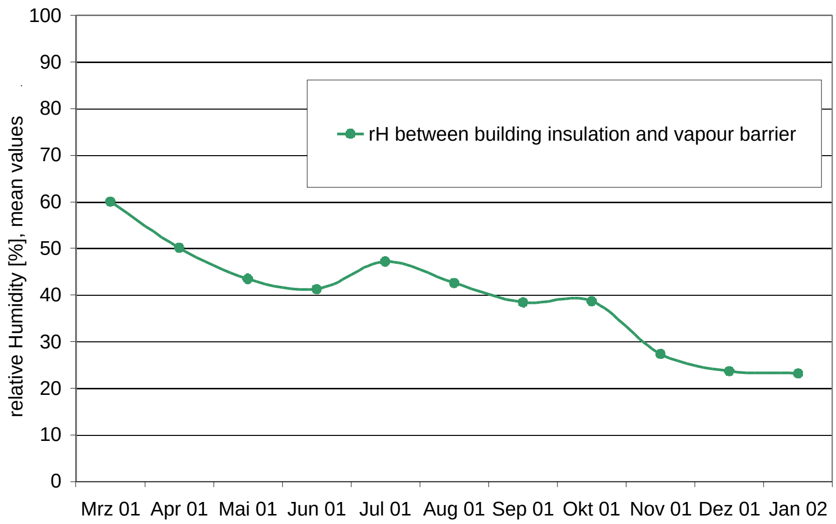

Figure 15: Monthly mean values of the relative humidity in the layer between the building insulation and the vapor barrier from March 2001 to January 2002

Since a wall with a façade collector cannot dry to the outside, it must be possible to dry to the inside of the building. Therefore the inner layers of the wall must be relatively open for vapor. This should be considered when planning the building. Bathrooms should not be positioned behind a façade collector if there is the wish to install tiles on the wall. Tiles should not be used on the inner wall, as they form a vapor tight layer. If there is no way to do without tiles, wall heating is a possibility to raise the temperature level in the wall and to minimize the danger of condensation.

5.2 Test façade on a brick wall construction

The second test façade was erected on the south-west-façade of an office building in June 2001, the collector is attached to a brick wall. The total collector area is 25 m^2, a selective absorber was used. Figure 16 shows the mounting of the façade collector with the help of a crane.

Before constructing the façade collector simulations were made to optimize the construction in terms of thermal bridges. The stationary calculations have been made with the program Therm (multidimensional thermal bridge program).

In general mounting a solar thermal collector on a massive wall and also the fixing of the cover strip of the glazing should always be free of thermal bridges. Otherwise it lowers the U-value of the whole wall significantly and leads to high heat losses.

Figure 16: Mounting of test collector on a brick wall of the south-west façade of an office building with the help of a crane. 25 m^2 collector area (5 m x 5 m)

Figure 17 shows the temperatures of the test collector on the brick wall in July and August 2001. The solar thermal system was initiated in November 2001, therefore the collector has been in stagnation all summer. The temperatures between the absorber and the collector insulation reach about 110°C at the most (these are not the temperatures of the absorber sheet).

In November 2001 the temperature between the absorber and insulation reached temperatures up to 130°C, as the angle of irradiation in the façade is better in autumn than in the summer time. When the system started in the middle of November the temperatures decreased to 80°C at the most between the absorber and the collector insulation.

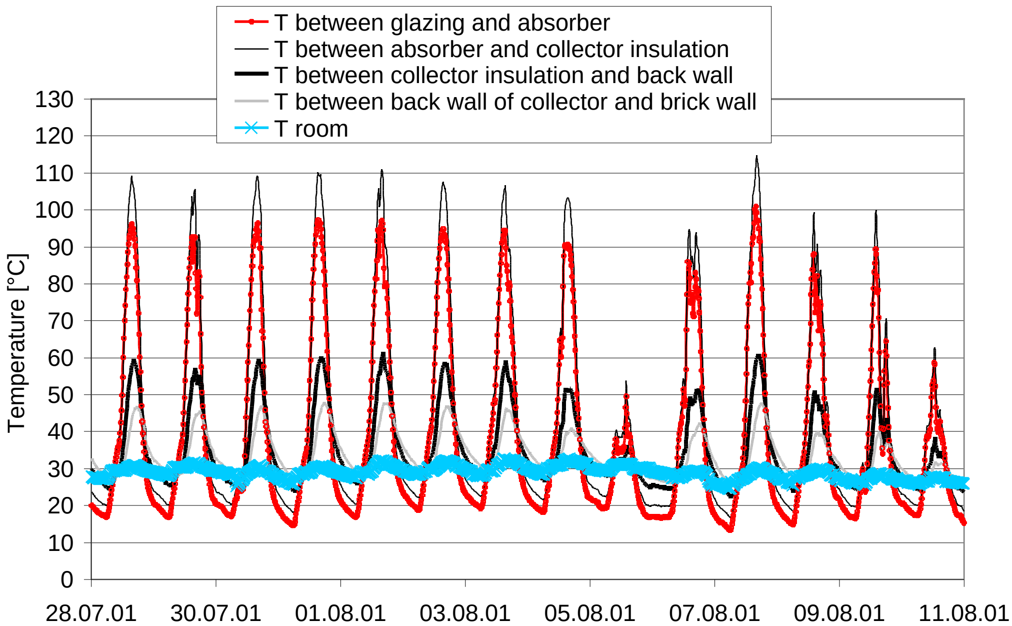

Figure 17: Temperatures in the wall construction of the test façade on the brick wall, July 28 to August 11, 2001.

6. Conclusions

Façade collectors are both an energy converter and an integral part of the architecture. Therefore architects and planners have to co-operate from the very beginning of a project to arrive at a successful conclusion.

When it comes to the design of a solar thermal system with vertical collectors less irradiation has to be taken into account compared to systems with collectors on an inclined surface. On the other hand a vertical collector has a better U-value than a tilted collector, because of the reduced heat losses of the collector due to the lower convection between the absorber and the glazing. If there is no thermal separation between the collector and the wall construction in the form of rear ventilation, the U-value is lowered even more because of the minimization of heat losses to the backside of the collector. This also leads to an improvement in the U-value of the whole wall.

If the collector is mounted without an air gap for ventilation the construction must have the possibility to dry to the inside of the building. Therefore the inner layers of the wall must be open for vapor. When mounting collectors on massive walls it is important to take care of thermal bridges, otherwise heat losses of the building in the winter time are significant.

7. References

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/6/ www.hausderzukunft.at

ARCHITECTURAL INTEGRATION OF SOLAR ENERGY

Per Kr. Monsen

Civil Architect MNAL
Arkitektkontoret GASA AS
Nedre Slottsgt. 11, 0157 Oslo
Tlf.: +47 22 31 34 70, +47 22 31 34 75
Fax : +47 22 31 34 71
E-mail: per.monsen@gasa.no

Ecological housing in an urban environment
Klosterenga - Oslo

Background:
The Klosterenga-project is one of Norway's first urban ecology projects, and represented Norway in GBC 1998. The project is supported through EU's Thermie 96 – program, and has received financial support from different Norwegian institutions.

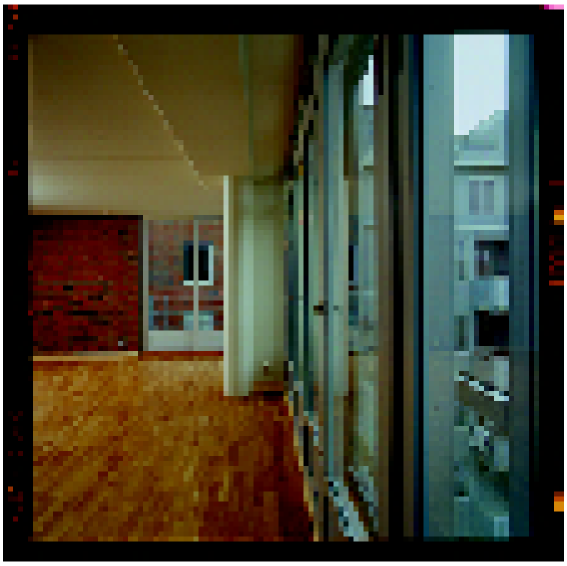
The following issues integrated in the project:

The most advanced element in the Klosterenga project is actually the integrated ecological and energy design process. As a result of this process most of the energy-saving measures are building – or architecture – integrated elements. Combined with a general ecological approach – containing elements of, among others, water-saving and local purification devices, reduced amount of both garbage and building waste, focus on building materials from an ecological point of view, indoor climate and of course energy saving design and installations and use of both passive and active solar energy.

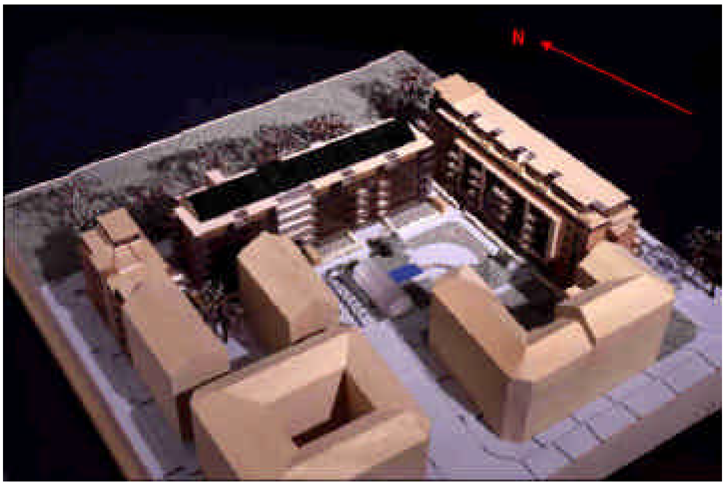
Integrated ecological measures are:
• Solar collectors for domestic hot water and water-based floor space heating
• Double-glazed south façade discussed as part of a passive solar system
• Improved insulation standards
• Combination of active and passive solar systems
• Individually metered apartments (energy consumption)
• Simplified building details
• Reduced number of materials
• Materials that can be recycled or reused
• Materials that can be easily maintained and repaired
• Materials that don't have bad influence on the indoor climate

• Local cleaning of grey water
• Collecting and use of rainwater for outdoor purposes and park elements
• Building volumes designed to give maximum access to neighboring park areas
• All apartments have visual access to both backyard and park
• High and narrow windows to the north improve amount of daylight

Illustrative drawings, photos, diagrams and reports are available.



Introduction



Klosterenga is a SHINE project

SHINE (Solar Housing through Innovation for the Natural Environment) is a European Commission Thermie project to reduce energy and improve comfort and environment. In involves different housing renovation projects demonstrating new and innovative solutions to energy and efficiency.

Klosterenga is an urban revitalisation project close to the city centre of Oslo. The 35 apartments were built with a focus on energy saving. Next to the buildings also the surroundings area upgraded. The most advanced element in the Klosterenga project is actually the integrated ecological design process. As a result of this process most of the energy-saving measures are building-or architecture- integrated elements. The project is monitored for heat, electricity and hot water consumption.

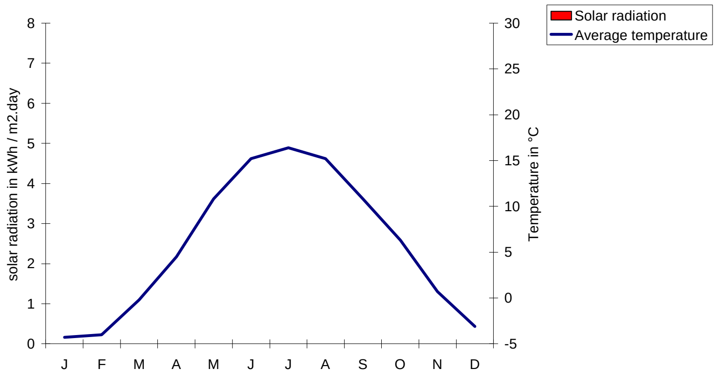
The general ecological approach includes, among others, water-saving and local purification devices, reduced amounts of both garbage and building waste, focus on building materials from an ecological point of view, indoor climate and of course, energy saving design and installations and use of both passive and active solar energy.

Integrated ecological measures are:

- Solar collectors for domestic hot water and water-based floor space heating.
- Double-glazed south facade discussed as part of a passive solar system.
- Improved insulation standards.
- Combination of active and passive solar systems.
- Individually metered apartments (energy consumption).
- Simplified building details.
- Reduced number of materials.
- Materials that can be recycled or re-used.
- Materials that can be easily maintained and repaired.
- Materials that don't have bad influence on indoor climate.
- Local cleaning of grey water.
- Collecting and use of rain water for outdoor purposes and park elements.
- Building volumes designed to give maximum access to neighbouring park areas.
- All apartments have visual access to both backyard and park.
- High and narrow windows to the North improve the amount of daylight.

Owner	*Boligbyggelaget USBL*
Consultant	*Architects and HVAC Consultant*
Contact	*Per Kr. Monsen GASA architects AS per.monsen@gasa.no or post@arkitektskap.no*
Publications	*http://www.greenbuilding.ca/gbc98cnf/studies/norway/st-n2.htm*

Regional and Urban Context



climate

Type of climate	*sea climate*
Altitude (m)	*204*
Latitude	*60°12' N*
Longitude	*11°05' E*
Average ambient temp (°C)	*5*
January	*-4,3*
July	*16,4*
Degree days (base 18°C)	
Global irradiation (kWh/m²)	
Sunshine hours (h)	

The site is situated close to the city-centre of Oslo. In the area one can find the remains of the first settlers in the city. During the last 20-30 years the area has had lots of well known urban problems, like heavy traffic, increasing railway traffic close to living area's, increasing number of immigrants, etc. Therefore a renewal program was launched 15 years ago, aiming to renovate old buildings and to reduce traffic and pollution. The quarter is now called "Environmental old Oslo quarter" The ecological project Klosterenga is an important part of this project.

Block and Building

Maximum use of sunlight
For minimising energy losses and consumption the building shape and orientation are according to requirements of solar geometry and building codes and regulations. The insulation values are high, while the plans are designed in zones.

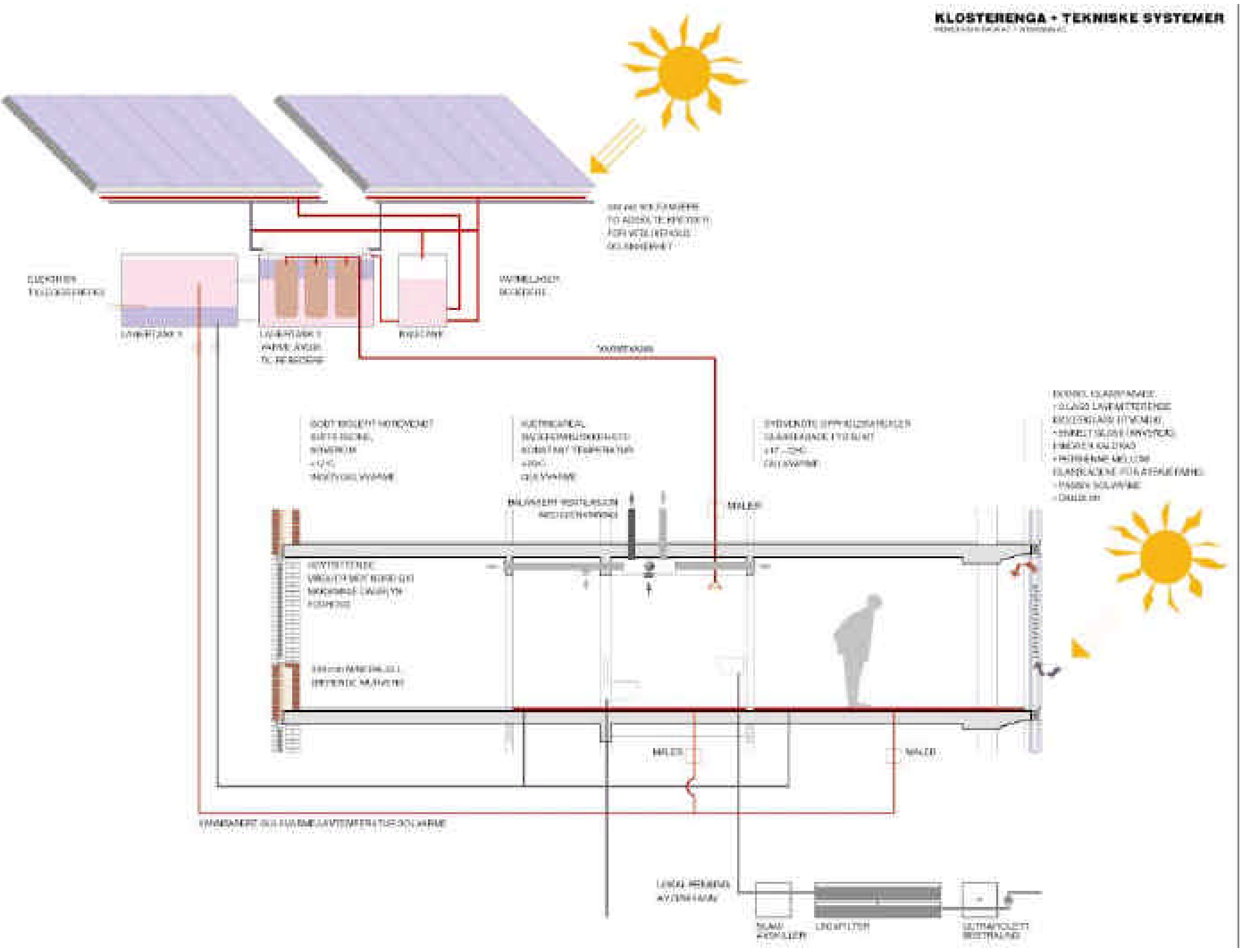
In order to optimise solar and renewable energy use, doubled-glazed south walls preheat ventilation air. The heavy mass construction walls and floors serve as heat storage.

Solar collectors
The solar active system is used for the water-based floor heating system. The apartments have individual metering of energy use.

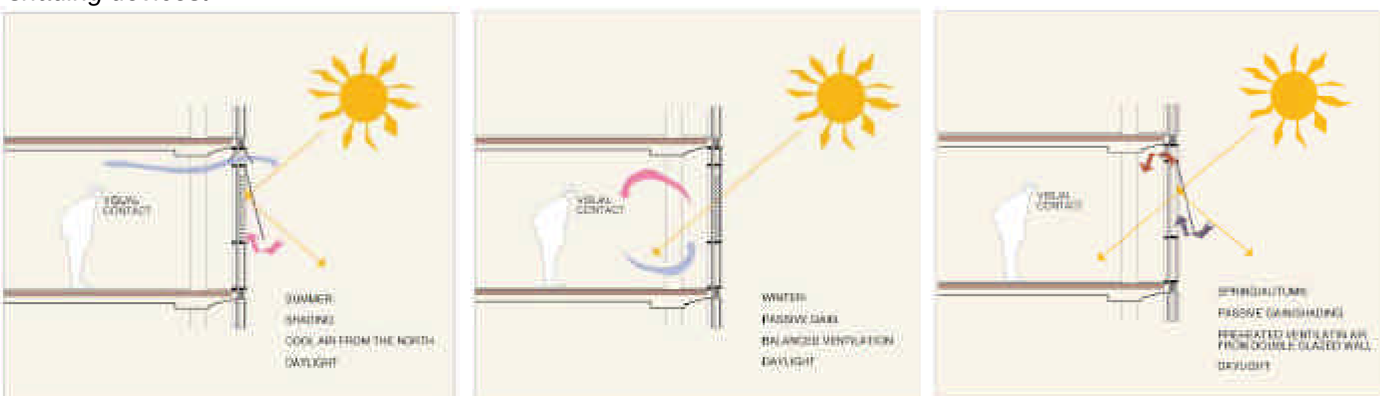
Materials
The building details are simplified and the number of materials is low. The used materials are easy maintainable, repaired and need minimum surface treatment.

Water
Water saving installations in bathrooms and kitchens reduce the water-use. The park elements within the project are used for cleaning of grey water.

Green building aspects



The indoor climate is kept on good condition by means of operable windows having filters, individual controlled balanced ventilation, minimised surface treatment (e.g. painting) of indoor areas, no vapour barrier in walls, breathing bricks, moisture controlled construction and natural materials. The apartments all have individual solar shading devices.



double skin south facade: passive solar + (stack) ventilation system

summer
- *shading*
- *cool air from the north*
- *daylight*

winter
- *passive gain*
- *balanced ventilation*
- *daylight*

spring/autumn
- *passive gain/shading*
- *preheated ventilation air from double glazed wall*

daylight

Project Data	**Project case**		**Reference case**	
Renovation	*1998-2000*			
Construction costs (Euro/m²)	*11,589*		*9,805 (normal renovation)*	
Urban plan				
Area (ha)	*1300*			
Floor Area (m² gross floor area)	*3500 (heated area)*			
Floor Area Ratio (m² gross floor area)	*2.7*			
Transport				
Distance to car park	*0*			
Distance to public transport	*50 m*			
Frequency of public transport	*10 min*			
Bicycle storage	*underground parking for bicycles and cars (0.7 car/apartment)*			
Waste separation				
Construction and demolition waste	*waste handled according by waste-plan (requires recycling of spec. parts)*			
Household waste	*local waste / garbage sorting in outdoor area*			
Design for deconstruction	*no*			
Building Materials				
Construction	*bricks/concrete*			
Facades	*low maintenance, bricks/glazed*			
Roof	*partial green*			
Window frames	*wood*			
Internal walls	*gypsonite/bricks*			
Recycled materials	*none*			
Insulation	**area (m²)**	**U-value (W/m²K)**	**area (m²)**	**U-value (W/m²K)**
Ground floor area (m²/bldg)	*500*	*0.22*		*0.22*
Roof area (m²/bldg)	*500*	*0.15*		*0.15*
External wall area (m²/bldg)	*880*	*0.22*		*0.22*
Window area total (m²/bldg)	*945*	*1.4*		*1.4*
South (m²/bldg)	*30%*		*20%*	
Ventilation system				
Infiltration	*mechanical, with heat recovery*			
Exhaust	*both*			
Heat recovery	*yes, 75%*		*no*	
Air exchange rate, heating season	*1*		*1*	
Back-up systems	**system**	**energy source**	**system**	**energy source**
Space heating	*floor, water-based*	*electricity+solar-collector*		
Domestic hot water		*electricity+solar-collector*		
Cooling	*no*		*No*	
Electricity production	*traditional,*	*hydropower*		
Ventilation				
Energy data	**(kWh/m²)**		**(kWh/m²)**	
space heating				
space cooling				
Domestic hot water				
Electricity (total)				
Lightning				
Fans + pumps				
Small power				
Solar systems				
Passive	*double glazed south façade*			
Active	*240 m2 collector*			
PV	*no*			
Water				
Supply				
Toilet system (4, 6, 9 litres)	*4*			
Shower				
Bath				
Sewage				
Rainwater collection				
Grey water system	*local bioclimatic water cycle*			

THE NORWEGIAN SOLAR ENERGY INDUSTRY

Alf Bjørseth

Renewable Energy Corporation AS
P.O. Box 280
1323 Høvik, Norway
Tel.: + 47 6781 5250
E-mail: alf.bjorseth@scanwafer.com

The solar industry of Norway is growing rapidly and is becoming a substantial contributor to the international solar energy industry. Norwegian industry is currently involved in several areas of the solar industry, including solar thermal and solar electric (Photovoltaic) activities. This growth has a basis in the natural resources of Norway, including hydroelectric power and cooling water resources, R&D competence and public and private support for renewable energy in general.

1. Introduction

There are several activities related to solar energy in Norway. These include industrial activities, research and development, supply of consumables and services, and trade. In this presentation, we shall discuss the industrial activities only.

2. The solar industry

The solar industry in Norway is in principle divided into two groups – solar thermal and solar electric (photovoltaic). In the following, each of these groups is treated separately.

2.1. Solar thermal

Solar thermal activities in Norway are primarily carried out by the company Solarnor. This company has proprietary technology for production of a low pressure, low temperature, polymer-based solar collectors. The polymer material is developed in cooperation with GE Plastics with properties well suited for high temperature stability and high UV tolerance. The solar collector is produced by a new extrusion process which is very cost effective, resulting in a cost-competitive product.

In addition, the solar collector system has a proprietary control system and a heat storage unit, which make the system suitable both for small houses as well as larger apartment houses, office buildings, industrial building, sports arenas and hospitals etc.

A schematic presentation of the system is given in Figure 1.

Solarnor has today about 10 employees and is operating in Norway, the Netherlands and Spain.

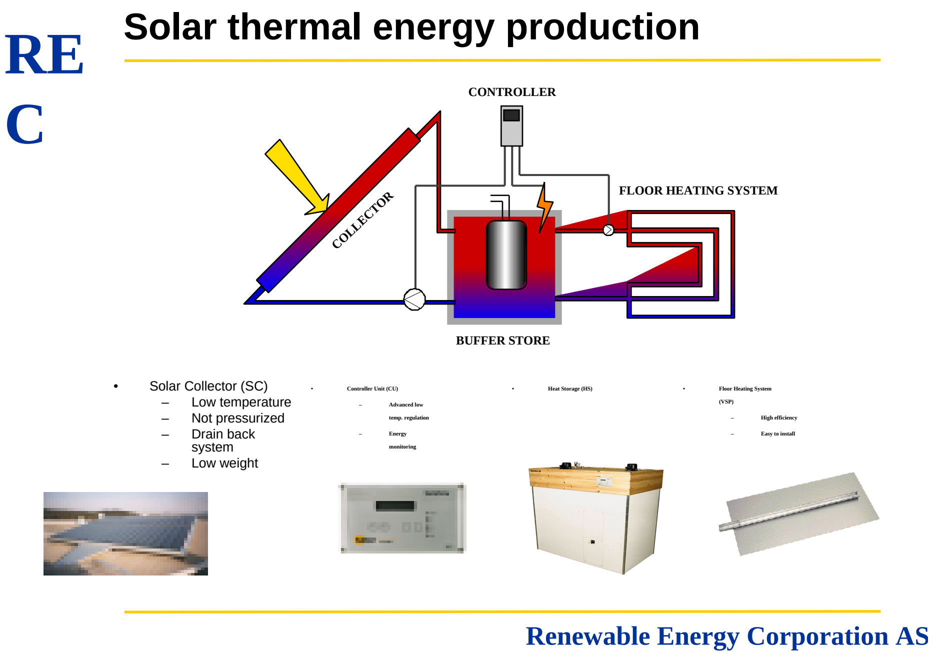


Figure 1: Schematic presentation of the solar thermal system

2.2. Solar Electric (Photovoltaic)

More than 95% of all PV technologies are related to the element silicon, and about 90% of the Si-technologies are based on crystalline silicon. The crystalline silicon is again divided into multicrystalline and single crystalline silicon. In Norway, we are mainly dealing with multicrystalline silicon technology.

The silicon value chain for solar energy is shown in Figure 2. There are Norwegian industrial activities related to all the steps in the value chain. Below, these companies are discussed separately.

A. Metallurgical silicon

Norway is the largest producer of metallurgical silicon in the world. About 25% of the global production is controlled by the companies Fesil and Elkem. About 50% of all the metallurgical silicon for the semiconductor industry has Norwegian origin and in Japan, the percentage is even higher. Therefore, the silicon technology has a strong foothold in Norway and silicon competence is available both at Universities and research organizations.

B. Silicon feedstock for PV

Metallurgical silicon does not have the purity to give sufficient photovoltaic effect. Therefore, the silicon for PV has to be purified. The only proven process today is a chemical process where metallurgical silicon is converted into silane or chlorinated silane, with subsequent deposition by the Siemens process or a fluidized bed reactor. This process gives a polysilicon which meets the quality standard of the semiconductor industry, but the production cost is too high for the PV industry.

Strategically, the availability of solar grade feedstock is the most important challenge for the international PV industry. The present source of feedstock is scrap material from the semiconductor industry. However, the PV industry is growing much faster than the semiconductor industry and a lack of material may appear already in 2003.

The Norwegian company Silicon Technologies is working to develop a method for purification of metallurgical silicon based on a simplified polysilicon process. Recently, Silicon Technologies entered into a joint venture with the American company ASiMI which is a semiconductor polysilicon producer. The JV will convert the present ASiMI plant in Moses Lake, (USA) into a solar grade silicon plant and supply the international PV market with high quality solar grade silicon.

The plant will start production in 3. quarter 2002 and will have about 220 employees.

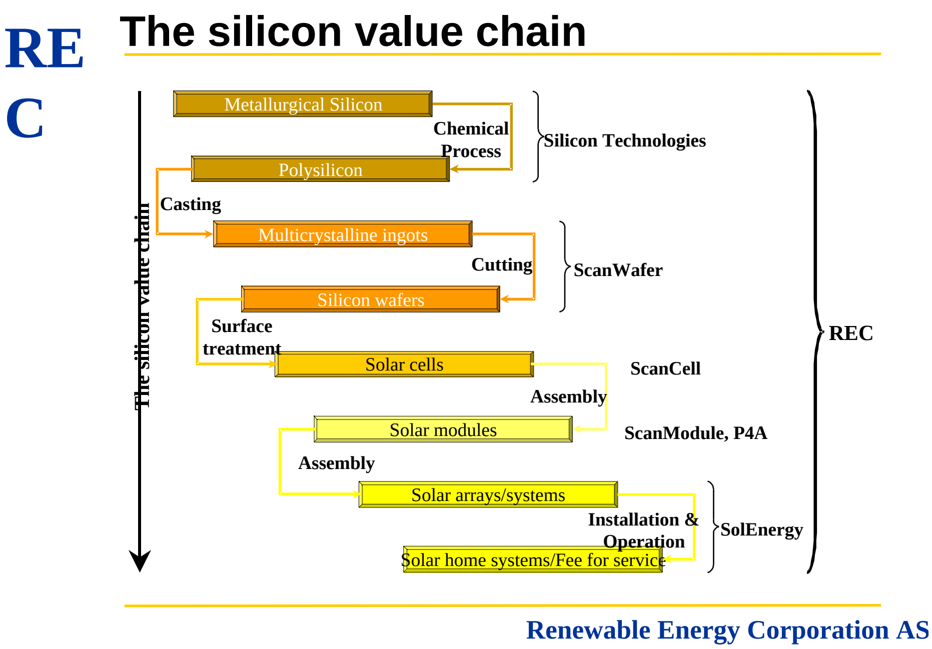


Figure 2: The silicon value chain for solar energy

C. Wafer production.

The Norwegian company ScanWafer is a dedicated producer of multicrystalline silicon wafers for the international PV market. The company has two plants in Glomfjord, and is currently building one new plant in Porsgrunn. The total production capacity of the plants in Glomfjord is about 70 MW and the new plant in Porsgrunn will add about 60 MW. By end 2003, the total production capacity will be about 130 MW.

ScanWafer has about 115 employees (1. quarter 2002).

D. Solar Cell production.

A limited production of solar cells is planned in Narvik. A new plant – ScanCell – will start production in August, 2002 with an expected annual production capacity of 3 MW. The company will be served with wafers from ScanWafer and will in the initial phase have about 25 employees.

E. Solar Module production.

There is currently no module production in Norway, but a small module production is planned to be started at Arvika, Sweden by a Norwegian company. Production start is estimated to 2. quarter of 2003 and will mainly be using solar cells from ScanCell.

The company – ScanModule - shall have an initial production capacity of about 4 MW and have 15 employees.

F. Solar systems, production of PV electricity.

There is currently no systems production in Norway, but a Norwegian company - SolEnergy - is involved in several companies in developing countries as well as other countries with a strong growth in the PV market.

SolEnergy is involved in the company Solar Vision in South Africa having a concession with the South African Government for supplying 50 000 solar home systems to villages with no electricity grid connection. Furthermore, the company is involved in a similar activity in Namibia with the company Sun Energy. These two companies will internally have a significant request for solar modules. Therefore, SolEnergy has also started a module production in Namibia – Power4Africa – having an annual production capacity of about 2 MW.

Furthermore, SolEnergy is involved in companies and projects i.a. in Switzerland, Italy, Marocco and Panama.

3. Summary

Industries related to solar energy are currently gaining momentum in Norway. Companies are currently involved in all parts of the value chain of the PV industry and is also building a basis for solar thermal industry in Norway as well as abroad.

Up to now, the solar industry has attracted strong support from investors, governmental funding organizations and financial institutions, supporting this strong growth.

(1) The present proceedings can be downloaded as PDF-file with figures in color from the workshop homepage

http://www.fys.uio.no/kjerne/norsk/energi/workshop/ieaworkshop.html

or as listed in (2).

(2) The proceedings of all workshops arranged in connection with the IEA-task 26 - Solar Combisystems can be downloaded from following links:

http://www.solenergi.dk/task26/downloads.html or:

http://www.iea-shc.org/task26/
(see: "Information" >>> "Meetings, seminars and newsletters")