SOLAR COMBISYSTEMS

Task 26

Industry Workshop

Stuttgart, Germany, October 4, 1999

INTERNATIONAL ENERGY AGENCY
Solar Heating & Cooling Programme

13:30 h	**Welcome Address** Prof. Hahne & Harald Drück
	Chair: Werner Weiss
13:45 h	**The solar thermal market in the participating countries** Focus on solar combisystems and boundary conditions Representatives from Austria (Werner Weiss), Denmark (Line Louise Overgaard), Finland (Petri Konttinen), France (Thomas Letz), Germany (Harald Drück), Sweden (Chris Bales), Switzerland (J.-C. Hadorn), The Netherlands (Huib Visser) and the United States (Bill Beckman)
	New materials and components for solar heating systems
14:30 h 14:50 h 15:15 h 15:40 h 16:05 h	**European product standards for solar domestic hot water systems reaching maturity** Huib Visser, Amelie Veenstra, TNO, Delft, The Netherlands **New materials for solar collectors** Michael Köhl, Fraunhofer ISE, Freiburg **Advanced Polyphenylenoxide and Polycarbonate Thermoplastics for Solar Collectors** The SolarNor system design for thermoplastic absorbers and translucent cover sheets Markus Peter **Plastics for thermal solar systems** - The dependence of performance properties on time, temperature and environment Gernot Wallner, Leoben University, Austria **Discussion**
16:30 h	**Coffee break**
	Innovations in the field of pumps for solar heating systems ***Chair: Harald Drück***
16:50 h 17:15 h 18:05 h 18:30 h	**Development of a Low-Flow-Solarpump,** Klaus Henning Terschüren, SOLVIS Solarsystem GmbH, Braunschweig, Germany **Future solar thermal pump strategy** Detlef Ipach, WILO GmbH, Dortmund, Germany **Innovative pump developments in Switzerland** Jürg Nipkow, ARENA, Zurich **Discussion**
19:00 h	**Break**
19:20 h	**Life cycle analyses of solar heating systems** Bernd Achatz, Berlin, Germany
20:00 h	End of workshop

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THE AUSTRIAN SOLAR THERMAL MARKET

Werner Weiss
Arbeitsgemeinschaft ERNEUERBARE ENERGIE – AEE
A-8200 Gleisdorf, Feldgasse 19

Since the beginning of the 1980‘s the use of solar energy using thermal collectors has continued to increase so that a total of 2 million m^2 of collector area will be installed this year. In 1980, 23,000m² of collector area were installed in Austria and in 1995 the 200,000 m^2 level was surpassed for the very first time. At the current moment in time it would appear that the market is stabilising at this high level.

The average cost of the system of thermal solar plants equals between ATS 7,000 and 8,000 per m^2 (excluding VAT). With around 200,000m^2, which are installed yearly, this corresponds to a turnover of approximately ATS 1.5 billion – of which approximately 55% is accounted for by collectors (incl. assembly), and the remainder is accounted for by storage tanks, regulating elements, pipelines etc. – and a total number of employees of about 2140 (employees in the primary and secondary sectors).

At the start of this development, systems were predominantly used for the preparation of warm water in private plants on a small scale, however, the first plastic absorber areas on a larger scale were also erected to heat swimming pools.
Vacuum tube collectors have barely been able to assert themselves to date and have a market share of a mere 1%.

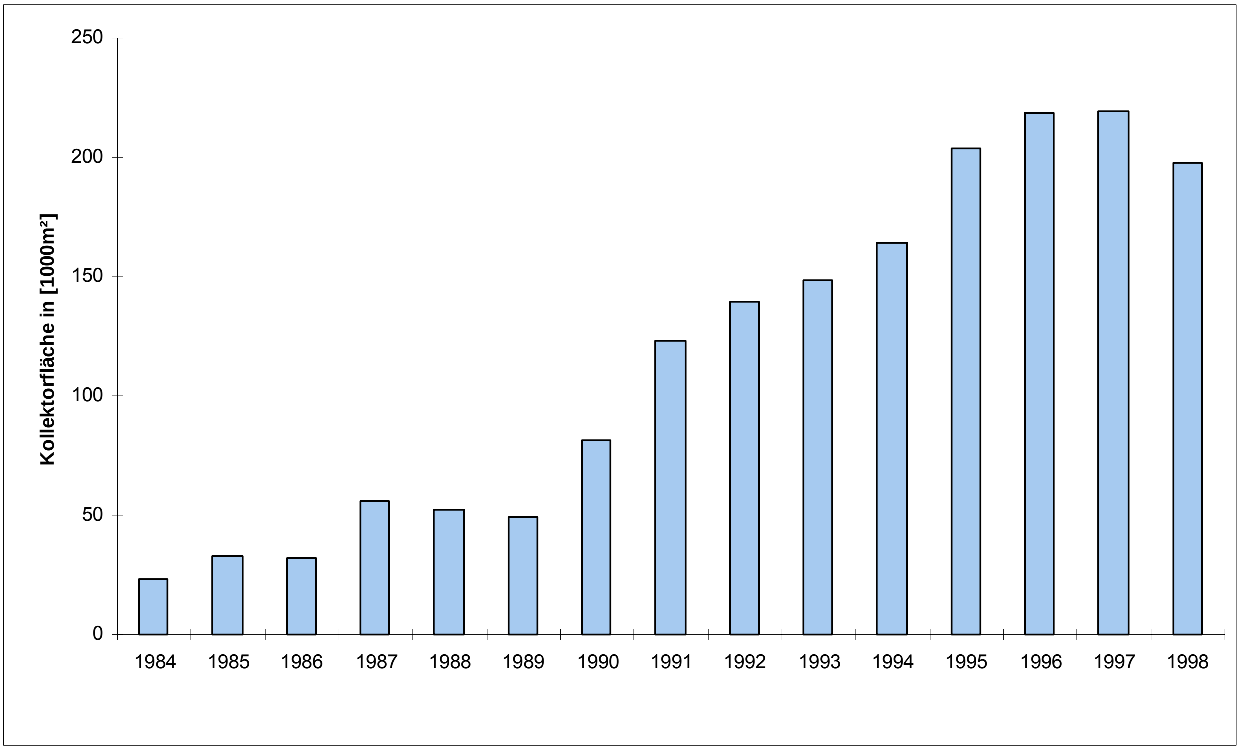


Fig.1: Solar market in Austria /2/

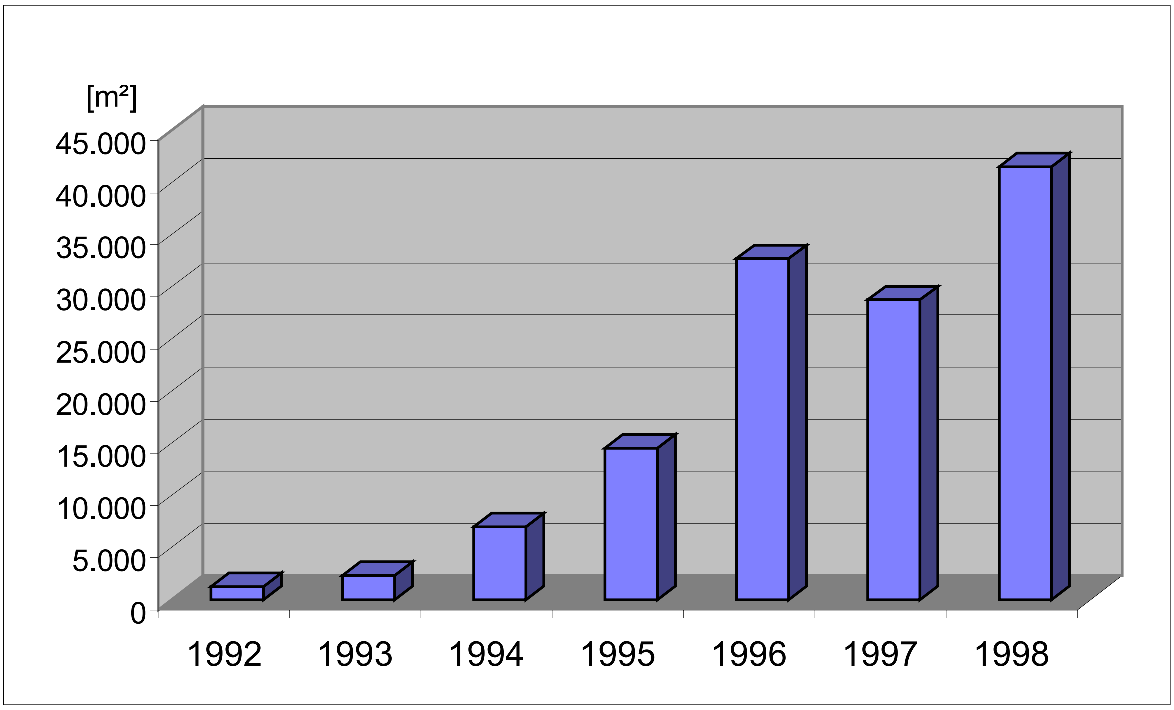


Fig.2: Exports of flat collectors between 1992 and 1998 /2/

New applications

The market share of Combisystems (warm water and room heating) in the collector area installed already equalled 50 % in 1998.

The large scale application of solar thermal plants has until now concentrated almost exclusively on the sector of single family homes. New and above all cost-efficient applications in houses for several families, places of accommodation, in biomass local heating plants and in the trade-industrial sector, have scarcely been developed or tapped until now. To make use of the potential available it will, however, be necessary to develop technologically and economically optimised systems for the medium-sized systems in these medium-sized plants.

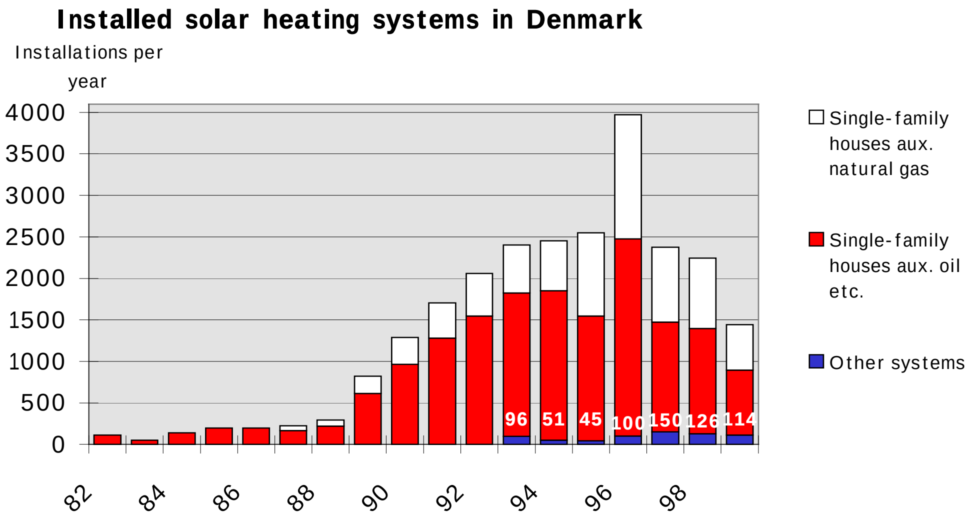
Literature list:

/1/ Purkarthofer, G.: Marktübersicht Thermische Solaranlagen, Arbeitsgemeinschaft Erneuerbare Energie, Gleisdorf, 1998
/2/ Faninger, G.: Solarmarkt in Österreich, Bundesverband Solar, 1998

MARKET DEVELOPMENT IN DENMARK SINCE 1990

Klaus Ellehauge
Solar Energi Center Denmark
Teknologisk Institut ,DK-8000 Aarhus C

Up to 1996, the number of installed solar heating systems in Denmark steadily increased (see the figure below). Since 1996, the number has decreased.



Other systems (multiple houses, industries etc.) only stated from'93. Numbers for '99 are estimates.

No investigations have been performed regarding why there has been an increase and a decrease, respectively, and therefore conclusions are uncertain.

However, the following conditions might have influenced the situation:

- Steady growth up to 1996 is seen as a result of increased confidence in quality, campaigning and reliable subsidies. In 1996, subsidies amounted to DKK 5 per kWh net solar energy produced by the systems each year. However, as a maximum no more than 30% of the total cost of the systems. For most systems subsidies amounted to about 25-30%.

- In 1996, the large sales were a result of campaigns in co-operation with natural gas companies.

- In 1996, subsidies decreased to DKK 4/kWh and were removed from areas with district heating and cogeneration.

- In the past years, the economy among people in Denmark has been good and that has made the installers busy. As they have higher profits on i.e. bathroom components they are not interested in promoting solar heating systems.

- Most manufacturers in Denmark have based their sales on the local installers in Denmark and maybe that is why they have experienced a heavier decline in sales than companies having there own sales and installation personnel.

Once there were 10-15 manufacturers. A few have closed recently and perhaps more will have to close if the market does not increase once again.

<u>Annually installed collector area</u>
The number of installed systems can be seen in the above figure. The collector areas are approximately 10 times the number of systems. The collector area installed in 1996 was approximately 40.000 m² while it in 1999 is expected to be only app. 15.000 m². Plastic collectors and vacuum tube collectors only represent a minor market share.

<u>Main use</u>
As seen from the figure, most systems are single-family systems, while approx. 100-150 systems a year are for multifamily houses, industries, tourist facilities etc. A few systems are very large systems (Marstal 8.000 m²) for district heating without cogeneration.

About 2/3 of the installed systems are DHW systems while the remaining are combisystems of which the major part are systems with a heat exchanger in the collector loop (like DK1).

FINNISH SOLAR COLLECTOR MARKET DEVELOPMENT 1995-1998

Janne Jokinen
Fortum Advanced Energy Systems
P.O. Box 100
FIN-00048 Fortum

	Yearly installed	**Total installed**	**Specific energy yield**	**Total energy yield**
	m^2	**m^2**	**MWh/m^2**	**MWh**
1995		6000	0,3	1800
1996	500	6500	0,3	1950
1997	700	7200	0,3	2160
1998	800	8000	0,3	2400

Practically all are flat plate collectors.

Main use: hot water preparation.

Market share of solar combisystems: 10 %

SOLARMARKET IN FRANCE

Thomas Letz
Association Savoyarde pour le Développement des Energies Renouvelables
299 rue du Granier - B.P. 45 - 73230 SAINT ALBAN -LEYSSE
Tel: +33 4 79 85 88 50 Fax: +33 4 79 33 24 64 E-mail: asder@club-internet.fr

Background :
Compared with the other European countries, the conditions for solar energy use are very special in France. More than 80 % of electricity is produced in nuclear power plants by an only company. Each year, this company spends more than 350 Millions Euros for advertising and support for electric heating. Compared with that, solar energy development is supported by the state with only less than 6 Millions Euros !

The French market :
In France, about 450 000 square metres solar collectors have been installed until now, most of them however in older plants (more than ten years old). After the oil shock (1986-1987), the yearly installed area has decreased to 10 000 square metres until 1992. Since that time, it has increased again by about 13 % per year until 1995. About 20 % of them have been installed in the French Overseas Departments (Martinique, Guadeloupe, and Reunion), mainly for individual domestic hot water preparation. This proportion reached 50 % in the next following years, because consumers could profit of favourable payment conditions thanks to a development plan : they have to pay only about 300 Euros when the installation is finished, and a small monthly amount five or six years long. With this new system, the yearly installed area has been increased to 30 000 square metres per year.

With this plan, the flat plate collectors constitute the main part of the market growth. They represent now about 55 % of the market share, against 45% for unglazed plastic collectors. Vacuum tube collectors are of uncommon use.

Overseas, most solar plants are installed for individual domestic hot water preparation. At the opposite in the mother land, flat plate collectors are used in some collective domestic hot water installations and more individual combisystems. For each of these two categories, a specific innovation has been developed :

- Guarantee for Solar Results (GSR) : this proceeding allows to guarantee the owner that the solar plant produces a energy amount consistent with a theoretical calculation. In case of bad functioning, the interdependent grouping constituted by the solar collector manufacturer, the design office, the installer and the operator compensates the owner in function of the deficit observed. This proceeding has been used with success on about fifty plants for ten years, with collector area between 50 and 700 square metres.
- Direct Solar Floor (DSF) : in this combisystem, the fluid heated in the solar collectors flows directly without intermediate heat exchanger in concrete heating floors, which store the heat injected with an intermittent way, according to the irradiation and give it back in a far more regular and smoothed way. Heating floors play a part in both heat storage and heat emission. So their thickness results from a compromise between a raised value, providing an important storage, and a weak value, facilitating the control of the heat emission and of the indoor temperature. The recommended value, coming from several research works and from the observation of the behaviour of many realisations, is currently 12 to 15 cm from the insulation layer until the coating of the floor. About hundred plants with collector areas between 10 and 30 square metres are build each year, one third of them with auxiliary heating brought by wood stoves, and two third with a coupled auxiliary oil or gas boiler. This combisystem is today the only one distributed in France.

Future development :

The French state has prepared a new solar plan for the next years : "Helios 2006", and will distribute subsidies in three fields :

- 700 to 1150 Euros for individual domestic hot water systems (3 to 7 m² collector area)
- 2600 to 4100 Euros for individual combisystems using the Direct Solar Floor system (10 to 20 m² collector area)
- 400 Euros/m² collector area for collective domestic hot water plants with GSR.

We hope that this plan will stimulate the market, even if the whole budget seems to be inadequate !

THE SOLAR MARKET IN GERMANY BY THE END OF 1999

prepared by H. Drück and H. Kerskes
Institut für Thermodynamik und Wärmetechnik (ITW), 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
for the IEA Task 26 Industry Workshop, October 4, 1999, Stuttgart

One indicator which is often used to asses the 'solar market' is the installed collector area. By the end of 1998 approximately 2.1 Mio m^2 of solar collectors for domestic hot water preparation, space heating and swimming pool heating were installed in Germany. In Figure 1 the yearly installed collector area (absorbers, flat plate collectors and vacuum tube collectors) is shown.

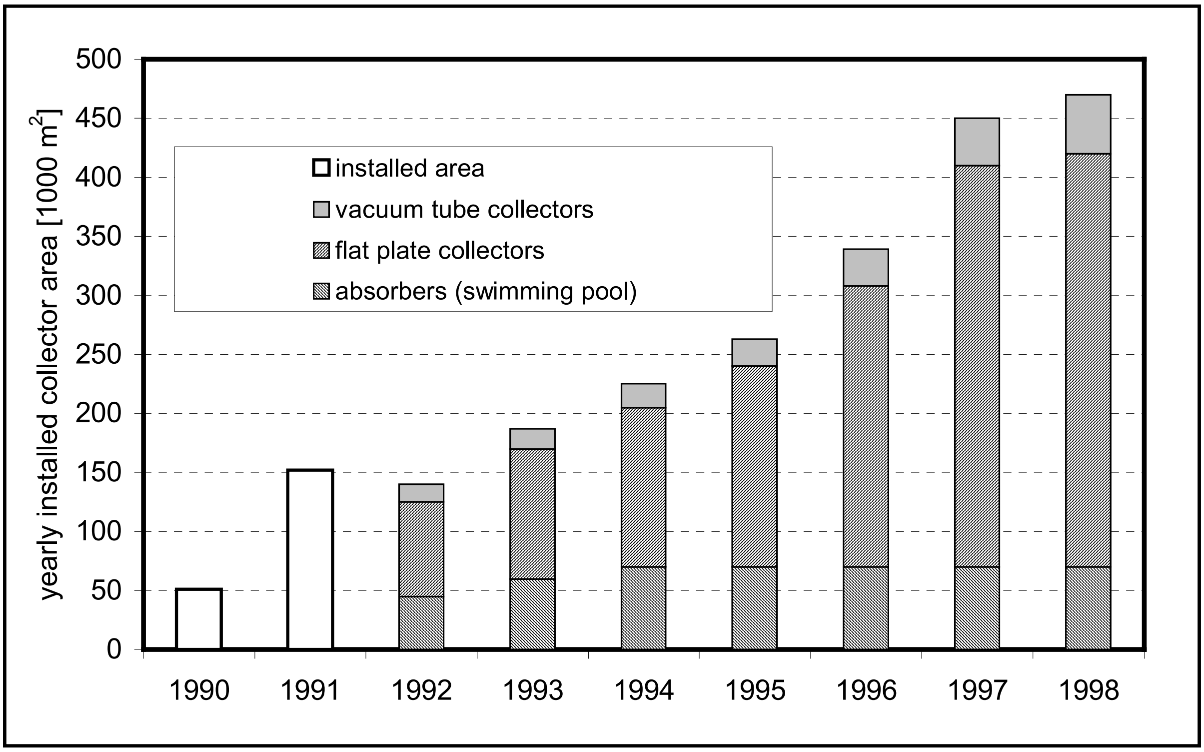


Fig. 1: Yearly installed collector area (absorbers, flat plate and vacuum tube collectors)

The figure shows a continuous growth from 1992 to 1999. But in 1998 the increase of the installed area is with approximately 20.000 m^2 quite small. This effect was due to a fundamental change in the German government which led to uncertainties and changes in the subsidy system, but this period is now over. A few days ago, the government decided to support the market penetration of solar, hydrowpower and biomass with 100 Mio EURO per year. Hence, at least the growth rate of the past can be expected for the future.

../2

Area of application

Reliable figures concerning the application of the 2.1 Mio m^2 collector area are not available. However it is obvious that the absorbers are made of platics and are mainly used for swimming pool heating. For this application the use of solar energy is cheaper than electricity or fossil fuels. The amount of collector area which is installed in large systems (> 100 m^2) can be estimated to 10% to 15%.

Concerning the market share of combisystems, reliable figures are also not available. One problem is the indicator used for the determination of this figure. Since combisystems are usually connected to a larger collector area than domestic hot water systems, the percentage of combisystems based on the application of the collector area will be higher than the one based on the number of systems installed. However, the share of collector area connected to combisystems can be roughly estimated between 20% to nearly 50% depending on the region of Germany - more in the southern part of Germany and less in the north.

Economical aspects

The price for a 'typical' solar domestic hot water system with a collector area of about 5 m^2 and a store with a volume of approximately 300 litres is in the range of 2500 EURO to 4000 EURO plus approximately 1500 EURO installation cost.

The combisystems commonly used in single family houses consist of a collector area between 8 and 20 m^2. The volume of the combistores is in the range of 500 to 1500 litres. The price for a system with 15 m^2 flat plate collector area and a 1000 litre combistore comes up to 6000 to 10000 EURO plus approximately 2000 EURO installation cost.

With regard to the economical potential of the solar market, it is important to look at the development of the prices for solar thermal equipment in the last few years. Since 1995 a decrease of approximately 10 to 15 % per year can be observed. This is due to both an increase in the number of sold systems leading to more mass production and a high price pressure on the market.

Taking into account this price degradation, the increase of the financial turnover is not the same as the increase of the yearly installed collector area shown in figure 1. For the last five years the increase in turnover can roughly be estimated to 10 % to 15 % except for 1998.

Perspectives for the future

In addition to the price degradation two other interesting aspects can be observed. One is the trend to a higher level of integration. More and more components like heat exchangers and pumps are combined to prefabricated subsystems or are even connected directly to the storage device at the factory. As a consequence of this continuous integration process, some manufacturers already integrated a fossil fuel burner into solar combistore.

The campaign called Solar Na-klar! is the other important aspect that has to be mentioned with regard to the German solar market. Solar Na-klar! is a large information campaign about the thermal use of solar energy. The objective of Solar Na-klar! is to increase the yearly installed collector area by 400.000 m^2 in the next two years, just by means of promoting solar energy in newspapers and on the television. The budget of Solar Na-kla! for the next four years is about 5 Mio EURO. About half of the project is financed by the Deutsche Bundsstifung Umwelt.

CURRENT STATUS IN SWEDEN (1999)

Solar Combisystems (SDHW&H)

Chris Bales
Solar Energy Research Center SERC
Högskolan Dalarna, 781 88 Borlänge, Sweden
Tel: +46 23 778700 Fax: +46 23 778701 email: cba@du.se

CONDITIONS FOR SOLAR COMBISYSTEMS

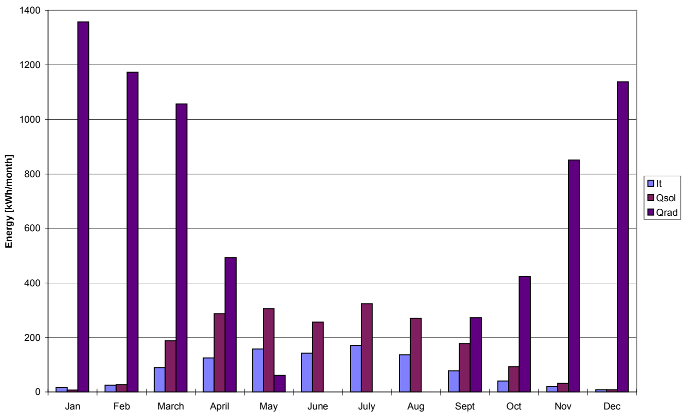


Fig 1. Global irradiation on collector surface, collector gain and heating load for a typical new house in Gothenburg with standard Swedish combisystem

The yearly solar radiation on a horisontal surface is surprisingly similar over most of Sweden.It varies from 900-1100 kWh/m^2.year. Fig. 1 shows global irradiation on a horisontal surface for Gothenburg. The heating load varies in the opposite manner, with largest loads in the winter, as shown in fig. 1 for a typical new house.

The heating load for typical houses varies from roughly 50 kWh/m^2.year for new houses in the south of the country to well over 100 kWh / m^2.year for older houses.

THE SOLAR HEATING MARKET

The solar heating market in Sweden is small, but increased steadily during the first half of the 1990's. Since then the market has decreased substantially due to the fact the state subsidy of 25% was removed at the end of 1996. No statistics for installed systems has been made since 1996. A new state subsidy has been proposed and seems likely to start at the end of 1999. Electricity is cheap (0.07 Euro / kWh), as is biomass.

In 1996 approximately 11 000 m^2 of solar collectors for small systems were installed, at an average cost of roughly 580 Euro / m^2 incl. installation, storage vessel and 25%VAT. Of this, 10% were installed on multifamily houses, the remainder being for single family dwellings. Solar combisystems dominate with 90% of the small systems market, roughly 700 systems per year. More than half of all systems are self-build systems. Retrofits dominate. No single company sells large numbers of systems (>200/year).

Over the last two years, with a smaller market, the larger systems have had a larger share of the market. Very few evacuated tube collectors are sold. Plastic collectors, mainly for pool heating are also sold in small quantities. Pool heating is currently the only heating application in Sweden which can easily shown to be profitable.

PURE DHW SYSTEMS

Duning 1996 only approximately 200 such systems were installed. The majority of these are traditional SDHW ”high-flow” systems, with roughly 5 m^2 single glased flat plate collector and a storage vessel of 300-350 liter with an inbuilt finned coil heat exchanger for solar. The auxiliary heater is electrical. Other systems do occur, but the numbers are very small. A relatively large number of companies (>10) compete for this minimal market.

OLDER SWEDISH COMBISYSTEMS

The market for solar heating has largely been created by the self-build movement, where potential buyers/builders participate in an evening course with both theory and practical experience of building collectors. Many have wood fired heating systems where a storage vessel is either already installed or is required. These tanks traditionally have one finned coil heat exchanger for the preparation of DHW or a small DHW tank placed inside the uper half of the larger storage tank. Fig 2. Shows a typical combisystem sold now. The older ones differ in that only one coil heat exchanger, placed at the top of the tank, was used. Vacuum tube collectors are not common. Electricity is often used as auxiliary in the summer with biomass being the heat source the rest of the year.

CURRENT COMBISYSTEM DESIGNS

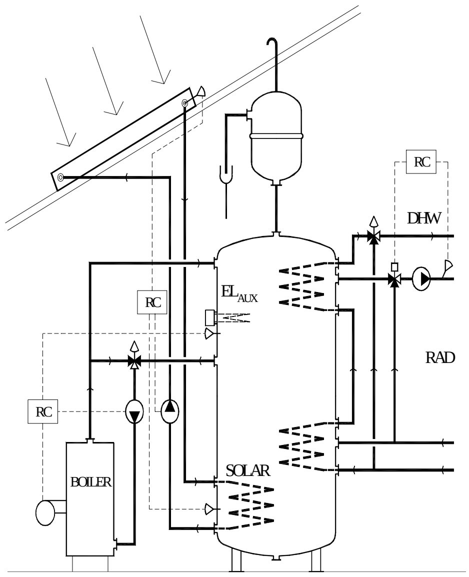


Fig 2. Typical design for Swedish solar combisystems.

Fig. 2 shows the most common design being installed now. The tank-in-tank construction is still a common alternative. Single glased flat plate collectors dominate, most using the selective absorber ”Sunstrip” which is manufactured in Sweden. The collector loop is often capable of withstanding stagnation temperatures of 160°C and the corresponding pressure without losing fluid. Drainback systems are very uncommon. The space heating loop is nearly always connected to the tank, and so system variations are largely variations in tank design, including associated heat exchangers.

Few new designs have come on to the market. This can be attributed to the fact that there are many companies sharing a limited market, resulting in little in the way of resources to develop new systems. This situation is changing now with several designs attempting to achieve more stratified tanks. Examples are: external flat plate heat exchangers for the solar loop, with several fixed temperature controlled inlets; two, coiled heat exchangers in the tank for solar and advanced electronic control; DHW preparation unit outside the tank, consisting of flat plate heat exchanger, pump and control mechanism. The latter has been tested and results in substantial improvements in system performance compared to traditional designs, but has not started selling in large quantaties.

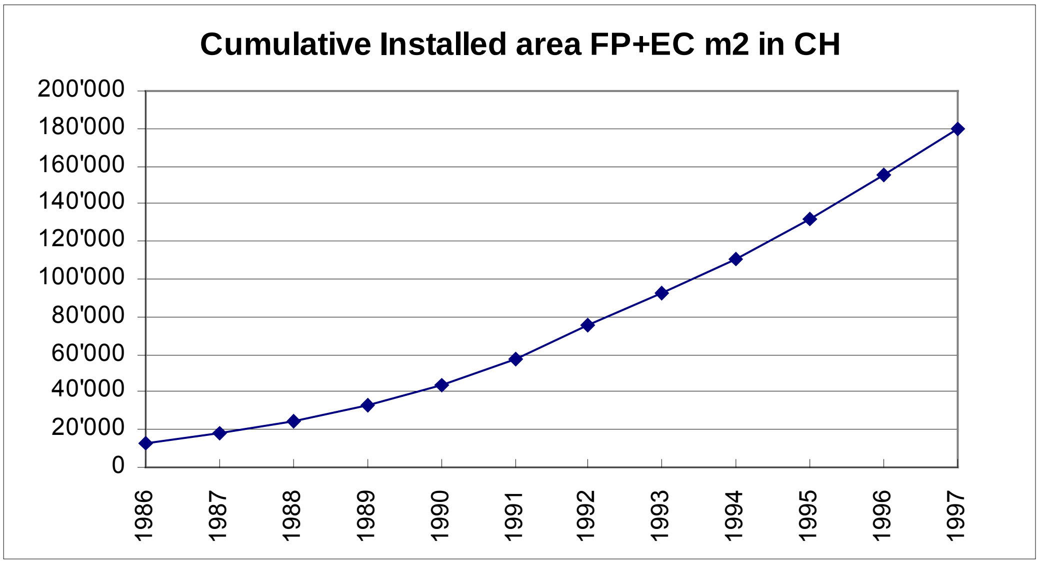
SOLAR MARKET IN SWITZERLAND 1990 - 1998

JC Hadorn
Swiss Research Program
CH-1035 Bournens
Data from SOFAS : 125 companies, 65 answers, May 1998

1. Average yields (Swiss Plateau climate)

Flat plate collectors for DHW one family	450 kWh/m^2 an
Flat plate collectors for DHW multi-family	590 kWh/m^2 an
Flat plate collectors for combisystems	270 kWh/m^2 an
Evacuated collectors for DHW one family	480 kWh/m^2 an
Evacuated collectors for DHW multi-family	620 kWh/m^2 an
Evacuated collectors for combisystems	360 kWh/m^2 an

2. Market development since 1986



In 1997, there were 180'000 m^2 of flat plate glazed collectors (FP) + evacuated tube collectors installed in Switzerland, and 170'000 m^2 of unglazed collectors for various uses (pools, DHW and heating !). There were also 780'000 m^2 of collecting surfaces for hay drying (special roofs or unglazed collectors) !

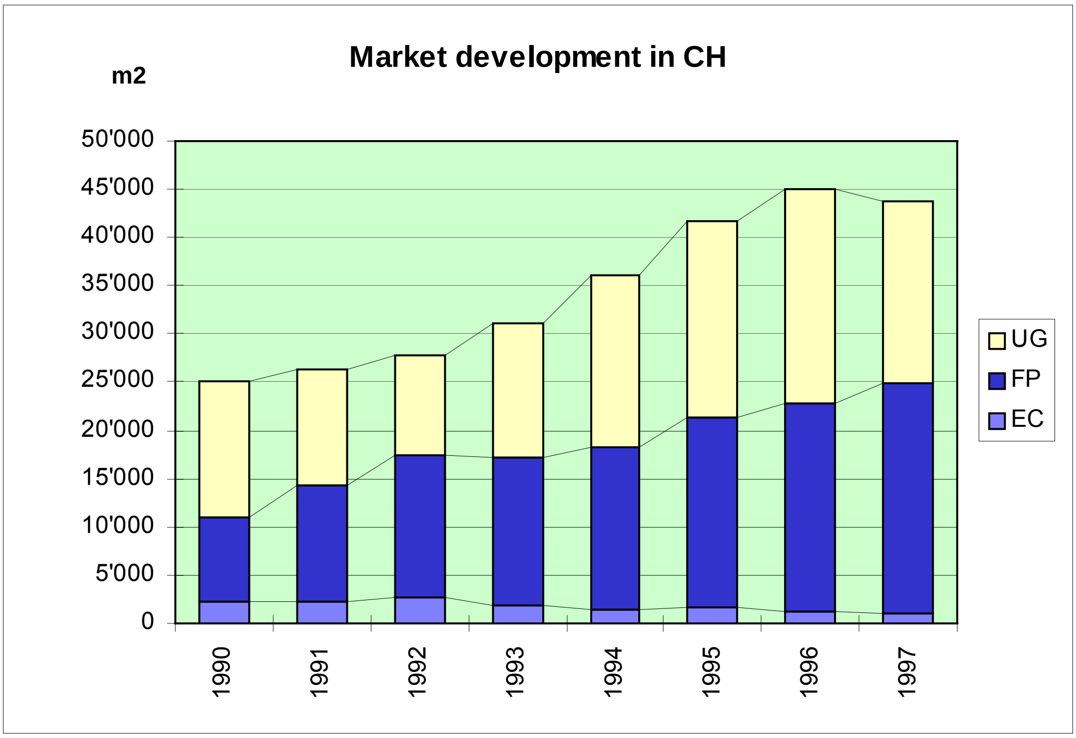
The increase rate is slowly decreasing from 33% per year in 1990 to 15% per year in 1998. This is still a noticeable high rate ! The market is far from being mature.

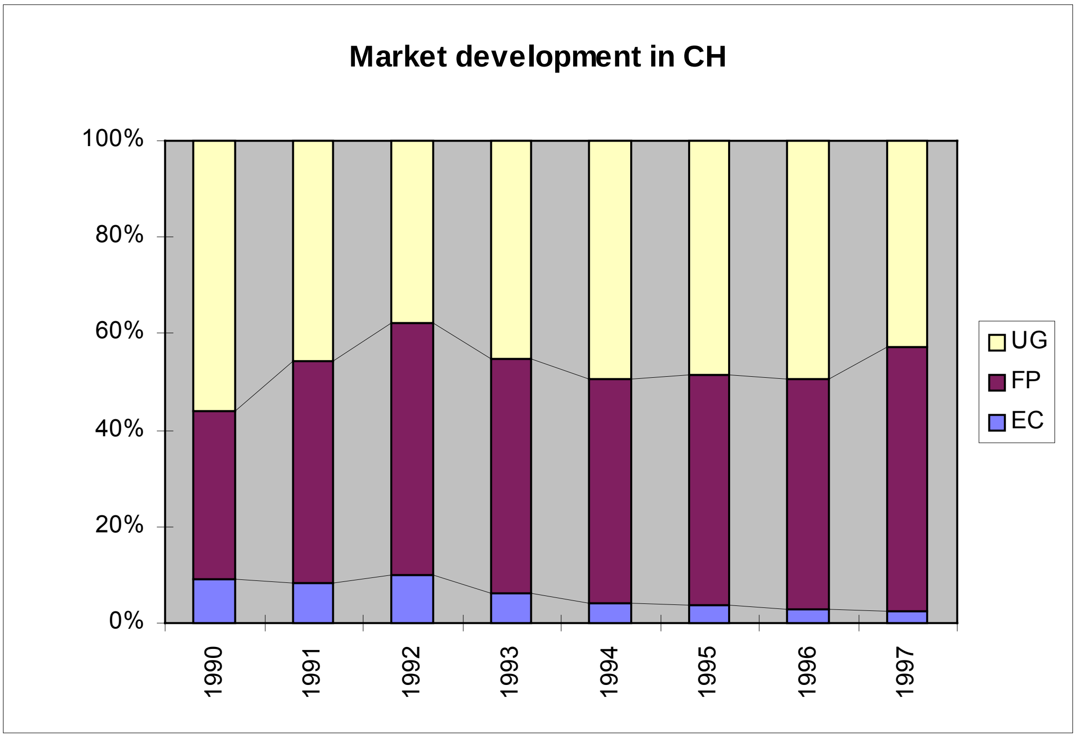
In 1997 the breakdown between collector type was :

	23'900 m² of FP	55%
	1'100 m² of EC	3%
	18'700 m² of unglazed collectors	42%
Total:	43'700 m²	100%

+ 21'000 m² of collecting surfaces for hay drying (130 kWh/m²).

Since 1990, flat plate collectors sales are growing from 10'600 m²/y in 1990 to 25'400 m²/y in 1997.
Flat plate collectors share the market with unglazed collectors, and evacuated tube collectors have a 2-3% declining market share.
Flat plate collectors is gaining some market share over both unglazed and evacuated collectors.





3. Main uses

Type of use is mainly for DHW in terms of number of installations (60%), but in combisystems in terms of installed area (around 50%), specially for one family houses.

1997 Type of use	Area %	# of installations	% of inst.
DHW one family	21.9%	947	53%
Combisystems one family	42.8%	592	33%
DHW multi-family	12.8%	113	6%
Combisystems multi-family	7.1%	50	3%
others	15.4%	74	4%
	100.0%	*1'776*	*100%*
DHW	34.7%	1'060	60%
Combisystems	49.9%	642	36%
others	15.4%	74	4%
	100.0%	*1'776*	*100%*

Installation size is mainly under 20 m² per installation. The segment 1 to 10 m² is largely dominating.
The average installation size is around 15 m².

1997 Installation size		# of installations	% of inst.	nominal area	Est. area m2	Share
Compact Kit for DHW		389	22%	5	1945	7%
1 - 10 m2		636	36%	8	5088	19%
11 - 20 m2		438	25%	15	6570	25%
21 - 50 m2		276	16%	35	9660	37%
51 - 100 m2		31	2%	75	2325	9%
more than 100 m2		6	0%	100	600	2%
		1'776	*100%*		26188	100%

4. Conclusions

The swiss market is small compared to fossil competitors but smoothly increasing since 1986, at a recent rate of 15% per year.

Main market of solar energy is in the domestic heating sector for small individual installations and for medium sized installations for multi-family buildings.

Combisystems for one family houses, with an average area of 10 to 20 m² of flat plate collectors are dominating the market with around 600 installations per year.

The energy cost of such systems is around 30 cts per kWh.

The revenues of the solar thermal market were altogether around 44 milllions CHF in 1997.

THERMAL SOLAR ENERGY IN THE NETHERLANDS IN 1999

Huib Visser
TNO - Building and Construction Research
Division Building & Systems
NL-2600 AA Delft

SYSTEM DEVELOPMENT

In the Netherlands, market for solar thermal energy has been dominated by solar hot water systems for a long time. Only in recent years, solar combisystems with integral gas burner have been developed. This development supports the wish to save space for installation of the solar energy system in the house. A different development in this respect is the development of Integral Collector Storage systems. In earlier years, there were a few experimental solar combisystems with large collector areas (20 m^2 and larger) and solar domestic hot water systems with double size collectors and extended with a small floor or wall heating net.

STATE-OF-THE-ART AND MARKET DEVELOPMENT

At the end of 1998, a total of 220 thousand m^2 collector area has been installed in active thermal solar energy systems. Small domestic hot water systems (with collector area smaller than 6 m^2) take about 40% of that area and unglazed systems (mainly for swimming pools) about 45%. Large systems involve about 12%. Solar combisystems are part of the larger solar energy systems and have a relatively small market share, i.e. about 3% of the glazed systems. Estimation of the market share of solar combisystems in recent years is between 5 and 10%. Major part of the glazed solar collectors has a single glass cover and a spectral selective absorber.

Dutch market for small solar domestic hot water systems grew from about 2000 systems in total in 1990 to about 34.000 systems in total in 1998. Between 1995 and 1997, the sales more than doubled; during the last two years, however, the sales are quite constant: about 8000 systems per year; see the figure below.

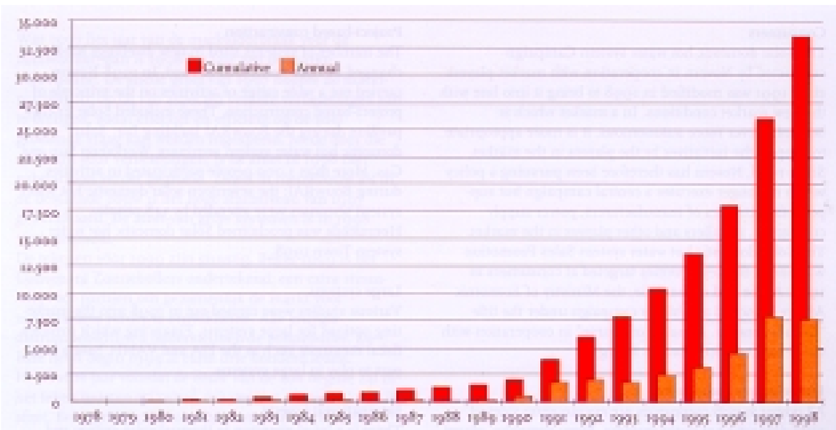


Figure: Solar domestic hot water systems installed in the Netherlands (source: Novem).

APPLICATION RANGE

Major application range for systems with glazed collectors is domestic use: in small households, apartment buildings and service flats. Large solar hot water systems have also been installed for hotels, restaurants, sport centres and camping sites.

SOLAR MARKET IN THE USA - 1998

William A. Beckman
University of Wisconsin, Solar Energy Lab
1500 Engineering Dr., Madison, WI 53706

Solar DHW systems sold: 6000 systems (guess 4 square meters per system = 24000 m^2)
Solar pool heating systems sold:10000 systems (guess 10 m^2/system=100.000 m^2)
Solar Combisystems installed; estimates range from zero to less than 100.

EUROPEAN PRODUCT STANDARDS FOR SOLAR DOMESTIC HOT WATER SYSTEMS REACHING MATURITY

Mrs. Amelie Veenstra
TNO Building and Construction Research
P.O. Box 49, 2600 AA Delft
The Netherlands
Tel: +31 15 269 52 43
Fax: +31 15 269 52 99
E-mail: a.veenstra@bouw.tno.nl

Abstract

Since 1994, the European Committee for Standardization (CEN) Technical Committee TC 312 has been active in producing European Standards for thermal solar energy systems and components, which are now reaching its final stage. In this paper, an overview of the present State of the Art of the draft standards is presented. These standards will specify both General Requirements and Test Methods for thermal solar energy products. All common systems presently available on the European market are reflected in a set of seven standards, which offer a good stimulation for manufacturers to develop optimized systems. Furthermore, the expected developments in the next years are described. Consequences for the solar energy market in Europe are outlined, like quality labeling.

1. Introduction

Standardization of thermal solar energy systems and components has received attention on national and international levels since more than 15 years. In several countries, national standards for solar energy products have been established. On international level, the International Organization for Standardization Technical Committee ISO/TC 180 has produced International Standards since around 1980.

In 1993, the European Committee for Standardization (CEN), upon request by the European Solar Industry Federation (ESIF), decided to erect a new Technical Committee CEN/TC 312 to produce standards for thermal solar systems and components, aiming at improved market conditions for free trade in Europe. The first meeting of this committee took place in 1994. The European Altener Commission is also supporting the CEN/TC 312.

2. Structure of CEN/TC 312

The work of CEN/TC 312 is structured in three Working Groups, each consisting of a number of experts from research institutes and industry and supported by a Project Team, responsible for preparing the standards for the respective sub-field (see figure 1). In the standards, 'General Requirements' are specified concerning durability, reliability and safety aspects, uniformly imposed on all European systems and collectors. In the 'Test Methods' parts, tests are given to verify compliance to those requirements and to determine the energy performance of collectors and systems. [3]

The Project Teams, which are sponsored by the CEC Altener Program, take care of the drafting and editing of the standard text. The drafts are repeatedly submitted by the Working Groups to the main body, the TC 312, in which all EU/EFTA members have official membership. Within the TC 312 it is decided how to proceed with the draft standards, and voting rounds take place to promote them to new phases. Also, major and non-technical problems are solved here.

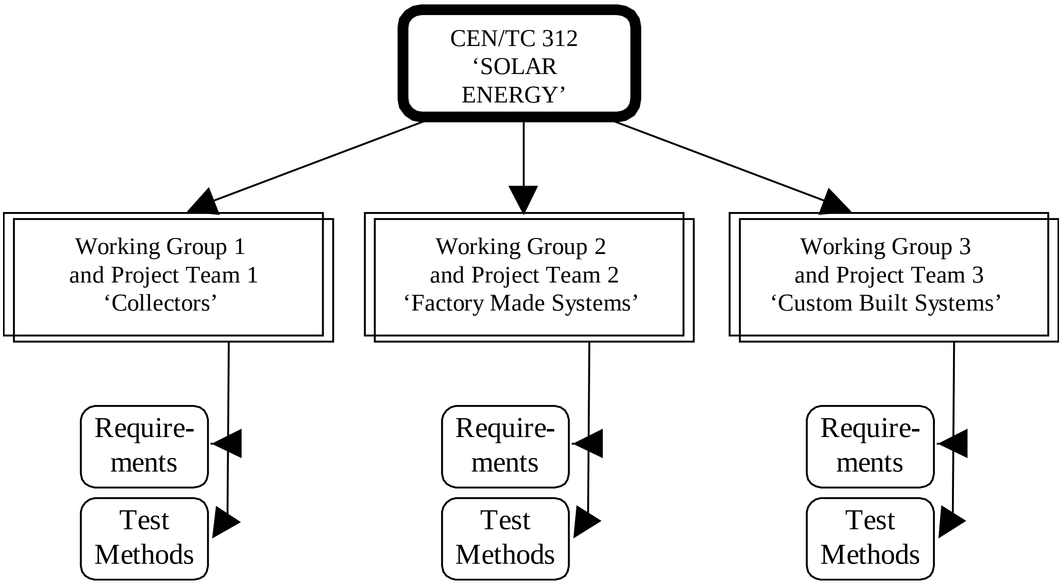


Fig. 1: Structure of the CEN/TC 312

The three Working Groups are called after their working fields, see Figure 1. Working Group WG 1 directs itself to the requirements and test methods to be used for solar collectors. WG 2 is for factory made systems, whereas WG 3 covers the custom built systems. See below for an explanation of these terms. The titles of the standards being produced by the CEN/TC 312 are given in Table 1.

3. Standards for solar collectors: Working Group WG 1

Requirements are imposed on solar collectors with respect to durability, reliability and safety. The scope covers glazed and unglazed collectors operated with liquid heat transfer media. The test methods are based on those specified in international standards ISO 9806, Part 1, 2 and 3. Dynamic collector performance testing was introduced as an alternative to the classical collector test according to ISO 9806, Part 1.

The standards for collectors cover the collector as a product, but also serve as a base for the standards for whole systems in Working Groups 2 and 3. From the standards for whole systems, a number of references are made to the standards for solar collectors.

4. Standards for whole solar heating systems: Working Groups 2 and 3

The standards for whole solar heating systems mainly have the goal to establish a common level of quality in the sense of durability, reliability and safety of solar heating systems on the European market. Various requirements are put on the system technique in order to ensure that the system operates well under normal, but also under extreme conditions (for example stagnation conditions and large temperature changes in summer time or high snow and wind loads). Requirements on the technical documentation of the system ensure good installation and operation manuals.

Table 1: Titles of the future CEN/TC 312 standards.

Working Group	Number	Title "Thermal solar systems and components-…"
1	EN 12975-1	Collectors – Part 1- General Requirements
	EN 12975-2	Collectors – Part 2- Test methods
2	EN 12976-1	Factory Made Systems- Part 1 – General Requirements
	EN 12976-2	Factory Made Systems- Part 2 – Test Methods
3	ENV 12977-1	Custom Built Systems- Part 1 – General Requirements
	ENV 12977-2	Custom Built Systems- Part 2 – Test methods
	ENV 12977-3	Custom Built Systems- Part 3 - Performance characterization of stores for solar heating systems.

The standards further enable the determination and presentation of the thermal performance (energy savings) on a common base for the whole European market. This has been achieved by choosing performance test methods, which allow predicting the system long-term performance for different climates independently from the location of the test lab. This ensures the possibility to test systems meant for a different climate than the climate of the test institutes location, which provides good condition for free trade in Europe. The performance test methods used for the different system types are ISO (or ISO/DIS) standards 9459, part 2, 3 and 5, described in [1] and [2], depending on the type of system. Four reference locations have been chosen for which the performance is always calculated: Athens (for southern Europe), Davos (for mountain regions), Würzburg (for middle Europe and sea climates) and Stockholm (for northern Europe). This will facilitate comparison of the thermal performance of different systems.

The work fields of WG 2 and WG 3 are subdivided in two types of solar heating systems: *Factory Made Systems* and *Custom Built Systems.* This distinction was chosen in order to handle the variety of types of solar heating systems found on the European market, which covers from small compact systems (e.g. thermosiphon or ICS system units) to unique large solar heating systems, planned by engineers. The demarcation between Factory Made and Custom Built Systems can be clarified as follows.

Factory Made solar heating systems are batch products with one trade name, sold as complete and ready to install kits with, i.e. with fixed configuration of components. Systems of this type are considered a single product and therefor assessed as a whole.

Table 2: Division for Factory Made and Custom Built solar heating systems

Factory Made Solar Heating Systems (EN 12976-1, -2)	**Custom Built Solar Heating Systems (ENV 12977-1, -2, -3)**
Integral collector-storage systems for domestic hot water preparation	Forced-circulation systems for hot water preparation and/or space heating, assembled using components
Thermosiphon systems for domestic hot water preparation	and configurations described in a documentation file (mostly small systems)
Forced-circulation systems as batch product with fixed configuration for domestic hot water preparation	Uniquely designed and assembled systems for hot water preparation and/or space heating (mostly large systems)
NOTE: Forced circulation systems can be classified either as Factory Made or as Custom Built, depending on the market approach chosen by the final supplier.	

Custom Built solar heating systems are either uniquely built, or assembled by choosing from an assortment of components depending on local conditions. Systems of this category are regarded as a set of components. The components are separately tested and test results are integrated to an assessment of the whole system. Custom Built solar heating systems are subdivided into two categories: **Small Custom Built systems** (assembled using standard components and configurations described in a documentation file) and **Large Custom Built systems** (uniquely designed and assembled).

Table 2 gives a concrete division for the different system types. As can be seen, the category of Custom Built solar heating systems also includes forced-circulation systems for domestic hot water preparation. These can be technically similar to Factory Made forced-circulation systems. However, when such forced-circulation systems for domestic hot water preparation are not marketed as a complete and ready to install kit, they are considered as Custom Built and not Factory Made.

5. Present status of CEN/TC 312 draft standards and future developments

The CEN/TC 312 and its subgroups have worked at an intense level in order to produce the standards in a fast and efficient process. This has involved a considerable number of meetings, a large investment of manpower from the people involved and two iterations of the draft standards inside the TC. The result is that the drafts are published as Draft (preliminary) European Standards (prEN) in 1997 and circulated for comments from the official members bodies (i.e. the national standardization institutes) in a formal enquiry round, the so called CEN Enquiry.

Presently the TC and Working Groups are processing the comments resulting from the CEN Enquiry and imbedded in the final drafts, which will be subject to the Final Vote within this year. This is a weighted vote with duration of two months, where the EU/EFTA countries can either approve or disapprove of the standards. When the standards pass this Formal Vote, they will be published as European Standards (EN) by early 2000. Alternatively, the standards can be published as European Pre-Standards (ENV) in order to allow a practical use of the standards for a period of three years before they are once more revised and finally published as ENs.

As soon as the standards are published, procedures for next revision rounds will be started. Due to fast research and market developments of solar heating products the standards should follow accordingly, in order to provide good up-to-date market conditions. Several developments are foreseen, e.g. application of new materials or components, an increase of types of systems with space heating option, development of (new) performance test methods [4] and changing perception of type of performance indicators. Moreover, a change in the structure of the standards is foreseen towards more transparency in relation to ISO standards and towards a more clear reflection of solar heating components market versus system markets within CEN standards. These developments, amongst others, will be subject to further revisions.

6. Expected impact on European market

As mentioned above the preparation of European CEN standards for solar domestic hot water systems is reaching its final stage. It can be expected that these standards will have a considerable influence on the solar energy markets on national, European and global scale. Once they are published as CEN standards, conflicting national standards in all European member states shall have to be withdrawn within a limited time. This means that the European Standards will effectively replace any conflicting national standards, which could have strong effects on national markets. Because all common systems presently available on the European market are reflected in the CEN standards they offer a strong stimulation for manufacturers to develop optimized systems

Also, the standards provide a basis for quality certifications of solar domestic hot water systems in the near future, currently initiated by the industry associations. As soon as the standards are released it is up to the European industry to work out a certification scheme. The results of the test methods being standardized will be valid all over Europe. This will reduce the cost of testing for companies intending to export systems within the EU and EFTA, resulting in a reduction of trade barriers and the further development of a European market.

Guaranteed quality, including safety aspects and thermal performance characterization is considered very important for the further development of the solar heating market. Mature markets require consumer protection and high quality products, in order to ensure good conditions that allow solar energy technologies to grow. The completion of the standards gives rise to developments like preparation of uniform European design and install guidelines, development to environmental rating methods serving environmental labeling, preparation of test methods for solar space heating systems and optimizing performance test methods. All these developments will eventually lead to broader acceptance of solar heating systems as a mature and reliable technique.

References:

[1] Th. Pauschinger
Performance testing and certification of small solar heating systems
Proceedings of Eurosun '96, Freiburg, 1996

[2] H. Visser and B.G.C. van der Ree
The DST method for solar domestic hot water systems - Research and development for ISO and CEN standards
Proceedings of Eurosun '96, Freiburg, 1996

[3] B.G.C. van der Ree and Th. Pauschinger
CEN standards for solar thermal systems – State of the Art and expected Impact
Proceedings Eurosun ’96, Freiburg, 1996

[4] D.J. Naron, B.G.C. van der Ree, M. Rolloos
Bridging the Gap: Research and validation of the DST performance test method for CEN and ISO standards, progress and preliminary results
Proceedings Eurosun ’98, Portorož

FUTURE SOLAR THERMAL PUMP STRATEGY

By Detlef Ipach, Manager Marketing New Business Fields
Wilo GmbH, Dortmund – Germany

ACTUAL SITUATION

Most of the quoted and installed pumps in solar thermal circuits are oversized. Only a few optimized pumps for the thermal solar applications are available.

The mainly use of standard heating circulators implements an non neglectable demand for electrical energy in solar systems, and reduce serious the energy saving summary.

The implemantation of primary energy as result of the power consumption of the pump (F=3 for primary energy calculation) could take a share up to 25% of the collected solar energy.

TECHNICAL CONDITIONS FOR SOLAR THERMAL PUMPS *

The influence on solar thermal pumps is given by the different solar systems.

- Low Flow - 12 l/m²
- High Flow - 30 – 50 l/m²
- Matched Flow - 12 – 50 l/m²

All pumps are steered by a electrical or electronical solar regulation unit. Sometimes the pumps are pre-installed by complete assembled pumpstations or will be installed individual by the „solateur".

The technical conditions regarding the capacity, temparatures, fluids, switch on/off, running times, would be analysized for one and two family house applications
(5 –20 m² panel square) as follows:

- Q	= Low Flow	≅	60 - 240 l/h
	= High Flow	≅	150 - 1000 l/h
	= Matched Flow	≅	60 - 1000 l/h
- H	= Low Flow		1 – 30 m/WS
	= High Flow		1 – 6 m/WS

- T = max.. 120 °C, real < 90°C
- P = max 6 bar
- Fluid = water, water/glycol , mixtures (Antiforgen L Tyfocor L/HTL, H30 L etc.)
- Running time = 10 s - 5 h , main value of r.t. 2 – 3 min.
- Working period = 1100 - 1900 h/y

ACTUAL DEVELOPMENTS OF SOLAR THERMAL PUMPS

Through employment of the knowledge and the resources in the development of hydraulic and electronic Wilo will launch the first range of real solar thermal pumps end of 1999. The features for this kind of pumps are

Type ST 15/40

- special gear hydraulic for Low Flow applications.
- wet runner motor
- low noise level
- corrosion proof pump housing

Type ST 25/4 , 25/6., 25/7

- special impeller for High Flow applications
- reduction of power consumption up to 30 %
- wet runner motor
- corrosion protected pump housing

Beginning of the year 2000 will be launch the first electronic solar pump with an integrated M-Bus interface. Together with temperatur measurements it is possible to give following features to the market:

- Variable speed dependent to Δt / t
- Pump and system regulation
- Function control
- Failure analysize
- Heat counting

More technical information will be given earliest end of 1999.

NEXT STEPS

The near future development steps will be focussed on getting better efficiency for solar thermal pumps. That means in detail

- New Q/H hydraulics
  - by 3D-impellers
  - by new gears
- Implemantation of new electronic
  - for motor drive with different voltage 12V – 230V
  - for lower power consumption
  - for pump performance according to demand

This kind of pumps will be available in approximate two years.

Stuttgart , October 4th, 1999

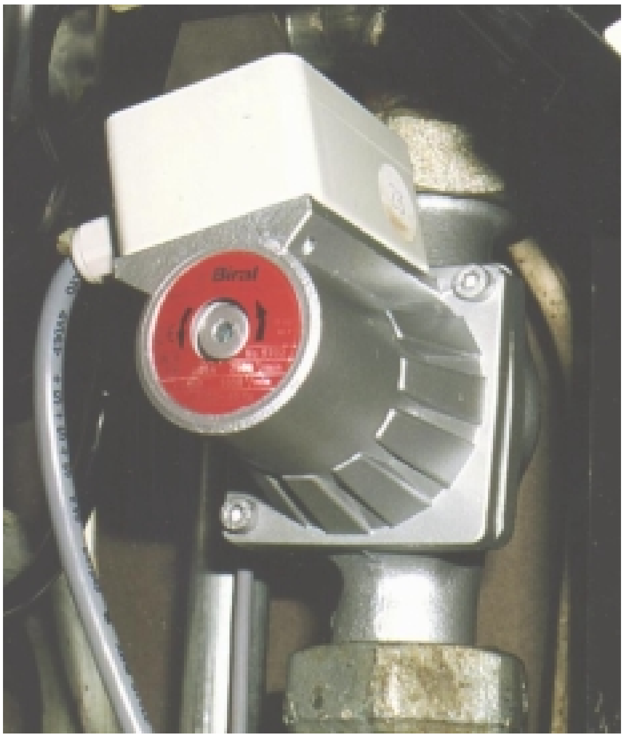
*Source: Study ITW-Wilo , Dez. 98

IEA Task 26: Solar Combisystems

Experts Meeting Stuttgart Oct. 4, 1999

INNOVATIVE PUMP DEVELOPMENTS
IN SWITZERLAND

Jürg Nipkow, ARENA, CH - 8006 Zurich
Wolfram Meyer, Biral AG, CH - 3110 Munsingen



High Efficiency Pumps for Solar Heating Systems

Solar heating systems require auxiliary energy for pumps, control etc. The share of this – electrical – energy is often surprisingly high, and the great part of it is claimed by circulation pumps. It is a fact, that small circulation pumps show very poor efficiencies and in most cases are dimensioned too large. BIRAL AG, most important Swiss pump manufacturer, is pursuing for several years the development of small high efficiency pumps. Actually, a period of field tests with some 20 pumps has been accomplished successfully. As a next step, another series of 50 to 100 pumps shall be installed in normal heating systems and also in suitable solar heating circuits, which are to more difficult to find. As the efficiency of the new pumps achieves up to 40%, compared to 5...10% of conventional pumps, the auxiliary energy share in solar systems can be reduced dramatically.

Preliminary research project:

"High Efficiency Small Circulation Pump"

Swiss Department of Energy, 1992 – 1994 (report in German).

Project team:

Jürg Nipkow (Projektleitung), ARENA, Zürich
Prof. Marcel Jufer, EPFL, Lausanne
Dr. Thomas Staubli, ETHZ, Zürich
Wolfram Meyer, Biral AG, Münsingen BE
Dr. E. Schmiedl und B. Bikle, Rütschi Pumpen AG, Brugg AG

English Extract, illustrated: pp. 3 - 7

Pilot project of Swiss Department of Energy, 1997 - 1999

"Field Tests of High Efficiency Small Circulation Pump"

Jürg Nipkow, ARENA, Zürich
Wolfram Meyer, Biral AG, Münsingen BE

(deutsche, illustrierte Kurzfassung)
English extract: p. 8

Extract of the preliminary research project

Circulating pumps for heating systems in small buildings show very poor total-efficiencies ($\square_{electromechanical}$, *$\square_{hydraulic}$) around 10 %. This is partly due to the use of a canned induction motor (a submerged rotor turns inside a stainless steel case which protects the stator from liquid), and partly due to the important hydraulic losses of such small centrifugal pumps. Unfortunately, not much information on reasons for the losses in this type of small pumps could be found in technical references. Relating to measurements and calculations, it was possible to describe the energy flows of such pumps (**fig. 1**) and to simulate the parameters of canned motors by a computer model.

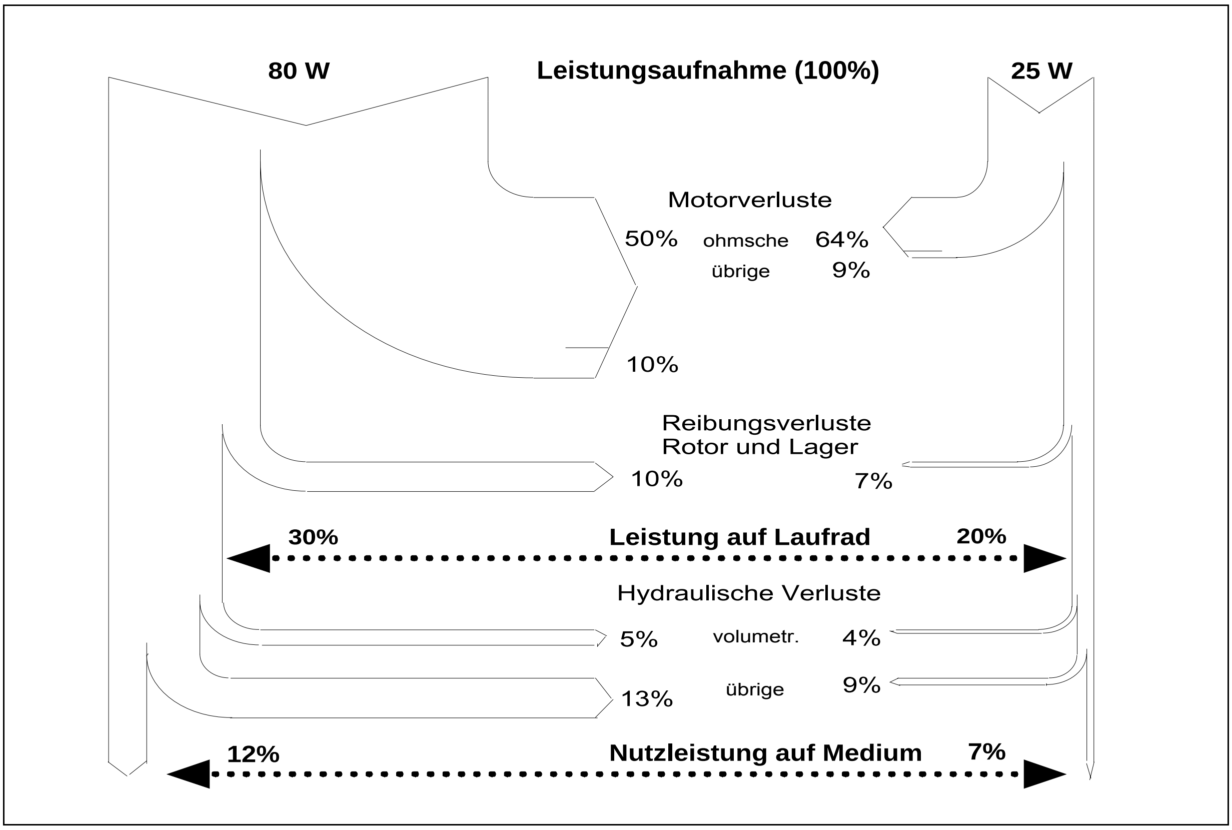
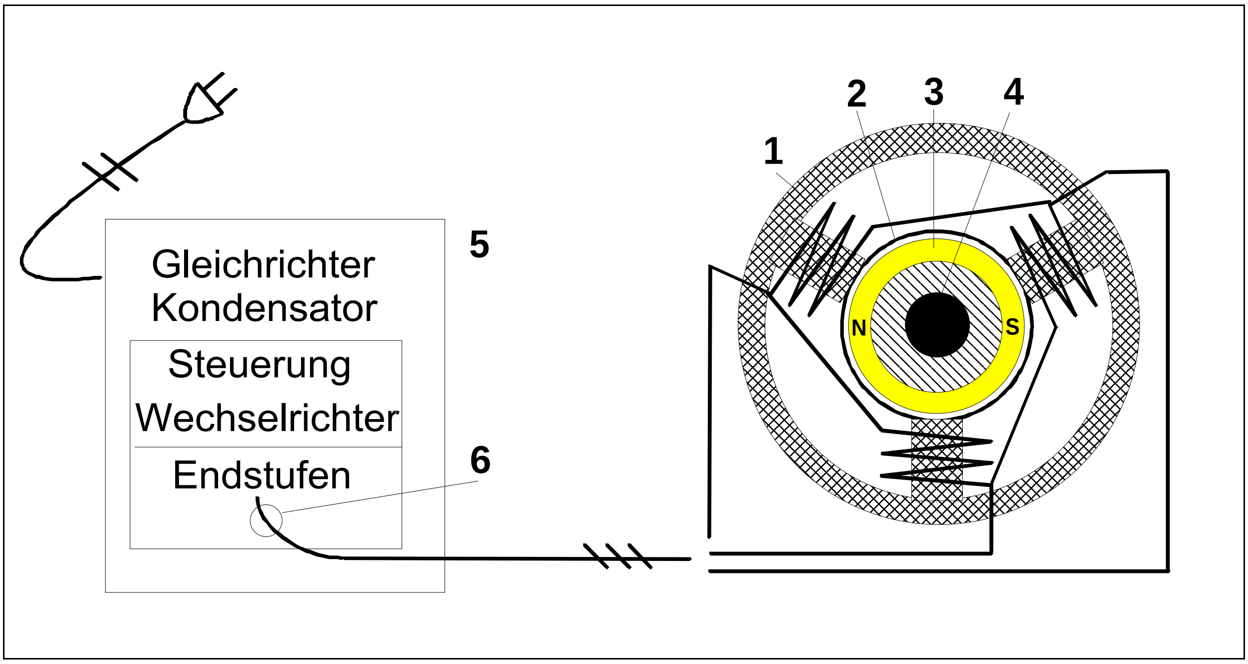


Fig. 1 Energy flux of conventional small circulation pumps
(25 W = reduced speed level)
Verluste = losses, Reibung = friction, Lager = bearings, Laufrad = impeller

Hydraulic performances for small pumps in modern heating systems were evaluated. The results, together with the requirements of common heating controls, were used as a basis for further investigation. The analysis of the specifications of commonly used pumps gave information about the variations in efficiency of similar type pumps, and about the technical attributes of very good and very bad pumps. The search for fundamentally new pump systems led mainly to new aspects of known technologies. None of them turned out to be really useful for our purpose.

As a result of the analysis and search phase, two strategies seemed to promise better efficiencies: the use of permanent magnet motors (**fig. 2**), and the development of hydraulically optimized impellers. The synchronous motor with a permanent magnet rotor offers very good efficiency at low shaft power ratings and can be easily speed regulated by low-cost electronic equipment. However, the stainless steel gap tube (or case) still turned out to be the most appropriate solution for a sealless pump. Therefore, effects of rotor and gap tube dimensions on the fluid-friction in the gap had to be studied.



1 Stator mit Wicklungen (winding)
2 Spaltrohr (gap tube)
3 Magnetring (Rotor)
4 Welle (shaft)
5 Elektronik
6 Drehzahl-/Drehmoment-Erkennung (scanning of speed and torque

Fig. 2 Brushless DC permanent magnet motor

Calculations for optimization of the canned permanent magnet motor led to a dimensioning basis and to specifications for permanent magnets and other motor-components, including the electronic power supply. Two sizes of motors (5 and 10 Watt shaft power) have been realized. Testing and measuring has been accomplished at the Federal Technical High School of Lausanne (EPFL). The expected high motor efficiencies of over 80% were confirmed (**fig. 3**). Due to power supply losses the complete drive efficiencies ranged from 60 to 80%. These values do not include the losses of a mains transformer, which will be eliminated in a later development.
An analysis of theoretical and statistical references on hydraulic efficiency of small circulating pumps offered improvement aspects for these systems as well. Experimental research on the subject has been performed by students working on diploma projects of the Hydraulic Machines Laboratory of the Technical High School of Zurich (ETHZ). Established impeller shapes of the pump manufacturers Bieri AG and Rütschi AG have been adapted to the needed sizes (Ø 20...30 mm) and designed by CAD. As the precise manufacturing of such shapes is extremely difficult for the required sizes, a stereolithographic method (laser controlled solidification of synthetic resin plastic) has been used at the ETHZ. A small number of prototype impellers manufactured stereographicaly served for the measurements and test-pumps.
At speeds up to 4500 rpm hydraulic efficiency figures up to 60 % were measured, which is much more than could be expected according to the "Anderson-rule".

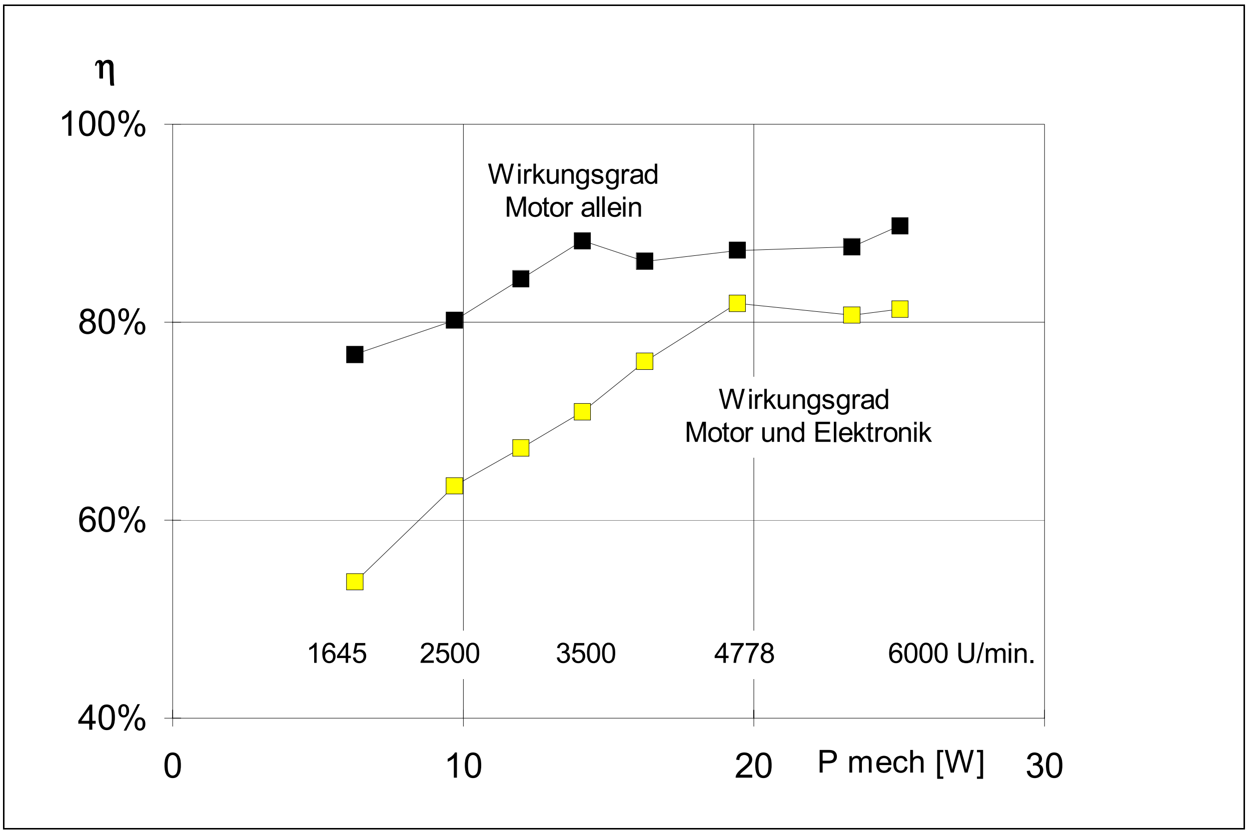


Fig. 3 Motor efficiency of prototype motor "10 W", measured at Federal Technical High School of Lausanne (EPFL), at constant torque

Performances of prototype pumps

Four different prototype pumps have been assembled with one size of pump casing, two motor sizes and three different impellers. They have been measured on the testing rigs of the companies Biral AG and Rütschi AG. The results corresponded to the expectations from the separate motor and impeller tests. Overall efficiencies of 25% (smallest impeller) up to 38% have been achieved, at 5800 rpm in the maximum. These values include the electronic power drive losses of approximately 3 W, which may be reduced in further development steps. Relating to the primarily established aim of doubling the efficiency of common small pumps, ranged at around 10%, these results are a good success. No technical problems have been observed so far within the few operating hours.

The diagrams of **fig. 4** show pump characteristics (head, total efficiency , power consumption over flow rates). Power was measured at DC level for accuracy reasons.

The marked flow rates A, B, C are related to typical applications in heating systems.

Fig. 5 shows an example of economies with circulation pumps: step 1 is realized by correct dimensioning, step 2 by new efficient pump technologies.

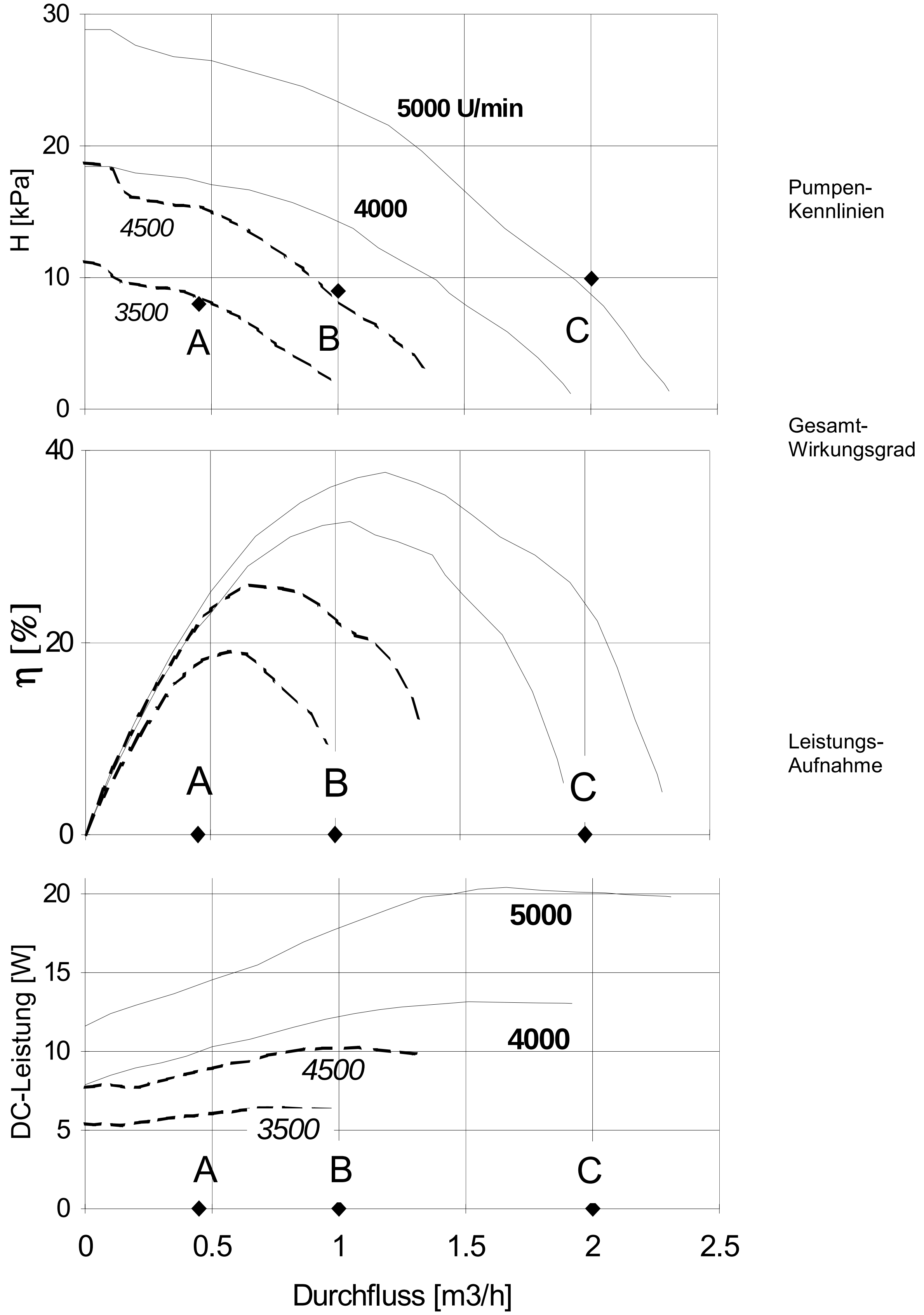


Fig. 4 Prototype performances —— **Motor 10 W/Laufrad B28Z**
---- *Motor 5 W/Laufrad R25Z*

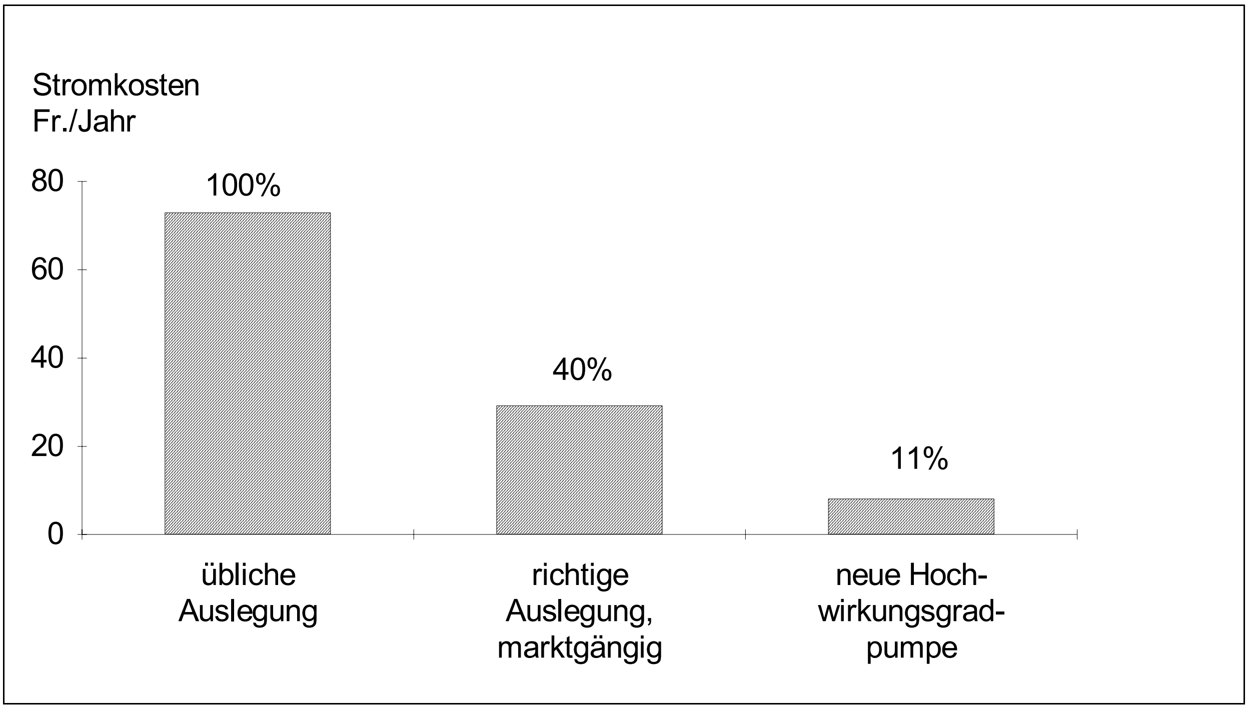


Fig. 5 Economies (cost as well as energy) with pump application:
usual dimensioning, correct dimensioning / conventional pump, new high efficiency pump.

FIELD TESTS OF HIGH EFFICIENCY SMALL CIRCULATION PUMP

Pilot project of Swiss Department of Energy, 1997 – 1999

Jürg Nipkow, ARENA, Zürich
Wolfram Meyer, Biral AG, Münsingen BE

Extract (illustrated project paper in german)

The success of the energy research project, "Small circulation pumps with a high level of efficiency", was a pre-requisite for further development in view of series manufacture. As a first step towards industrial production, a preliminary series of approximately 30 pumps was produced and tested in normal heating systems. Among the main goals in connection with technological development were the reduction of production costs and finding ways of assessing these costs for later series manufacture, while another was to test the pump's faultless and reliable operation.

A suitable product for preliminary series production was developed by the end of 1997 and installed in a variety of heating systems in buildings ranging from single-family dwellings to small apartment blocks in Switzerland. Most of the pumps used in these field trials have been fitted with measurement modules for constant recording of data, and this meant it was possible to obtain valuable findings with respect to operating parameters and problems that arose in the individual installations (e.g. temporary interruptions, unstable current characteristics). Solutions to most problems have already been found or are currently in development.

The most commonly identified problems and criteria for solutions were as follows:

- Mechanical problems: in some installations, rapid changes of water temperature led to a build-up of air in the rear pump bearing, and this caused jamming and subsequent stoppage. In most cases the pump functioned again after it was switched off and back on again. The solution here is to be found in more efficient automatic ventilation of the rotor room.
- Noise: in some installations the frequency of the current converter was audible in the form of a whistling sound, which it was possible to eliminate using prepared switching software in the control unit.
- Starting problems: in connection with mechanical disturbances it became apparent that the programming of automatic restart after stoppage needs to be improved.
- The electric stability of 500 V in the electronic components proved to be insufficient in some of the installations. By subsequently installing a network filter, it was possible to increase the stability to more than 1000 V.

Outlook

Now that the functional operation and suitability for practical application of small pumps has basically been demonstrated with the aid of field trials, the technical pre-requisites for further development in the direction of industrial production and marketing are now in place. The problems identified during the pilot stage have meanwhile been solved with sufficient reliability, and the next step that is envisaged before actual industrial production consists in a enlarged field trial with 50 to 100 pumps, which will provide an opportunity to also assess the degree of reliability on the basis of statistical data. During this stage it is also planned to push ahead with marketing activities. One specific marketing field will be the application in solar thermal circuits, where users are very sensitive on the amount of auxiliary energy.

IEA Task 26: Solar Combisystems
Industry Workshop, 04. October 1999, Stuttgart, Germany

LIFE CYCLE ANALYSES OF SOLAR HEATING SYSTEMS

Bernd Achatz
Deutsche Bahn AG, Bahn-Umwelt-Zentrum
Schicklerstr. 5-7
10179 Berlin
Tel: ++49-30-297 63243 / Fax: –63328
email: bernd.achatz@bku.db.de

1. Introduction

The question, if renewable energy technologies actually save as much energy in their lifetime as their production, use and disposal consumes, is not new. As severals studies in the 90's have proved ([1], [2]) the so-called energy-pay-back-time for thermal solar systems for domestic use averages at about 2-3 years. During an estimated lifespan of about 20 years a solar system 'produces' about 10 times the energy that was needed for construction and running the system.
This presentation is based on an investigation carried out in 1997 for the German consumers' magazine "test", in which several environmental aspects of 12 domestic hot water systems and 8 combisystems were investigated.
One aim of the study was to find a methodology that includes quantifiable (energy-pay-back-time) and non-quantifable aspects (toxicology, recycling, etc.) of an ecological life-cycle-assessment. Secondly it intended to highlight ecological hot-spots and produce advice how to improve the ecological properties of thermal solar systems.

2. Principles of Life-Cycle-Assessment (LCA)

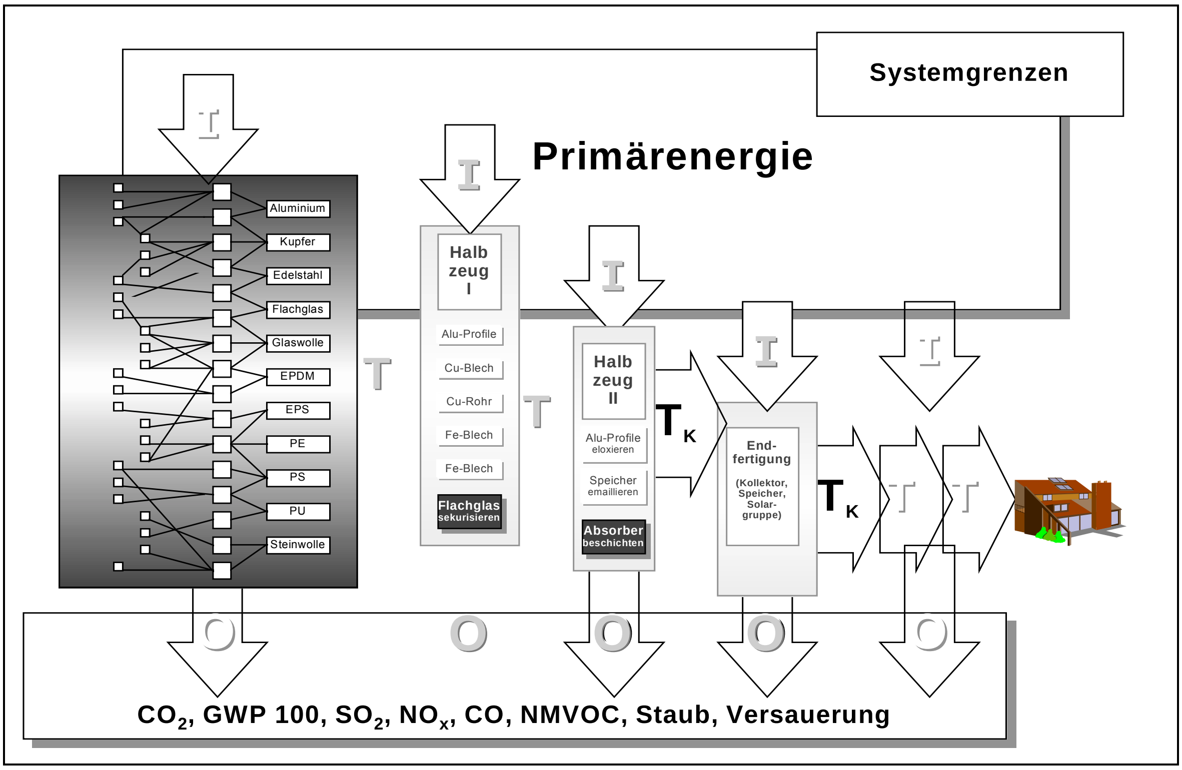
The overall principle of an LCA is simple: summing up every enviromental impact of a product from the 'cradle to the grave' – from the production of the basic materials, refining steps, distribution, use, recycling and finally disposal of the product. After this input/output bilance of various materials the environmental impact of those input/output processes is summed up and evaluated. A simply principle, but only in theory.
The definition of the system boundaries have a decisive influence on the result of an LCA: which input factors (materials, energy, processes, transport) are taken into account, and which output factors are considered (emissions, waste). In principle, everything would have to be included from the building of houses for the workers in Brasilian bauxite mines to the production of diesel fuel for machines. It is evident that certain simplifications have to be made. Furthermore, there are no or only a few quantifiable input or output flows for many processes. The database for gaseous emissions of energy producing processes is well examined.
Due to the lack of data on liquid an particulate emissions (waste, etc.) this study only sums up the energy used up during the life of a solar system and the gases emitted in this process (data used: [3], [4]).
Furthermore, there are always non-quantifiable effects, e.g. the effects of toxic emissions, that have to be considered (Example: How can particulate Pb-emissions in one process be compare to gaseous Hg-emissions in another one?). This study will introduce a pragmatic and very transparent approach to take these aspects into account.
The focus of this study is a comparison of thermal solar systems. A very detailled LCA of a single system can be found in source [3].

3. The Life-Cycle of a Solar System

The total energy consumption measured in an LCA is the so-called Primary Energy Demand (PED) for the production, use and disposal of a product. It discerns between primary and end energy. For 1 kWh of electrical energy (=end energy, 220V, W-Germany) 3,8 kWh of primary energy are being used for building the infrastructure (power plants, grid), the transformation of primary energy into electrical energy and for the distribution to the consumer.

PRODUCTION

The following picture shows the schematic life-cycle of a solar system and the system boundaries of this study.



Primary Energy Demand (PED) and emissions (CO_2, GWP100, SO_2, NO_x,NMVOC, particles, acidification) were bilanced for

- the production of basic materials (copper, aluminium, PE, PP, etc.),
- several typical processes (production of safety glass, absorber coating)
- and two transport steps from the producer to the retailer and from the retailer to the construction site

This assessment leaves out several processes between the production of the basic material and the assembly at the collector or store firm, which is due to a lack of data. Only few firms could give more information about the origin of their components or their production processes. A comparison between the mentioned 20 systems, however, is valid because both the system boundaries and the assumptions are the same.

For this study, 34 different materials were identified, weighed and the PED for every single system was calculated on the basis of the data found in [3] and [4].

The PED for the installation in a house was also considered (2 x 10m Cu-tubes or quick-installation tubes, if supplied by the manufacturer).

Use

Running a solar system over an estimated period of 20 years uses up both electrical energy for pumps, valves and electronic control system and material ressources (spare parts: e.g. pumps, panes, etc.).

This study did not make general assumptions on the use of spare parts (other than [1]) because it would not change the result of a *comparison* between different systems.

Several general assumptions for the consumption of electrical energy during the life of a solar system were made. The actual energy consumption was not measured on the test site, because every installation in every house is different and influences energy consumption. For combisystems it is more important to show the fundamental differences between the different concepts (two-store concept, external heat exchanger for domestic hot water, external heat exchanger for solar loop, etc.), using one or several pumps and one or several valves.

The following table states these assumptions for the use of electrical energy.

	[W]	[h/a]	[kWh_{el}/a]	[kWh_{PED}/a]
collector loop pump	50 W	1500 h	75 kWh_{el}	285 kWh_{PED}
secondary loop pump	50 W	1500 h	75 kWh_{el}	285 kWh_{PED}
valves	5 W	1500 h	7,5 kWh_{el}	28,5 kWh_{PED}
control	2,3 W	1500 h	20 kWh_{el}	76 kWh_{PED}

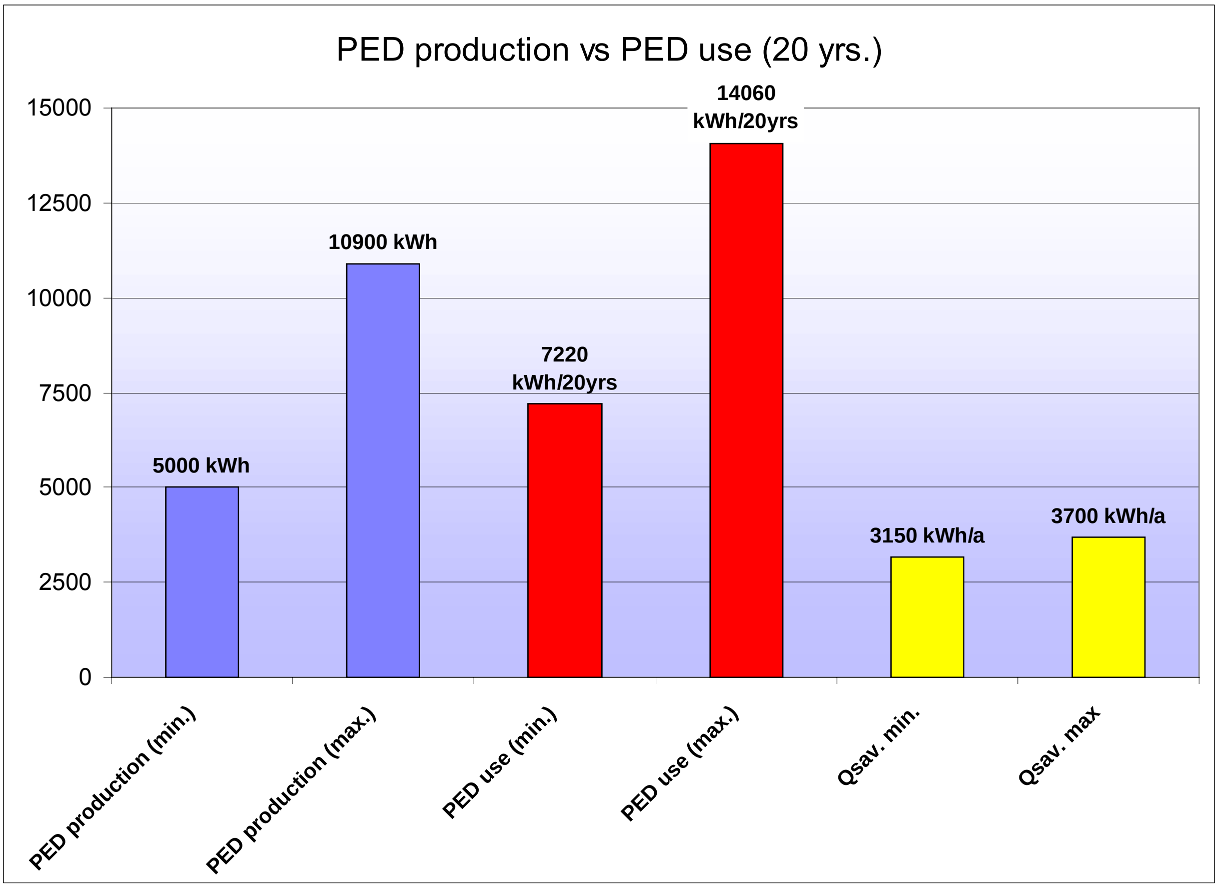
Recycling and Disposal

The PED of this step in the life-cycle of a product should include any input or output related to dismantling a combisystem, preparing it for recycling (esp. non-Fe-metal) and disposing of not reusable materials. Only few studies have been carried out in this field, which cannot be applied to solar systems.
Recycling and disposal of the components of a solar system are being emphasized in the discussion of the non-quantitative criteria.

4. Quantitative Results – PED & PBT

PRIMARIY ENERGY DEMAND

The following diagramm shows the maximum and minimum PED for the production of a combisystem (incl. the above mentioned transport steps), the total PED used for running the systems for a 20 years‘ lifespan and the annually saved primary energy.



It is surprising that running a combisystem (1 pump, 1 electronic control) over 20 years consumes as much or even more energy than producing a combisystem weighing several hundred kilogrammes of metal and other materials.

PED$_{production}$

Collectors consume about 40-50% of a combisystem‘s PED$_{prod}$, stores account for about 30-40%. The two combisystem with the least PED for production processes were the system with vacuum-tube collectors and a system with two large flat collectors.

The use of 5 or 6 small flat collectors doubles PED$_{prod}$ compared to CPC-collectors (ca. 40% compared to large flat collectors). The use of aluminium frames or heavy inox-collectors mainly contributes to an increased PED.

Heavy stores (two store systems or large heat-exchangers) quite obviously show an increased PED in comparison to other systems.

PED$_{use}$

The use of several pumps and valves almost doubles the energy demand for running the system while not necessarily increasing the combisystems performance.

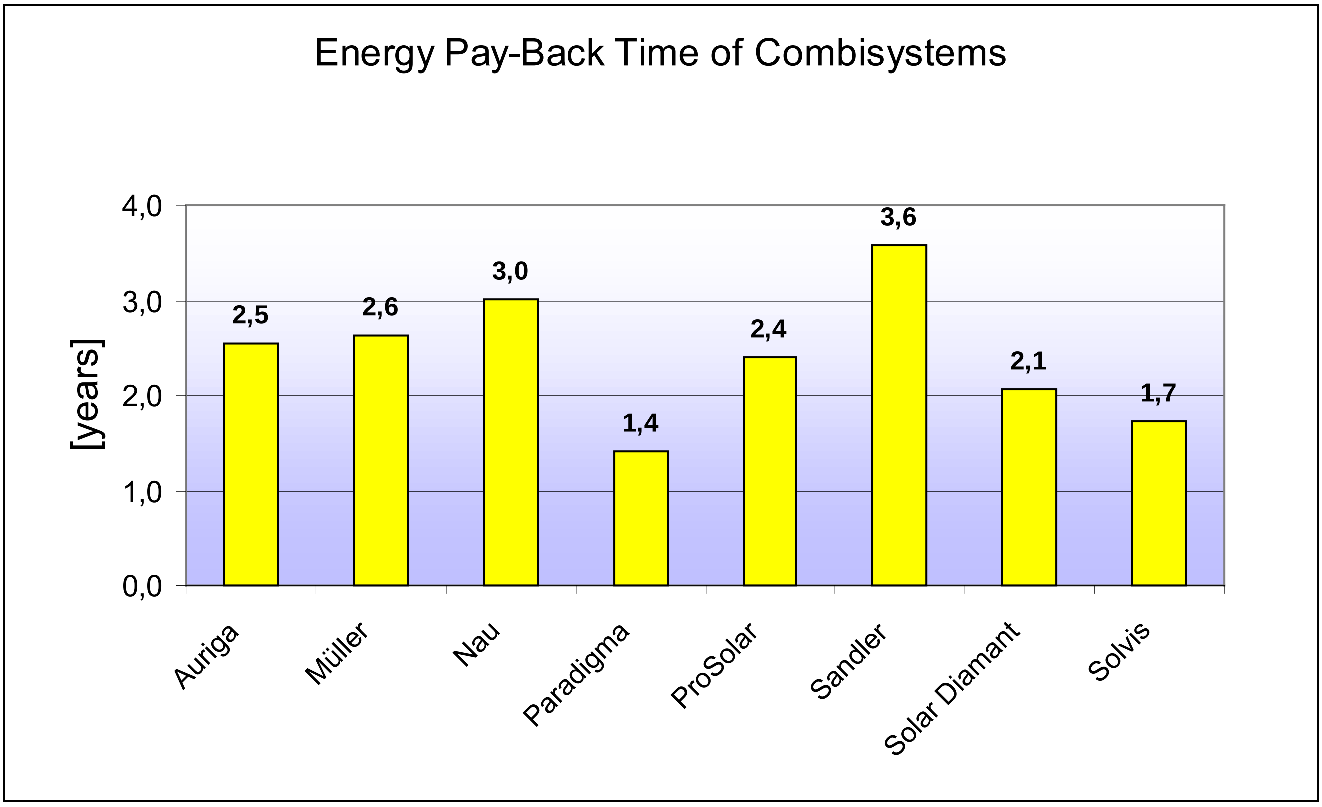
Both cumulative PED and system performance are combined in the so-called energy-pay-back time (PBT).

Energy-Pay-Back Time (PBT)

PBT is calculated as follows:

$$PBT = \frac{PED_{production}}{PED_{saved\_fuel} - PED_{use}}$$

(NB: PED saved_fuel heavily depends on the fossil-fuelled reference system, which, in this case, is a modern gas-fuelled heating)



As published in 'test' (03/97), the combisystems showed the following PBT results:

The differences in performance, i.e. saving of fossil fuel, were relatively small in comparison to the above mentioned differences in ressource efficiency for production and use.
The most 'ressource-efficient' concepts are the Paradigma CPC-system and the Solvis F50 system. Both use two large collectors and only one store. The other systems with small collectors and/or two stores clearly lie behind.

But: Even a less ressource-efficient combisystem with a PBT almost three times as high as the best competitor saves more than 5 times the energy it needs for production and use.

Emissions

This study also examined various emissions through production and use of solar systems. Naturally, the net reduction of PED results means a net reduction of 'greenhouse-gas' emissions.
The study, however, showed that sulfur dioxide emissions are not reduced (basis: gas-fuelled heating, electricity W-Germany). The reason for this are the low SO_2 emissions of domestic natural gas heating and is the extensive use of soft coal in electric power plants in Germany.
Under these circumstances, the use of renewable energy to run pumps and control system (e.g. PV-powered-DC pumps) would reduce net SO_2-emissions.
If a solar system substitutes electricity for producing domestic hot water (in 40% of all German households, hot water is heated electrically!) those emissions are of course reduced.

5. Non-quantitative Aspects

As mentioned above, there are always not-quantifiable aspects. One reason for this can be the lack of data: in this case hardly any quantifications of recycling and disposal processes are known. Other not quantifiable effects are questions of toxicity: How do you compare emissions of cancerogenic fibres during the assembly of a collector to heavy-metal polluted waste water discharge into a river (or alternatively the disposal of heavy-metal polluted galvanisation wastes).

Method

In principle the only difference between a quantitative LCA and this method is that yes/no-judgements (or A/B/C, or pos./neg. points) are counted instead of kg or kWh.
For the credibility of a non-quantitative comparative study it is vital to clearly
A) define the system boundaries (here: the different typical components)
B) define a set of ecological parameters which the processes you investigate are checked for
C) and to list up all scientific evidence

The German Environmental Agency ("Umweltbundesamt") suggests a set of parameters [5] out of which the following were applied:

Production - The use of substances, which are qualified as hazardous, toxic, cancerogenic etc., in the production process is examined
Assembly - This is only part of the production process, but it was taken up into this list due to great differences in the production of insulation material.
Combustion - Several insulation and cover materials produce toxic emissions in a fire or use hazardous fire retardants.
Recycling - Assessment of recycling aspects according to 'ecological ranking' (1. material recycling / 2. recycling as a raw material / 3. waste incineration)
Separability - Separabilty is a key prerequisite for recycling (materials that are per se well recyclable like aluminium and paper can form a hardly reyclable material bond)

Seven components of a solar system with significant differences between the individual systems were identified, which the picture on the next page illustrates.
The complete list of differences found plus the various ecological effects in the above mentioned five fields would be to long and to detailled for this summary, that is why I show the complete PACRS-matrix without further details on the next page (black box = negative env. impact) Three examples are explained in detail down.

Examples for non-quantitative assessment

collector frame	**Al (plastic coating)**	**Al (blank)**
P	unnecessary process, blank aluminium can be used → **negative**	**OK**
A	/	/
C	/	/
R	plastic coating ca. 10% of frame mass, recycling difficult → **negative**	**OK**
S	/	/

store insulation	**PU-hardfoam (foamed-in store)**	**melamin-formaldehyde foam**
P	isocyanates (tox.) → **negative**	formaldehyde (tox.) → **negative**
A	/	/
C	fire-retardants necessary, possibly toxic or carcinogenic → **negative**	fire-retardant unnecessary → **OK**
R	recycling problematic → **negative**	no information at all? → **negative**
S	PU-foam hardly separable, even metal recycling impaired → **negative**	**OK** (zip-up insulation)

insulation cover	**PVC (glued to insulation)**	**PE sheet (separate)**

P	toxic Cl_2-gas → **negative**	only hydrocarbons, not generally seen as hazardous → **OK**
A	/	/
C	formation of dioxines, HCl → **negative**	less toxic fumes (mostly C, H, and O) → **OK**
R	problematic recycling due to the many PVC-types → **negative**	easy recycling, widely available → **OK**
S	not separable → **negative**	separable → **OK**

Out of the complete PARCS-matrix it is possible to combine a 'virtual' most ecological solar combisystem. This list only includes the results of the 1997/98 study of 20 solar systems. Several firms are experimenting with other, even more environmentally-friendly solutions, which may be ready for use by now. This benchmark approach, only taking solutions from the market, is very conservative. This, however, avoids the problem of being too enthusiastic about brand-new ideas or solutions that might never make it to market-viability.

‘Virtual‘ most ecological solar system (combined out of 20 investigated systems)

collector housing	+ no coating
collctor insulation	+ microglass-textile
absorber	+ phys. coating
store insulation	+ melamine-formaldehyde foam + separable
insulation cover	+ PE-sheet + separable
pump & safety group insulation	+ EPP + no cover
packaging	+ wood / cardboard + (bring-back system)

6. Conclusion

Once again, this study proves that thermal solar systems are a very ressource efficient method to reduce primary energy consumption and greenhouse gas emissions. It is possible to improve a solar system’s ressource efficiency with simple means.
Under certain circumstances some emissions might actually be increased by the production and use of a thermal solar system.
Concerning non-quantitative environmental aspects, like the use of less toxic substances, the solar industry is definitely setting new standards. Innovative firms are introducing a whole range of alternatives to traditional less environmentally-friendly methods, which could easily be adopted.
As a side-effect, the solar industry will definitely accelarate ‘greening‘ the whole domestic heat and hot-water business.

Literature

[1] Wagner, Hermann-Josef
Ermittlung des Primärenergieaufwandes und Abschätzung der Emissionen zur Herstellung und zum Betrieb von ausgewählten Absorberanlagen zur Schwimmbadwassererwärmung und von Solarkollektoranlagen zur Brauchwassererwärmung; VDI Fortschrittsberichte Reihe 6 Energietechnik Nr. 325, Düsseldorf 1995

[2] Mahler, B.:
Energetische Amortisationszeit, ökonomisch-ökologische Beurteilung und Regelverhalten von 11 solaren Brauchwassererwärmungsanlagen, Diplomarbeit, Universität Stuttgart 1994

[3] Bundesamt für Energiewirtschaft:
Ökoinventare für Energiesysteme, 3.Auflage, Zürich 1996

[4] Marheineke, T.:
Datenbankprogramm „I/O-Table“, Institut für Energeiwirtschaft und Rationelle Energieanwendung der Universität Stuttgart

[5] Neitzel, H.:
Grundlagen und Grenzen von Ökobilanzen als Bewertungsinstrument, In: Nachwachsende Rohstoffe als Energieträger, Seminarband zum 343. Seminar des Fortbildungszentrums Gesundheits- und Umweltschutz Berlin e.V. (FGU), Berlin , 8.9.1994, S.60-85