SOLAR HEATING – SWEDISH EXPERIENCE

Jan-Olof Dalenbäck
Ass. Professor in Building Services Engineering
Department of Energy and Environment
Chalmers University of Technology
SE-41296 Göteborg

Tel.: +46 31 772 1153, Fax: +46 31 7721152
e-mail: Jan-Olof.Dalenback@bt.chalmers.se

Vice chairman Solar Energy Association of Sweden (SEAS)
Vice president International Solar Energy Society (ISES)

The following text summaries major experiences from the development of solar heating systems in Sweden, as well as major developments regarding large-scale solar heating systems in Europe, as background for a presentation in Barcelona, Spain, April 2005.

SOLAR HEATING IN SWEDEN

Research and Development

During the international energy crisis 1973-74 it was recognised that Sweden had to reduce the great dependency on imported oil and a new energy policy was developed. Energy used in buildings represents roughly 40 % of the total energy use and when the first Swedish Energy Research Program was adopted in 1975, the Swedish Council for Building Research (BFR) was given the responsibility for RD&D related to the building sector. The possible use of solar energy for buildings was one of the alternatives to be studied.

The RD&D program related to solar energy was rather extensive including participation in the IEA Solar Heating & Cooling Programme (IEA SHCP) and comprised a number of experimental projects were carried out until the mid 1990's. The Swedish State Power Board, Vattenfall, did also allot considerable efforts into solar energy research until end of the 1990's. However, RD&D related to solar energy has gradually been reduced from all times high with 220 MSEK of governmental support for the period 1981-84 and BFR was merged into the Swedish Research Council for Environment, Agriculture Sciences and Spatial Planning (FORMAS) in end 1990's. The latest RD&D program managed by the Swedish Energy Agency was with about 70 MSEK for the period 2000-02 on a much lower national, as well as international level, only partly compensated by increased involvement in R&D projects managed by the European Commission. The governmental support for R&D on energy topics is strongly reduced and present R&D support for solar thermal covers mainly minimum participation in a couple of IEA SHC programs and EC projects.

The Swedish RD&D program was early focused on large-scale applications for centralised solar heating plants with and without seasonal storage. This was supported by experimental building loans with favourable conditions granted by BFR. The Swedish RD&D programs have also covered small systems but here the development more or less has followed the same developments as in other European countries.

The first experimental solar heating plant with seasonal heat storage, supplying all year around heat for an office building, was constructed 1980 at Studsvik Energy. A number of large systems followed. One of the most well known plants is Lyckebo, initiated by Uppsala Energy with the aim to build a solar heating plant with more than 20 000 m² of solar collectors and 100 000 m³ of seasonal storage in a water filled rock cavern. Uppsala Energi tested a number of imported and at that time advanced collectors and everyone believed that a foreign collector manufacturer would present the best offer. The result, however, was that a small Swedish company group, Scandinavian Solar, having developed a large module flat plate collector based on the Sunstrip absorber and a convection barrier of Teflon, presented the best offer and was appointed to erect the first phase with 4 320 m² of solar collectors in 1983.

The large module collector, as well as the system design, was further developed by TeknoTerm in plants like Nykvarn with 4 000 m² in 1985 (and another 3 500 m² in 1991) and Falkenberg with 5 500 m² in 1989. In parallel a comprehensive study on the feasibility to initiate solar collector manufacturing and build a plant with more than 100 000 m² of solar collectors in the city of Kungälv was presented by a group of companies from Göteborg. Another unique development was initiated by the municipal housing association EKSTA that developed block heating plants with roof-integrated solar collectors combined with wood briquette and pellet boilers. The large module approach was further adopted by German, as well as Austrian, collector manufacturers in the early 1990’s.

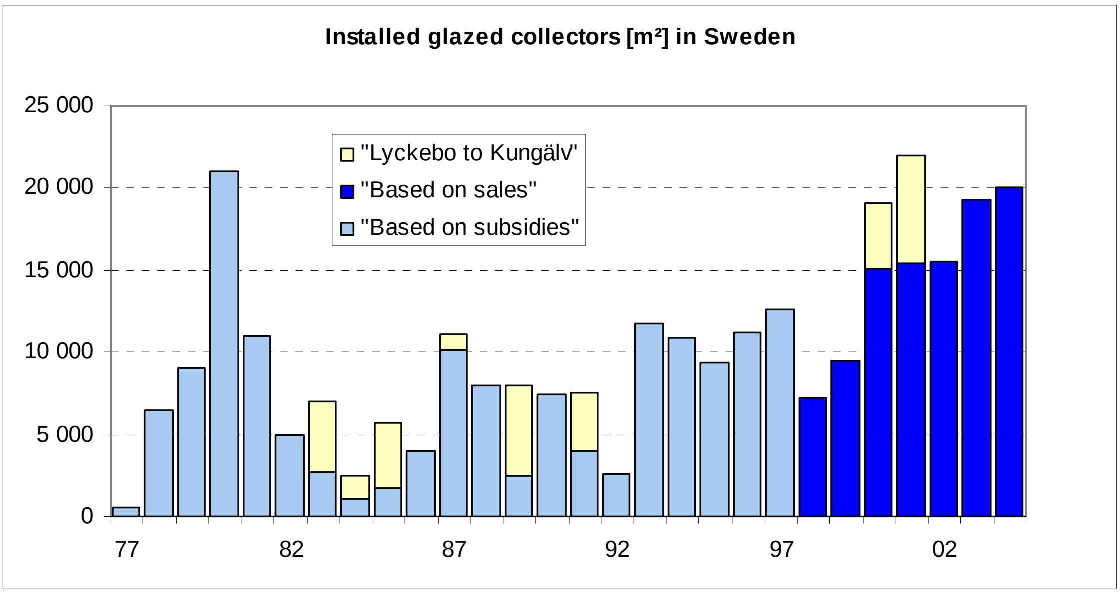
However, the Lyckebo plant was never extended to 20 000 m² and the necessary investment support for the Kungälv project was denied. Therewith the development of large-scale plants was more or less abandoned. A major reason was a declined governmental interest for solar energy and a strong development of wood fuels in block and district heating. The large module collector technology was transferred to the Danish company ARCON Solvarme A/S who until recently has delivered turnkey contracts all around Europe, e.g. Kungälv in Sweden with 10 000 m² in 2001 and Marstal in Denmark with 9 000 m² in 1996 and another 8 000 m² in 2003. All the mentioned large-scale plants from Lyckebo in 1983 to Kungälv were the largest solar heating plants ever built in Europe at that time.

Market Support

The market support has so far comprised a number of different short-sighted support schemes and there has not been any significant connection to ongoing R&D programs. All together, not the best circumstances for market development.

The first market subsidy for solar heating systems was introduced together with subsidies for other energy saving measures already in 1978. About 20 000 m² of solar collectors were sold in 1980, but the market dropped rapidly when the subsidy ended in 1982. This first subsidy was introduced too early, the technology was not mature and the quality of the products was not high enough which created a bad reputation.

The technology was improved considerably during the 80's and the industry managed to get a new support scheme in 1992, but only until 1997 and the market dropped again. After two years without support a new subsidy was introduced again in 2000. This support was initially valid until 2004, but has now been prolonged until 2007. So, when the technology and the quality were improved the support schemes have shown a lack of continuity. However, the present support is related to the collector performance and complemented with a comprehensive market development evaluation (e.g. sales statistics details) in cooperation between the Swedish Energy Agency and the Solar Energy Association of Sweden.



Solar collector market development in Sweden 1977 – 2004

Today there are about 200 000 m² of glazed solar collectors in Sweden, i.e. about 20 m² per 1000 inhabitants, and a number of small companies selling solar systems. In 2004 the sales amounted to about 20 000 m², i.e. the same as 20 years ago. The majority of solar systems sold are so-called combisystems combined with wood boilers, but the market for solar DHW systems has increased the last years.

Solar Thermal Industry

A couple of domestic industries started to import and develop solar collectors already in the mid 1970's. The only lasting product from these early times is the Sunstrip absorber, a roll-band based on a cupper pipe and aluminium fins introduced by Gränges Aluminium in the late 1970's. A production line was sold to China and Sunstrip was sold to Canada in the early 1980's due to the lack of market in Sweden and Europe at that time.

Scandinavian Solar developed the large-module collector and merged into TeknoTerm, who got Sunstrip back from Canada and put a new production line running in Sweden in about 1990. TeknoTerm developed into an expanding industry that produced solar absorbers, ceiling panels for irradiative heating and cooling, as well as cooling beams, based on the Sunstrip technology. TeknoTerm was split and all divisions except Sunstrip were sold out in the end 1990's. Sunstrip AB is now one of the leading absorber manufacturers in Europe with an annual turnover of about 25 MSEK and growing.

Sunstrip absorber with a selective sputtered surface

An important step for the Swedish industry was the implementation of the P-mark, a performance and durability test combined with production control for solar collectors introduced in 1992. The P-mark is now to be replaced by the Solar Keymark, a European quality label for solar collectors and systems supported by ESTIF and CEN.

So-called self-builder groups were a common European development in the 1980's. In Sweden this took a slightly different development as more or less all self-builders were organised in Svenska solgruppen and used the same collector based on the Sunstrip absorber, called LESOL. This solar collector, developed by a schoolteacher, is probably the most common collector installed on Swedish single-family buildings, even today.

Future Prospects

The Solar Energy Association of Sweden (SEAS) is approaching governmental bodies to set long term goals and adopt suitable promotion strategies for the further development of solar heating in Sweden. The public and governmental interest for solar heating is however rather limited and, besides Sunstrip, the solar thermal industry is dominated by small players that have a hard time to make a difference.

More or less abandon resources of wood fuels and rather favourable opportunities for the use of heat pumps does not increase the opportunities for solar heating. Large-scale solar systems are well developed but the interest among facility managers and thermal utilities is lacking, partly as existing alternatives show rather low energy prices and partly due to the lack of (governmental) incentives. Small solar systems are becoming more adapted to standard heating equipments in single-family buildings and there is an increased interest to develop combined solar and wood pellet systems to offer more complete alternatives for single-family houses.

LARGE-SCALE SOLAR HEATING IN EUROPE

Introduction

There are about 12 million m² of glazed solar collectors in Europe with a total (nominal) thermal power of about 8 400 MW. Solar collectors are mainly installed in small systems (2 – 30 m²) and so far only a minor part is related to large-scale applications. At present, there are 75 documented plants having more than 500 m² (~350 kWth) of solar collectors. The total collector area of about 135 000 m² in these plants corresponds to 1% of the total installations or about 30 000 SDHW systems.

Large-scale solar heating systems were introduced in the late 70's by the interest to develop solar heating systems with seasonal storage. Sweden had a leading role in the early demonstrations together with The Netherlands and Denmark. In the 90's the interest in large-scale solar heating increased in Germany and Austria and 57 new plants with more than 500 m² of solar collectors have been put into operation since the beginning of 1995. Unfortunately there is a clear negative trend with a decreased number of plants the last years. The continued interest to develop plants with seasonal storage remains mainly in Germany and Denmark, and most of the new large-scale plants are with (or without) diurnal storage. Sweden is still the leading country with a total of 22 plants with more than 500 m^2 of solar collectors in operation. Here, it should also be mentioned that seven Swedish plants, the first from 1979, have been closed after 10-20 years of operation and evaluation.

Applications and Technologies

Large-scale solar heating systems 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, via block and district heating plants. Industrial heat and heat driven cooling applications are also covered as long as the operating temperatures are below 100 °C.

The majority of the plants (62 out of 75) supply heat to residential buildings, in most cases via a central heating plant. Typical operating temperatures range from low 30°C to high 100°C (water storage). 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, hotels and commercial buildings.

The majority of the plants are designed to cover the summer heat load - i.e. hot water and heat distribution losses - using diurnal water storages, but 16 plants are equipped with seasonal storages and cover a larger part of the load. The seasonal storages comprise water in insulated tanks (above or in ground) in seven plants, the ground itself in six, aquifers in two and a combination of ground and water in one plant. Two plants are designed to cover the summer cooling load in heat driven cooling applications.

The early development of large-scale applications initiated the development of large-module collectors to be connected in large arrays with reduced amount of connecting pipes. Most of the plants have roof-integrated or roof-mounted solar collectors while 15 out of 22 plants in Sweden and all in Denmark have ground-mounted collector arrays. Flat plate large-module collector designs dominate, and only two plants are equipped with evacuated tube collectors. In a couple of cases in Sweden and Germany roof-mounted collectors are designed as more or less complete roof modules. 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.

The dominating contractor is ARCON (Denmark) having installed about 60 000 m^2 of large module collectors (pioneered by TeknoTerm, Sweden). Examples of other European contractors are ZEN and Atag (The Netherlands), Solsam and Aquasol (Sweden), Solvis and Wagner (Germany), SOLID (Austria) and Sole (GR). It could further be noted that the Sunstrip absorber is used in about 60% of the collectors in the large-scale plants, partly as the Sunstrip absorber has mechanical advantages in large-module collectors.

Solar district heating in Sweden and Denmark

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. The oldest plant still in operation dates from 1984.

Solar district heating plant with 10 000 m^2 large-module collectors in Kungälv, Sweden.

The early efforts were very much driven by a small number of pioneering utilities, e.g. Uppsala, Telge and Falkenberg Energi, within the experimental building program managed by BFR. 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 with 5 500 m^2 of collectors together with natural gas boilers (used for back up in the summer and winter peak demand). Kungälv Energi AB has recently built a 10 000 m^2

ground-mounted collector array as a complement to an existing wood-chips boiler plant. The plant has got EC support and yields close to 4 GWh/a out of a total load of about 100 GWh/a.

EKSTA, a municipal housing association in Kungsbacka, pioneered the use of roof-integrated solar collectors in new building areas already in the 80's. 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. EKSTA used initially site-built collectors, but took active part in the development of a roof module collector mounted directly on the roof trusses which has been used since 1995.

Roof module collectors on a renovated multifamily building in Gårdsten, Göteborg.

One recent project comprised 1 650 m² roof-integrated collectors on existing buildings in Fränsta. Another is Bostads AB Gårdsten carrying out a renovation project incorporating about 1 400 m² of solar collectors for pre-heating DHW in 20 block of flats from the 70's. Here, the previously mentioned roof module collectors are used to form new inclined roofs on top of existing flat roofs (and the project is part of two EC-projects; SHINE and RegenLink). Furthermore, a new residential building area with 2 400 m² of roof-integrated collectors combined with 100 boreholes in rock (about 60 000 m³) for 50 residential units is recently completed in Anneberg. The aim of the project (partly financed by EC-THERMIE) is to demonstrate seasonal storage in rock. There is also a recent initiative with a couple of decentralised solar heating systems in the city of Malmö.

The Danish large-scale solar heating plants are used in small district heating systems and all collectors are ground mounted. Based on Swedish experiences the first Danish plant, with 1 000 m² of ground-mounted collectors, was built in Saltum 1987. Later on the second plant with 3 025 m^2 of solar collectors was built in Ry with subsidy from EC and the Danish Energy Agency. Both these plants are operated using the district heating network as a buffer storage and cover about 5% of the heat load.

Table 1: European large-scale plants with ground mounted large-module collectors.

Plant, Year of operation	Owner, Country	Coll. [m²]	Nom. [kW]*
Marstal, 1996-	Marstal Fjernvarme, DK	18 300	13 000
Kungälv, 2000-	Kungälv Energi AB, **SE**	10 000	7 000
Nykvarn, 1984-	Telge Energi AB, **SE**	7 500	5 250
Falkenberg, 1989-	Falkenberg Energi AB, **SE**	5 500	3 850
Ærøskøping, 1998-	Ærøskøping Fjernvarme, DK	4 090	2 860
Rise, 2001-	Rise Fjernvarme, DK	3 575	2 500
Ry, 1988-	Ry Fjernvarme A/S, DK	3 040	2 130
Nordby, 2002-	Samsø Energiselskab, DK	2 500	1 750

* The collector thermal output is typically 85% of the nominal thermal power.

In 1995 Marstal District Heating decided to establish 8 064 m^2 solar collectors and a 2 100 m^3 water storage tank to cover up to 15% of their heating load. The next step was solar heating combined with straw or wood heated district heating plants. Ærøskøbing district heating company established the first plant of this type, 4 900 m^2 solar collectors covering 17% of the heat load, in 1999. A similar plant with 3 575 m^2 of ground-mounted collectors and 4 000 m^3 water tank, in order to cover about 50% of the annual load in a local district heating plant, has been realised in Rise. The Marstal plant is now extended to 18 300 m^2 and complemented with a seasonal storage (10 000 m^3 water) with support from EC. Mainly due to political budget constraints the governmental support for solar applications has unfortunately decreased in Denmark during the last years.

Block heating plants in other EC countries

Large-scale solar heating plants in **Germany** are mainly applied in new residential building areas using roof-integrated or roof-mounted collectors. Until 2003 eight projects with seasonal storage and about 50 large- to medium-scale projects with short-term storage had been realised. There is now an ongoing German R&D programme until 2008. For example, in Friedrichshafen a system with 4 050 m^2 of collector area and seasonal storage aimed to provide almost half of the heat demand for space heating and domestic hot water for 10 blocks of multifamily houses and about 50 terraced houses was put in operation in 1996. The water storage (12 000 m^3) is build out of reinforced concrete and partly buried in the ground. 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. Another example is the solar heating plant with >5 000 m^2 of roof-integrated solar collectors in a new residential building area in Neckarsulm. One of the aims of this project is to demonstrate seasonal storage in ground partly financed within the EC-THERMIE program.

By establishing local heating networks it is possible to convert the heat supply of entire cities 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. At the end of 1996, about 300 villages and small cities in **Austria** were supplied with heat from central biomass-fired plants. For technical and economic reasons, most of these plants are operated only during the heating season. Therefore it was interesting to add a solar plant in order 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 avoid operation of the wood chip boiler with reduced capacity (and low efficiency). The first local biomass-fired heating plant complemented with a solar system was a small plant in Deutsch-Tschantschendorf in 1995. The experiences from this plant were promising and more than 10 large-scale plants were developed. The largest plant in Austria so far comprises 1 400 m² of large-module collectors placed on the roof of the Arnold Schwarzenegger Stadion in Graz.

Table 2: European large-scale solar heating systems with roof-mounted or roof-integrated solar collectors in different residential applications.

Plant, Year of operation	**Owner, Country**	**Build**	**Coll. [m²]**
Neckarsulm, 1997-	Stadtwerke Neckarsulm, DE	New	5 263
Friedrichshafen, 1996-	Techn. Werke Friedrichsh., DE	New	4 050
Hamburg; 1996-	Hamburger Gaswerke, DE	New	3 000
Schalkwijk, 2002-	ENECO Energy, NL	New	2 900
Groningen, 1985-	De Huismeester, NL	New	2 400
Anneberg, 2002-	HSB Brf Anneberg, **SE**	New	2 400
Augsburg, 1998-	Bayerisches Staatsministerium, DE	New	2 000
Fränsta, 1999-	Vattenfall Energimarknad, **SE**	Exist	1 650
Stuttg.-Burgholzhof, 1998-	Neckarwerke Stuttgart AG, DE	New	1 635
Ekoviikki, 2000-	Misc. facility managers, FIN	New	1 430
Gårdsten, 2000-	Gårdstensbostäder, **SE**	Exist	1 410
AS Stadion, 2002-	nahwaerme.at GmbH & Co KG, AT	Exist	1 407
Bo01, 2001-	Sydraft Värme Syd AB, **SE**	New	1 400
Hannover-Kronberg, 2000-	Avacon AG, DE	New	1 350
Eibiswald, 1997-	Nahwärmegen. Eibiswald, AT	New	1 250
Älta, 1997-	Vattenfall/Fortum, **SE**	Exist	1 200
Berliner Ring, 2004-	Nahwärme Graz, AT	New	1 200
Kullavik 4, 1987-	EKSTA Bostads AB, **SE**	New	1 185
Kockum Fritid, 2002-	Sydraft Värme Syd AB, **SE**	Exist	1 100
Fjärås Vetevägen, 1991-	EKSTA Bostads AB, **SE**	New	1 095
Salzburg, 2000-	Gem. Salzburger Wohn. M.b.H., AT	New	1 056
Åsa, 1985-	EKSTA Bostads AB, **SE**	New	1 030

The most widely implemented application of large solar heating systems in **The Netherlands** is collective housing, institutions and homes for the elderly. Most systems have about 100 m² of solar collectors, but some are larger, for example “Brandaris” in Amsterdam, a project developed within IEA SHCP and built within an EC-project (SHINE). The system provides hot water and part of the space heating load using 750 m² of solar collectors placed on the rooftop at 45 m height. Based on the experiences from the Brandaris project a similar plant with 720 m² of collectors was recently put into operation in Kruitberg, Amsterdam (within EC-project RegenLink). Two large-scale plants are designed with seasonal storage, one is a recent plant with 2 900 m² of roof-integrated solar collectors connected to an aquifer storage for a new residential area.

Other large-scale applications

The rather low specific costs related to large-scale applications are also interesting in relation to heating loads in industrial processes and for heat driven cooling systems. However, here the economic prerequisites are harder than for applications in relation to buildings. Industries usually demand short pay off times (1-5 years) and heat driven cooling process have high specific costs and lower performance than electric vapour compression processes and require low heat costs to be competitive.

Tabell 3: Sample large-scale solar heating systems in special applications

Plant, Year of operation	Owner, Country	Application	Coll. [m²]
Sarantis, 1998-	Sarantis S.A., GR	Cooling	2 700
Breda, 1997-	Van Melle, NL	Sweet factory	2 400
Tyras, 1999-	Tyras S.A., GR	Food factory	1 040

Greece is the only European country with a stable market for solar systems since more than 20 years, but it is only recently that large-scale systems have been applied in Greece. The so far largest is a solar cooling plant with 2 700 m² of flat plate collectors in Athens providing heat to two adsorption chillers (2 x 350 kW). There is e.g. also a combined heating and cooling system with 900 m² flat plate collectors on Mallorca (ParcBIT) and one with close to 500 m² flat plate collectors in Kosovo.

Solar heating systems have been applied in industrial processes for many years but the interest for these applications has increased during recent years. A couple of the large solar systems in the Netherlands are industrial heat applications. One system with 2 400 m² of solar collectors is used in the sweet factory Van Melle in Breda. The system is the largest drain back system in the world and the generated hot water is used in the production and for cleaning. Another NL system with 1 200 m² of collectors is used for flower bulp drying in Lisse. There are furthermore three recent solar plants with 700 – 1 000 m² of solar collectors supplying heat in small food industries in Greece.

Discussion

The oldest plants still in operation date from 1984. This is a proof that large-scale systems can operate for a longer time than 20 years, especially as new plants are equipped with improved components. Most of the large-scale plants are operated and thereby evaluated by professionals with demands on the performance. There is however still a need to reduce the gap between the actual status of existing technologies and present knowledge about these technologies by potential users. The investment costs and thereby the solar heat costs are not yet low enough to convince conservative thermal utilities and facility managers. The so far positive development of and experience from contracting and third part financing should therefore be looked upon more carefully.