EUROPEAN LARGE-SCALE SOLAR HEATING NETWORK

Jan-Olof Dalenbäck
Department of Building Services Engineering, Chalmers University of Technology, S-41296 Göteborg, Sweden
Phone +46-31-7721153, Fax +46-31-7721152, e-mail: jod@vsect.chalmers.se

Abstract – Interest in large-scale solar heating has increased during recent years and 26 new plants have been put into operation since the beginning of 1997. A major reason is the favourable cost/performance ratio for large-scale applications. As a base for international co-operation a number of involved European institutes and companies have formed the 'European Large-scale Solar Heating Network'. One of the main efforts within the network is to keep updated information about and disseminate results and experiences regarding ongoing development. This is done via a website with an updated list of large-scale plants (>500 m²) and recent publications together with addresses and links to involved institutes and companies. This paper relates basic information about the network, summarises the recent development of European large-scale solar heating, describes sample applications and presents new and planned large-scale plants.

1 INTRODUCTION

Interest in large-scale solar heating, especially in Germany and Austria, has increased during recent years and 26 new plants have been put into operation since the beginning of 1997. However, Sweden is still the leading country with a total of 18 out of 52 European plants with more than 500 m^2 of solar collectors.

In total, there are about 8 million m² of solar collectors in Europe, corresponding to about 4 000 MW (thermal) power, which is of the same order of magnitude as for European (electric) wind power. However, unlike wind power, solar collectors are mainly installed in small systems. So far, only a minor part of the total market comprises large-scale applications. European large-scale solar heating plants having more than 500 m² (~250 kWth) of solar collectors have about 40 MW thermal power altogether.

Tab. 1 The ten largest European solar heating plants

Plant, Year in operation	**Owner,** Country	**Area** [m²]
Marstal, 1996-	Marstal Fjernvarme, DK	9 040
Nykvarn, 1984-	Telge Energi AB, SE	7 500
Falkenberg, 1989-	Falkenberg Energi AB, SE	5 500
Lyckebo, 1983-	Uppsala Energi AB, SE	4 320
Ærøskøping, 1998-	Ærøskøping Fjernvarme, DK	4 090
Ry, 1988-	Ry Fjernvarme A/S, DK	3 040
Hamburg; 1996-	Hamburger Gaswerke, DE	3 000
Friedrichshafen, 1996-	TW Friedrichsh., DE	2 700
Neckarsulm, 1997-	Stadtwerke Neckarsulm, DE	2 600
Groningen, 1985-	De Huismeester, NL	2 400

Table 1 shows the ten largest European solar heating plants. All together there are 52 plants (>500 m²) with a total collector area corresponding to about 20 000 SDHW systems.

Large-scale solar heating systems or Central Solar Heating Plants (CSHP) are here defined as solar heating systems designed to provide heat to large and small building areas, i.e. residential building areas or large buildings, as well as industries, via central block and district heating plants.

2 NETWORK

As a base for international co-operation a number of European institutes and companies with long experience in development and implementation of solar heating systems for housing areas have formed the 'European Large-scale Solar Heating Network'. The network is non-profit-making and is open to all countries in order to create a common forum for expert groups working with "Large-scale Solar Heating Systems".

The aim is to promote a wider utilisation of large-scale solar heating by encouraging knowledge transfer between consultants, architects, property owners, utilities and contractors. This is done by organising and/or promoting workshops and other co-operative efforts, e.g. the creation of an Internet home page with a list of 'European Large-scale Solar Heating Plants" together with addresses and links to involved institutes, etc. This was carried out under a THERMIE contract (DIS/1164/97) and the address is http://www.hvac.chalmers.se/cshp.

In order to have a moderate number of plants to keep track of, the list of plants is restricted to solar heating systems in operation and with >500 m² of collectors.

The 1998 workshop was held in Neckarsulm, Germany. The workshop gathered 42 participants from 8 countries sharing experiences from plants in operation and designs of new plants. Three topics: 'Project initiation'; 'Plants for existing buildings' and 'Design tools', were discussed in special groups. . A study visit to the Neckarsulm plant was also a part of the workshop.

The 1999 workshop was held in Amsterdam, The Netherlands. The workshop gathered 25 participants and two topics: 'Information' and 'Future co-operation', were discussed more in detail. A study visit to the Heemstede and Brandaris plants was also a part of the workshop.

Here, the development is presented country by country and then summarised regarding applied technologies.

3 AUSTRIA

At the end of 1996, 305 villages and towns in Austria were supplied with heat from central biomass-fired plants. By establishing local heating networks it is possible to convert the heat supply of entire towns to indigenous renewable energy sources in a short period of time, without having to perform a great deal of conversion work in the buildings to be connected.

For technical and economic reasons, most of these plants are operated only during the heating season. Therefore some local heating co-operatives have added a solar plant to their biomass plant to be able to offer all year round operation in an economic manner. The solar plant is designed to cover the entire heating requirement in the summer in order to prevent the starting up of the wood chip boiler in an extremely low power range.

3.1 The pioneer

The first local biomass-fired heating plant, which received solar support, was the plant in Deutsch-Tschantschendorf in Southern Burgenland.

Fig. 1 Solar-biomass plant Deutsch Tschantschendorf

The solar system operation was started up in October 1994 and the plant now supplies 34 customers with heat all year round. The connected load is 930 kW and the plant consists of a 600 kW wood-chip boiler and 325 m² of roof-integrated solar collectors with a 34 m³ buffer storage tank for solar heat and peak load coverage.

In the first summer of 1995 full coverage was reached in the months of June, July and August, in 1996 the solar coverage was over 90% in these three summer months. The specific collector yield, measured on the heat exchanger, has varied between 370 and 410 kWh/m²a during 4 years of operation (1995-98).

3.2 Bad Mitterndorf and Eibiswald

The results from Deutsch-Tschantschendorf were promising and two larger plants were put in operation in 1997. Main plant data are shown in the Table 2.

Tab. 2 Main plant data

	Eibiswald	**Bad Mitt.**
Network length [m]	3 200	3 500
Boiler power[kW]	2 000	4 000
Collector area [m²]	1 250	1 120
Storage volume [m³]	105	140

In extremely cold periods the solar storage tank makes it possible to cover peak loads even though the maximum power of the boiler is about 30% less than the maximum demand of the network.

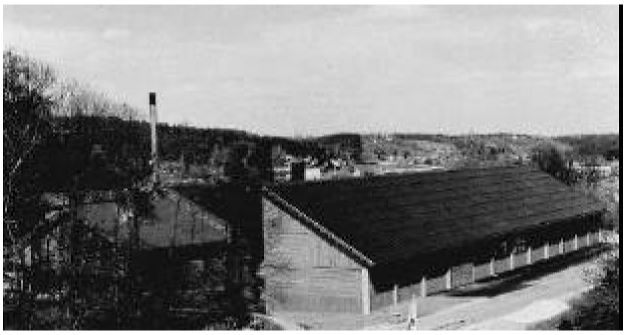

Fig. 2 Solar-biomass plant Eibiswald

Fig. 3 Solar-biomass plant Bad Mitterndorf

3.3 Solar yield and costs

The forecasted and already measured summer solar coverage is over 90% and the expected annual solar yields are around 400 kWh/m^{2}a. In Eibiswald first measurements have already confirmed the expectations. The system costs are around 250 Euro/m² collector area, this means half compared to plants of medium size (50 –

200 m²), respectively 30% of the cost of small plants for detached family houses.

At present about 20 solar-biomass plants are in operation and more are planned. Table 3 shows Austrian plants with > 500 m² of collectors, all mounted on roofs and combined with wood fuel boilers.

Tab. 3 Austrian plants > 500 m²

Plant, Year in operation	**Owner**	**Area** [m²]
Eibiswald, 1997-	Nahwärmegen. Eibiswald	1 250
Bad Mitterndorf, 1997-	Genossensch. Biosolar Bad Mitterndorf	1 120
Innsbruck, 1999-	"Wohnen am Lobach"	1 080
Poysbrunn, 1997-	Genossensch. B/SW Poysbrunn	870
Nikitsch, 1997-	FWG Nikitsch	780
Kroatisch-Minihof, 1997-	FWG Kroatisch-Minihof	756
Obermarkersdorf, 1995-	FWG Obermarkersdorf.	567

4 DENMARK

The Danish large-scale solar heating plants are used in district heating systems and all collectors are ground mounted. The development has taken place in two steps.

4.1 District heating without storage.

Based on Swedish experiences the first Danish plant, with 1 000 m² of ground-mounted collectors, was built in Saltum 1987.

Fig. 4 1 000 m^2 collector array in Saltum.

Later on the second plant with 3 025 m^2 of solar collectors was built in Ry. The Ry plant was put into operation in March 1990 with subsidy from EC and the Danish Energy Agency.

The district heating plant in Ry supplies annually about 32 GWh (1990) to the city of Ry, using wood chips boilers and solar heating.

The annual solar gain is about 1.2 GWh and the solar plant is operated using the district heating network as a buffer-storage. The total investment for the solar heating plant amounted to 6,0 MDKR (January 1990).

4.2 District heating with short-term storage

In 1995, Marstal District Heating, situated on the Island Ærø, decided to establish 8 064 m^2 solar collectors and a 2 100 m^3 hot water storage tank to cover up to 15% of their heating load. The main fuel is waste oil and the annual load is 26 GWh. The solar plant was put in operation in November 1996 and the annual yield in a normal year is 3.4 GWh.

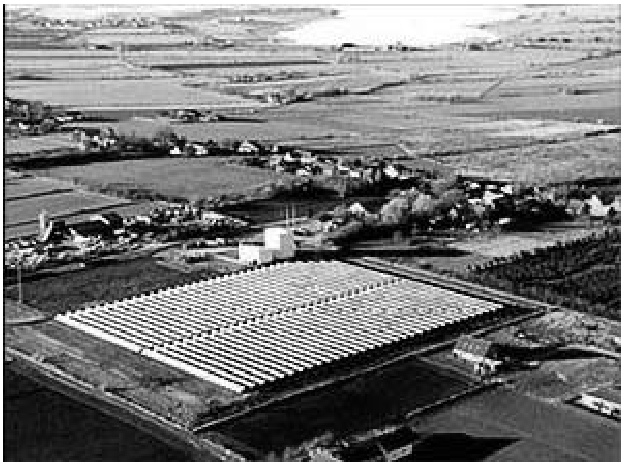

Fig. 5 9 043 m^2 collector array in Marstal. Photo: Marstal Fjernvarme.

The total investment for the solar heating plant including building and connection to the existing network was 20,6 Mio. DKR (1996). The solar plant is operated with variable speed pumps allowing a constant output temperature from the solar collectors. In 1999 the plant was extended to 9 040 m^2 due to the connection of more district heating customers.

Table 4 shows Danish plants with > 500 m² of collectors, all mounted on ground.

Tab. 4 Danish plants > 500 m²

Plant, Year in operation	**Owner**	**Area** [m²]
Marstal, 1996-	Marstal Fjernvarme	9 043
Ærøskøping, 1998-	Ærøskøping Fjernvarme	4 090
Ry, 1990-	Ry Fjernvarme A/S	3 040
Tubberupv., 1991-	Herlev kom. Boligselskab	1 030
Saltum, 1988-	Saltum Fjarnvarme A/S	1 005
Ottrupgaard, 1995-	Ottrupgaards bofaellessk.	565

4.3 Future development

The next step in the development is solar heating combined with straw or wood heated district heating plants. Ærøskøbing district heating company, also situated on Ærø, established the first plant of this type, 4 900 m^2 solar collectors covering 17% of the heat load, in 1999. Calculations show that up to 25% of the load can be covered by solar heat at a heat price only 30% higher than the present heat price with straw and wood. During the next 3-5 years the heat price using solar collectors may fall with 25-30% allowing solar heating plants to be competitive without support.

5 GERMANY

The first steps towards large-scale solar heating systems in Germany were taken in the late 80´s with pre-design studies. In 1992 the first two pilot plants with 115 and 190 m² collector area and short term storage were realised in Ravensburg. One of the main aims was to demonstrate the technology and show cost reductions and increased solar gains compared to small systems.

In 1993 the German government initiated a 10-year program called "Solarthermie 2000". The program was intended to allow demonstration of large-scale solar heating plants in real technical scale. Until 1999 five projects with seasonal storage and about 50 large-scale projects with short-term storage have been realised.

Table 5 shows German plants with > 500 m² of collectors, all mounted on roofs.

Tab. 5 German plants > 500 m²

Plant, Year in operation	**Owner**	**Area** [m²]
Hamburg; 1996-	Hamburger Gaswerke	3 000
Friedrichsh., 1996-	Techn. Werke Friedrichsh.	2 700
Neckarsulm, 1997-	Stadtwerke Neckarsulm	2 600
Augsburg, 1998-	Bayerisches Staatsministerium	2 000
Burgholzhof, 1998-	Neckarwerke Stuttgart AG	1 635
Brenzstrasse, 1997-	Neckarwerke Stuttgart AG	1 000
Göttingen, 1993-	Stadtwerke Göttingen	850
Nordhausen, 1999-	Suedharz-Krankenhaus GmbH Nordhausen	717
Oederan, 1994-	SWG Oederan mbH	700
Magdeburg, 1996-	Universität Magdeburg	657
Steinfurt-Borgh., 1999-	W & T Bau GbR	565
Chemnitz, 1998-	Solaris Verwaltungs GmbH	540

In Friedrichshafen a system with seasonal storage (12 000 m³ water volume) was put in operation in 1996. At present, 380 flats in 10 blocks of multifamily houses and about 50 terraced houses are connected to the heating net. 4.250 m² of collector area, installed on the roofs of the buildings, provide almost half of the heat demand for space heating and domestic hot water. After three years of operation it can be stated that involved researchers and utilities, as well as the inhabitants are satisfied with the results.

Fig. 6 Roof mounted collectors on new buildings in Friedrichshafen 1996. Photo: Boris Mahler.

The water storage is build out of reinforced concrete. To prevent water and moisture leakage a stainless steel liner covers the inside. The outer sides and the top are insulated with 20 to 30 cm of mineral wool.

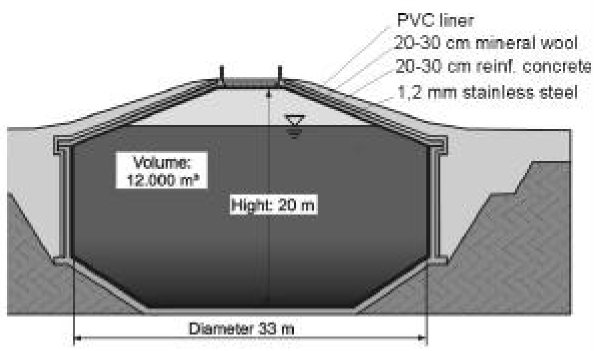

Fig. 7 12 000 m³ hot water pit storage. Cross-section, main dimensions and components.

In the city of Stuttgart an old military barrack in Brenzstrasse was converted to a new housing area. 1.000 m² collectors provide 50% of the domestic hot water demand.

Fig. 8 1 000 m² solar collectors in Brenzstrasse. Photo: Michael Guigas.

The collector arrays are spread over the settlement and only 15% of the (south oriented) roofs must be used. The cost/benefit ration in this project is less than 1 Euro/kWh and the solar price is about 90 Euro/MWh.

6 THE NETHERLANDS

The large-scale solar heating plants in the Netherlands are mainly used for providing hot water, in most cases for collective housing or houses for elderly people. One of the largest systems is however for an industrial application. Large-scale seasonal storage is limited to a few experimental plants but seasonal cold storages in aquifers are widely used.

Table 6 shows Dutch plants with > 500 m² of collectors, all mounted on roofs.

Tab. 6 Dutch plants > 500 m²

Plant, Year in operation	**Owner**	**Area** [m²]
Groningen, 1985-	De Huismeester	2 400
Breda, 1997-	Van Melle	2 400
Lisse, 1995-	Dames&Werkhoven	1 200
Brandaris, 1999-	Patrimonium WS Amsterdam	760
De Zwoer, 1990-	Stichting Zwembad Dr.-Rijsenburg	740
Heemstede, 1998-	Stichting De Hartekamp	520

6.1 Collective hot water systems

The most widely implemented application of large solar heating systems is collective housing, institutions and homes for the elderly. Most systems have a size of about 100 m².

Some are larger, for example "Brandaris" in Zaandam. This project is an example of solar renovation developed within the IEA Solar heating and Cooling programme and subsidised by the THERMIE program (SHINE project). The system provides hot water and part of the space heating. The collectors are placed on top of the building at 45 m height at a very windy site.

Fig. 9 The 'Brandaris' with 760 m^2 collectors on top.

Fig. 10 Collectors on the roof of the swimming pool of the Hartekamp.

Another interesting project is the "Hartekamp", an institute for mentally handicapped with a central hot water system. The solar system provides hot water and also heating for an indoor swimming pool. This project is interesting as the solar system is leased from the utility.

The cost for the lease is equivalent to the savings on the energy costs. This construction is possible by the use of different fiscal and other financial measures and solar leasing is now promoted throughout the country. In 1998 4 300 m² of solar collectors was installed in large systems. The costs for this system were approximately 400 Euro per m² solar collector (this price includes storage, control unit, piping and installation).

6.2 Seasonal storage

For residential buildings, there is a project from 1985 in Groningen with duct storage for 90 houses. In Lisse, solar heat is stored in a concrete tank and used for bulb drying.

6.3 Future developments

The aim is to get a lot of systems with collector areas in the range of 50 to 200 m^2. This should create enough volume to lower the price of the systems. Larger systems are planned when seasonal storage becomes more economic. For the storage the most interesting technology is aquifer storage. However, the high temperature that is needed is difficult to reach in an aquifer, therefor some projects that combine solar energy, aquifer storage and heat pumps are planned.

Fig. 11 Industrial use of solar heat. Van Melle factory, 1997.

Industrial applications are only few, but the largest system in the Netherlands is the 2 400 m² system for the sweet factory Van Melle in Breda. The system is the largest drain back system in the world. The hot water is used in the production and for cleaning.

7 SWEDEN

The Swedish large-scale solar heating plants are used by district heating and housing companies, mainly for existing building areas, using both ground mounted collector arrays and roof-integrated or mounted collectors.

7.1 District heating

The early efforts were very much driven by a small number of pioneering utilities, e.g. Uppsala, Telge and Falkenberg Energi, within an experimental building program by the Council for Building Research.

The district heating plant in Falkenberg supplies annually about 40 GWh to the central parts of the city using wood chips boilers and a solar heating plant together with natural gas boilers (used for back up in the summer and winter peak demand).

The annual gain is close to 2 GWh and the solar plant is operated using a 1 500 m³ water storage tank. The total investment for the solar heating plant amounted to 12.3 MSEK (March 1990).

The solar heating plant was initially designed to cover the summer load, but is now covering a smaller part, as the district heating network has been extended over the years.

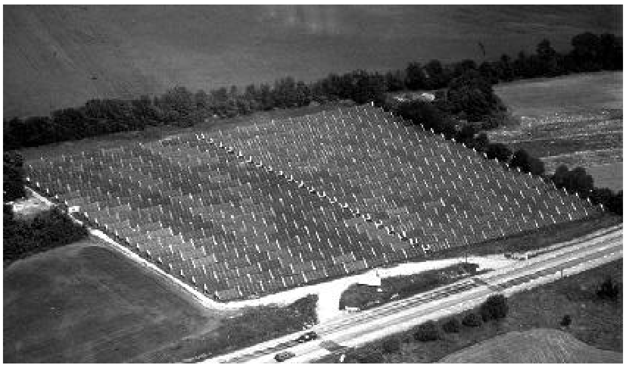

Fig. 12 5 500 m² collector array in Falkenberg 1989. Photo: Falkenberg Energi AB.

Fig. 13 Pilot plant with 500 m² MaReCo collectors in Torsåker 1999. Photo: VUAB.

Figure 13 shows a recent pilot plant for a new compound parabolic collector, called MaReCo, developed for northern latitudes.

7.2 New housing areas

EKSTA Bostads AB pioneered the use of roof-integrated solar collectors in new building areas already in the 80's. EKSTA is a municipal property owner which has bought and built 100 000 m² of housing facilities and service premises in the urban districts of Kungsbacka. One marketing catch phrase is "Close to nature in solar heated houses".

At present EKSTA owns and operates ~6 000 m² of roof-integrated collectors (generating heat equivalent to ~250 m³ of oil per year). All plants are still in operation with very low operation and maintenance costs.

Initially EKSTA used site-built collectors, but the latest development, a roof module collector mounted directly on the roof trusses, has now been applied in a couple of recent projects. This development has resulted in even better integration in the building process, as well as further reduced investment cost and improved thermal performance.

In a new residential area in Onsala, 220 m² of prefabricated roof modules with integrated collectors, are mounted on the heating plant and a carport.

Fig. 14 220 m² roof module collectors in Onsala. Photo: Jochen Dahm

The solar heating plant, designed to cover 20% of the annual heat demand in nine buildings with 36 residential units with 2 500 m² heated area, is operated together with a pellet and an oil boiler (summer back up and winter peak demand).

Based on real contracts (Nov. 1995) the investment cost for the solar system amounted to 194 SEK (~23 EURO) per m² heated floor area, or 2% of the total investment cost.

Fig. 15 Roof-mounted collectors in Fränsta. Photo: VUAB.

Present efforts focus on replacing the use of oil in combination with wood fuels in existing heating plants and most recent projects comprise roof-integrated collectors on existing buildings, e.g. as in Fränsta.

7.3 Plants in operation

Large-module collectors were pioneered in Sweden with experimental building loans managed by the Swedish Council for Building Research. The first large-scale plant was built already in 1982.

Tab. 7 Swedish plants > 500 m².

Plant, Year in operation	**Owner**	**Area** [m²]
Nykvarn, 1984-	Telge Energi AB	7 500
Falkenberg, 1989-	Falkenberg Energi AB	5 500
Lyckebo, 1983-	Uppsala Energi AB	4 320
Fränsta, 1999-	Vattenfall Energimarknad	1 650
Säter, 1992-	Säter Energi AB	1 250
Älta, 1997-	Vattenfall Energimarknad	1 200
Åsa, 1985-	EKSTA Bostads AB	1 030
Odensbacken, 1991-	Örebro Energi, SE	1 000
Fjärås Vetev., 1991-	EKSTA Bostads AB	1 000
Hågaby, 1998-	Uppsalahem AB	930
Kullavik 4, 1987-	EKSTA Bostads AB	920
Hammark., 1985-	Gbg Bostads AB	850
Ekerö, 1997-	Ekeröbostäder AB	800
Särö, 1989-	EKSTA Bostads AB	740
Henån, 1997-	Orust kommun	685
Malung, 1987-	Malungsbostäder	640
Älta, 1998-	HSB Brf Stensö	600
Torsåker, 1999-	Vattenfall Energimarknad	500

Table 7 shows Swedish plants with > 500 m² of solar collectors, the largest mounted on ground, but most mounted on roofs. It should be noted that three large experimental plants, Ingelstad (in operation 1979-1996), Lambohov (1980-1993) and Torvalla (1982-1992), are already taken out of operation.

8 OTHER COUNTRIES

8.1 Finland

The first large-scale solar heating system in Finland was built in the early 1980s in Kerava. This system consisted of 1,100 m² of solar collectors and a seasonal storage in ground.

Fig. 16 Kerava solar village.

In the early 1990s, a pilot project with 100 m² of ground-mounted collectors was connected to a district heating plant at Orivesi town.

to 51%, showing the good performance of this system type even under the Mediterranean climate.

8.2 France

To our knowledge, there is only one plant from 1999 with >500 m² of collectors in France. It is situated in Echirolles and is operated by OPAC 38.

8.3 Greece

The most interesting project is a recent large-scale solar cooling plant with 2 700 m² of flat plate collectors providing heat to two adsorption heat pumps (700 kW).

The system is operated to provide the heat pumps with water at 75°C for cooling (summer) and the space heating system with water at 55°C (winter). The system is designed for 22 000 m² of heated/cooled building area and the operation of the system started in August 1999.

Fig. 17 Lykovrissi with seasonal storage tank in front of the heated building.

The Lykovrissi Solar Village was the first 'large-scale' project in Greece. The aim of the project was to test all existing thermal solar technologies for space heating and DHW existing at the time of its design (1984). Passive solar applications were also used. Among the active solar systems a seasonal storage system, designed to cover the needs for hot water and space heating of a multi-storey building, comprising 24 apartments with a total heated area of 1 700 m^2, was also tested. At present, the seasonal storage system has been in operation for about 11 years.

The Lykovrissi solar system consists of 162 m^2 solar collectors. Their tilt angle is 38°, facing due south. The 500 m^3 seasonal storage tank is made of stainless steel. The total annual load to be covered by the system is of about 134 MWh.

Monitoring results covering a two and a half-year period showed that the average contribution of solar energy for DHW was of about 69% for all solar systems and 82% for the seasonal storage system. Regarding space heating, the average contribution of all the solar systems was 19%, while the seasonal storage system climbed up to 51%, showing the good performance of this system type even under the Mediterranean climate.

8.4 Italy

The Melegnano project is the first public initiative of this kind in Italy. Additionally, it is the first time in Italy that a simplified "Guaranty of Solar Results Contract" has been applied. The main aim of the project is to demonstrate the technical and economical feasibility of the implementation of solar energy heating systems in a residential area. As a first step in this direction, a pilot solar plant in a public swimming pool centre has been realised.

Fig. 18 Melegnano: View from poolside.

The plant comprises 200 m² of flat plate solar collectors and 10 m³ of tank storage volume. It is designed to provide hot water for the swimming pool facilities. Estimated total load: 145 MWh/a, solar plant contribution: 104 MWh/a and solar fraction: 72%.

The aim of the plant is twofold: to provide energy and economic savings, as well as to influence the public opinion, preparing the way for the introduction of a solar district heating system. Thus, in parallel with the plant construction, a feasibility study is being carried out for the implementation of a solar thermal space heating plant to a nearby large residential area using a seasonal storage.

8.5 Switzerland

Early participation in international co-operation regarding the development of solar heating systems with seasonal storage has resulted in one large-scale plant. The plant is equipped with 1 120 m² of collectors in combination with 2 000 m³ of water storage providing heat to an office building in Neuchatel.

9 TECHNOLOGIES

The largest plant so far, comprising 9 000 m² of large-module collectors, was built in 1996 by Marstal Fjernvarme A/S on the island Ærø in Denmark. ARCON Solvarme A/S supplied the collectors and similar plants have earlier been built by e.g. Falkenberg Energi AB in

Sweden and Ry Fjernvarme in Denmark. The oldest plant still in operation dates from 1983.

Almost all the plants (44 out of 52) supply heat to residential buildings, in most cases via a central heating plant. Two thirds of these plants are connected to existing buildings, especially in Sweden, Denmark and Austria. About one third are built in connection to wood fuel fired heating plants: this is most common in Sweden and Austria. Non residential plants are e.g. connected to industries, hospitals and commercial buildings.

Most of the plants are designed to cover the summer load using short-term water storage, but 12 plants are equipped with seasonal storage that covers a larger part of the load. The storage medium is water in 8 plants and the ground in 4 plants.

Most of the plants have roof-integrated or roof-mounted collectors while some in Sweden and all in Denmark have ground-mounted collector arrays. See table 8.

Tab. 8 No of European large-scale plants > 500 m².
GM = Ground mounted, RM = Roof mounted.

Country	GM	RM	Tot
Austria		7	7
Denmark	6		6
Finland		1	1
France		1	1
Germany		12	12
The Netherlands		6	6
Sweden	8	10	18
Switzerland		1	1
	14	**38**	**52**

Flat plate collector designs dominate, and only two plants are equipped with evacuated tube collectors. Most plants have pressurised collector systems with an anti-freeze mixture; usually glycol and water, while four plants in the Netherlands have drain back collector systems.

Sweden is the leading country, with 18 plants and more than 35% of European installed collector area. The dominating contractor is ARCON (Denmark) which has installed close to 30,000 m^2 of large module collectors (pioneered by TeknoTerm). Examples of other contractors on the European list of large-scale plants are ZEN and Atag (The Netherlands), TeknoTerm, Solsam and Aquasol (Sweden), Solvis and Wagner (Germany), SOLID, Sonnenkraft and Krautsack (Austria).

10 NEW PLANTS

At present several new plants are under construction and several more are planned in the near future. Plants and projects known by the author are shortly described in the following.

10.1 Denmark

There are ongoing plans for a third large-scale plant with another 4 000 m² of ground-mounted collectors on Ærø (where Marstal is situated). The collectors will be combined with a large storage, 4 000 m³ water tank, in order to cover about 50% of the annual load in a local district heating plant. Supplementary heat is provided by wood pellet.

10.2 Finland

The new Ekoviikki site in Helsinki (60 ^{o}N) comprises 9 individual building integrated solar heating systems with a total area of 1 250 m² and covers about half of the houses in Ekoviikki.

The solar heating systems will provide about 50% of the hot water demand of connected apartments. In some cases, solar will also provide low temperature heat for floor heating and thus increase the solar yield. The basic heating in Ekoviikki is provided by district heating.

The Ekoviikki solar project is partly financed within the THERMIE program. The main innovations relate to a large-size collector (10 m^2) especially designed for roof integration, low flow and low temperature operating strategy and heat storage stratification. Moreover, the integration of solar aspects is strongly present both on organisational and construction matters. The construction of the first solar installations started in autumn 1999 and the monitoring will extend to the end of 2001.

10.3 Germany

There is a new plant with 1 350 m² collector area in combination with a 2 750 m³ water-filled concrete tank in ground under construction in Hannover- Kronsberg. The plant will provide 106 residential units with the major part of their annual heat demand, which is of the order of 700 MWh.

The existing plant in Friedrichshafen-Wiggenhausen will be complemented with another 1 550 m² (total 4 250 m², finished 2001) and the existing plant in Neckarsulm will be complemented with another 2 100 m² (total 4 700 m², finished 2000-2001).

The are ongoing studies for similar plants, e.g. one plant with 6 000m² in Crailsheim and one with 5 500 m² in Heidelberg.

10.4 The Netherlands

Based on the experiences from the Brandaris project a new plant with 1 000 m² of collectors is on the way in Kleiburg.

10.5 Spain

There are plans to install 850 m² high temperature collectors connected to the CHP district heating and cooling system to be installed in a new development called ParcBIT in Palma de Mallorca within a THERMIE project.

10.6 Sweden

Kungälv Energi AB has recently decided to build a 10 000 m^2 ground-mounted collector array as a complement to an existing wood-chips boiler plant. The plant has got governmental, as well as EC support and is expected to generate 4 GWh/a. The total load is about 100 GWH/a. The plant will be in operation with 4 000 m^2 of collectors in August 2000.

A new residential building area with 2 400 m^2 of roof-integrated collectors combined with 100 bore holes in rock (about 60 000 m^3) for 50 residential units is under construction in Anneberg. The aim of the project is to demonstrate seasonal storage in rock and is partly financed within the EC-THERMIE program.

Tab. 9 Swedish plants under construction.

Plant, Year of construction	**Owner**	**Area** [m^2]
Kungälv, 2000-2001	Kungälv Energi AB	10 000
Anneberg, 2000-2001	HSB Brf Anneberg	2 400
Gårdsten, 1999-2000	Bostads AB Gårdsten	700

Bostads AB Gårdsten is carrying out a renovation project incorporating solar collectors for pre-heating DHW in 10 block of flats from the 70's. Here, roof module collectors are used to form new inclined roofs on top of existing flat roofs. This project is part of the THERMIE project 'SHINE'.

11 CONCLUSIONS

The work within the network has been an important catalyser for recent developments along with an increased interest for large-scale applications. It has also enhanced knowledge and information transfer between countries and enabled competition between potential contractors in different countries.

The first large-scale plants still in operation dates from 1983. Figure 19 shows how the number of large-scale plants has developed since 1983.

The network was formed within a working group under the IEA Solar Heating & Cooling Programme. The first co-operative EC project was carried out in 1995 and further co-operation between institutes has resulted in a couple of important demonstration projects within the EC-THERMIE program.

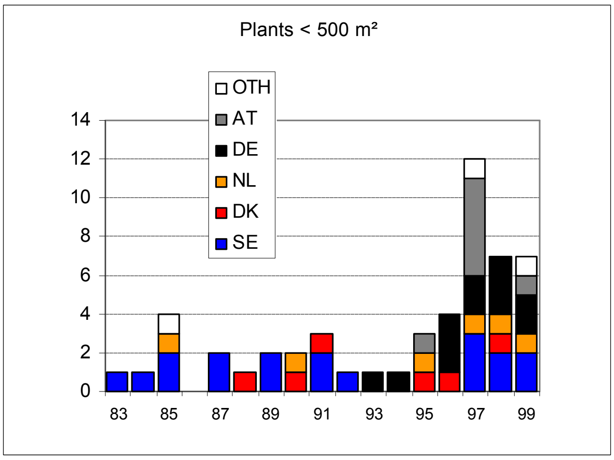

Fig. 19 No of large-scale European plants per year.

Large-scale applications have cost/performance ratios much less than small-scale applications due to effects of scale. In favourable cases today investment costs may be down below 250 €/m^2 of collector area, resulting in a solar heat cost of 0.06 €/kWh or less under typical conditions. However, there is still a need to reduce the gap between the actual status of existing technologies and present knowledge about these technologies by potential users. Ongoing activities in the area show great opportunities for continued co-operation.

ACKNOWLEDGMENT

This paper is based on a co-operative effort to document and enhance the development of large-scale solar heating within the European Large-scale Solar Heating Network.

Major inputs are provided by Boris Mahler (STZ-EGS, DE), Per Alex Sørensen (Planenergi, DK), Carsten Wesenberg (Niras, DK), Alexander Thür (AEE, AT), Peter Lund (Helsinki Univ. of Technology, FI), Lex Bosselaar (NOVEM, NL), Athanassios A. Argiriou (NOA, GR) and Aris Aidonis (Poli di Milano, IT).

REFERENCES

Website www.hvac.chalmers.se/cshp

Personal communication: A. Thür (AEE, AT), B. Mahler (STZ-EGS, DE), M. Bodmann (TU-BS, DE), F. Ulbjerg (Rambøll, DK), G. Donze (w/e, NL), A. A. Argiriou (NOA, GR) and A. Sevilla (Geohabitat, SP).