TREES Training for Renovated Energy Efficient Social housing

Intelligent Energy -Europe programme, contract n° EIE/05/110/SI2.420021

Section 1 - Techniques

1.4 Solar hot water

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Partners

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Intelligent Energy Europe

CONTENT

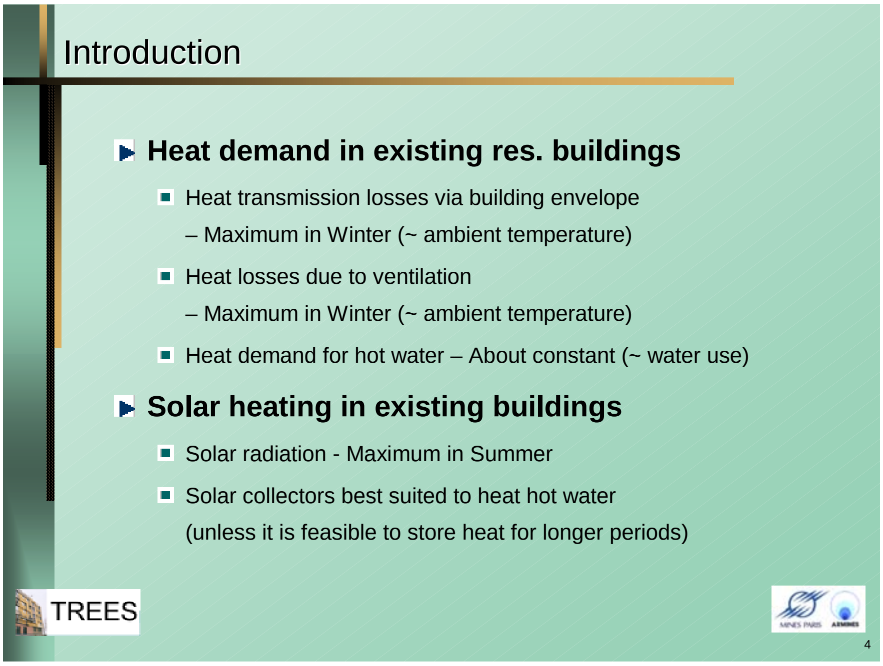
INTRODUCTION

The European market for glazed solar collectors and solar heating systems has increased with about 10% per year the last decade. Solar heating is thus becoming a mature technology in several countries.

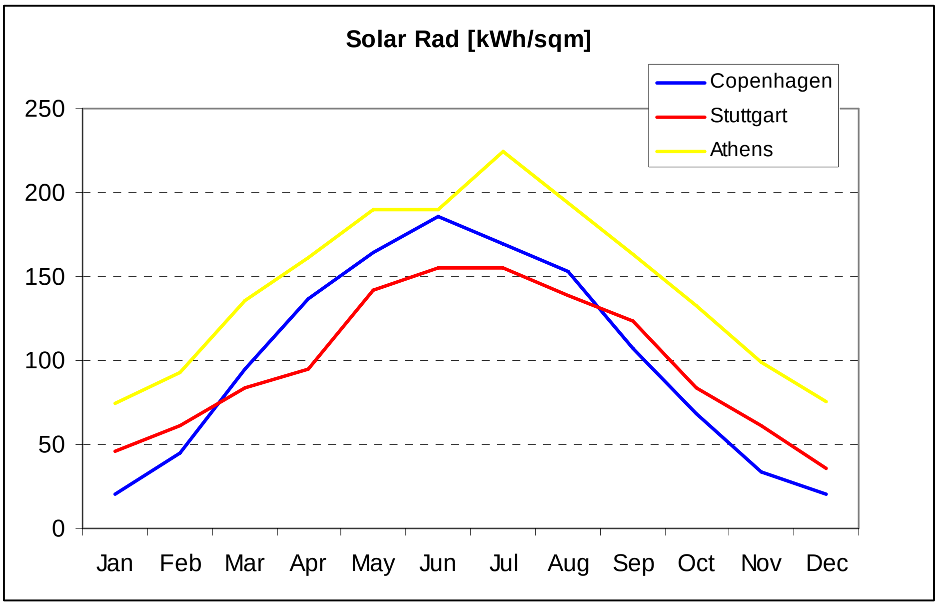
The market is dominated by Germany but the market penetration is largest in Greece and Austria. Solar heatings systems are mainly used in single family buildings, the following is an introduction guide how to apply solar heating systems in existing multifamily buildings.

Roof-intergrated solar collectors on multifamily building in Austria
Photo: SOLID / Austria Solar

Roof-mounted solar collectors on multifamily building in the Netherlands
Photo: Zensolar

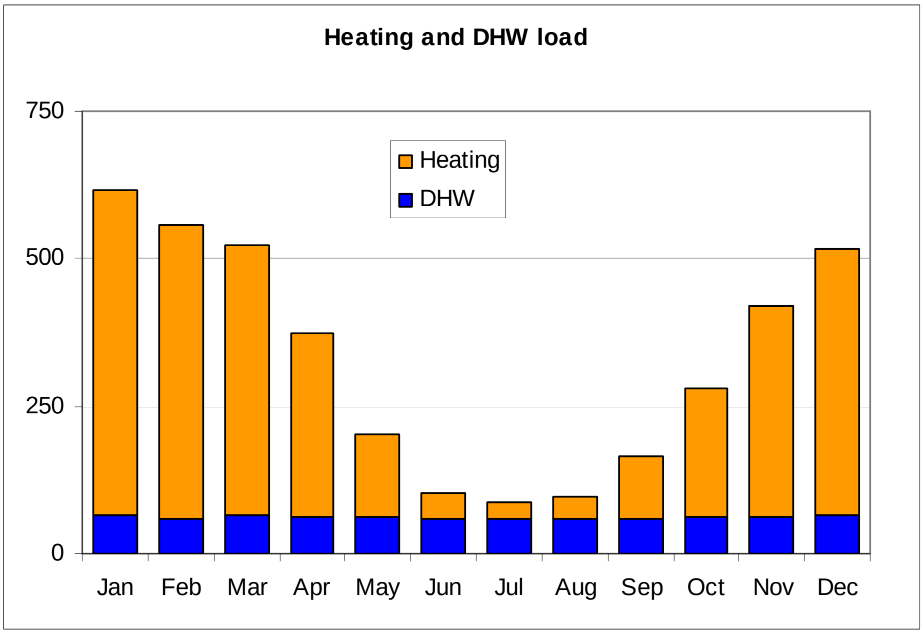


The design of a solar heating system should be based on the available solar radiation in relation to the need for heating. The following diagrams show the available solar radiation in three different locations from north to south Europe.



Solar radiation per sqm on a 45 deg sloped south facing surface/roof in Copenhagen (Top), Stuttgart (Middle) and Lisbon (bottom).

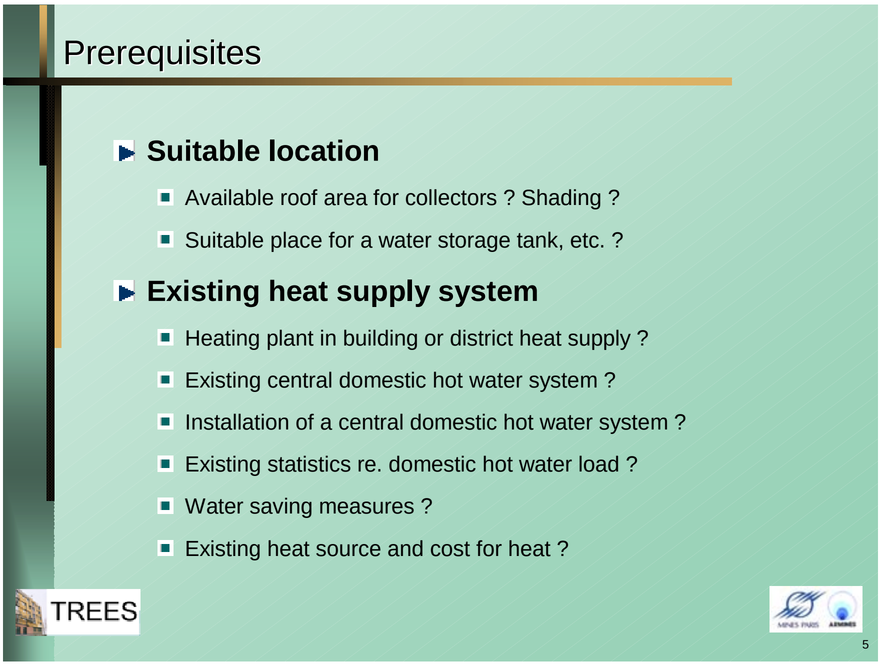
A typical existing building needs to be heated during the heating season to cover heat transmission and ventilation heat losses due to the required 20-22° indoor temperature and varying ambient temperatures due the lack of solar radiation during the heating season and is thus not the first choice in relation to solar heating.



Heat demand in a sample existing residential building in north to mid Europe.

All residential buildings have a heat demand for heating domestic hot water. This demand is fairly well distributed over the whole year and is thus more suitable for solar heating.

PREREQUISITES



Suitable location

The solar system requires a suitable location for the solar collectors. For required area see the following. The most logical location for the collectors is on or in the roof, but collectors can also be integrated in facades. An important aspect, especially related to facades is to avoid shading.

A solar system also needs a suitable location for a buffer storage. The most logical location is in a suitable space on the ground floor or in the basement. The storage can also be placed outside the building. For required storage volume, see the following.

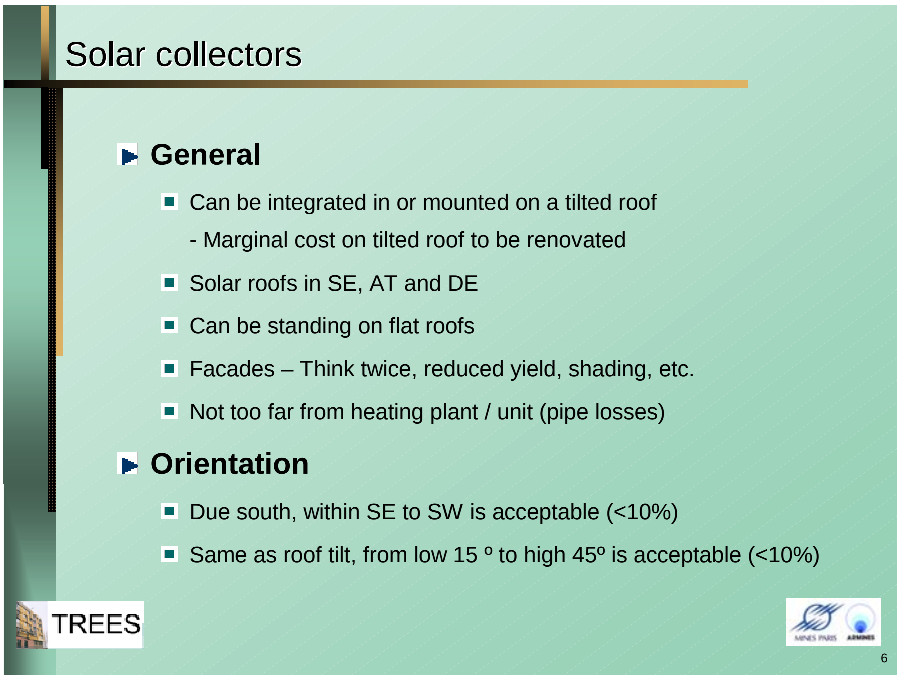
Existing heat supply system

If it is suitable or not to have a solar system as well as the design of the solar system depends on the existing heat supply system. Most multifamily buildings in northern Europe are equipped with a central domestic hot water system, which in most cases is suitable to complement with a solar system. In case the building comprises individual domestic hot water heaters in each apartment, the implementation of a solar system requires the installation of a central domestic hot water system in 9 out of 10 cases.

The design of the solar system should if possible be based on the measured demand for hot water. The alternative is to use key numbers based on number of people or heated area. In the case it is possible to implement water savings measure, it is very important to consider these to be carried out before the solar system is designed in order not to have a too large solar system.

The question weather the solar system will pay off or not depends on the alternative cost for heat. Here it is important to consider the low efficiency of existing boilers on low summer load conditions.

SOLAR COLLECTORS

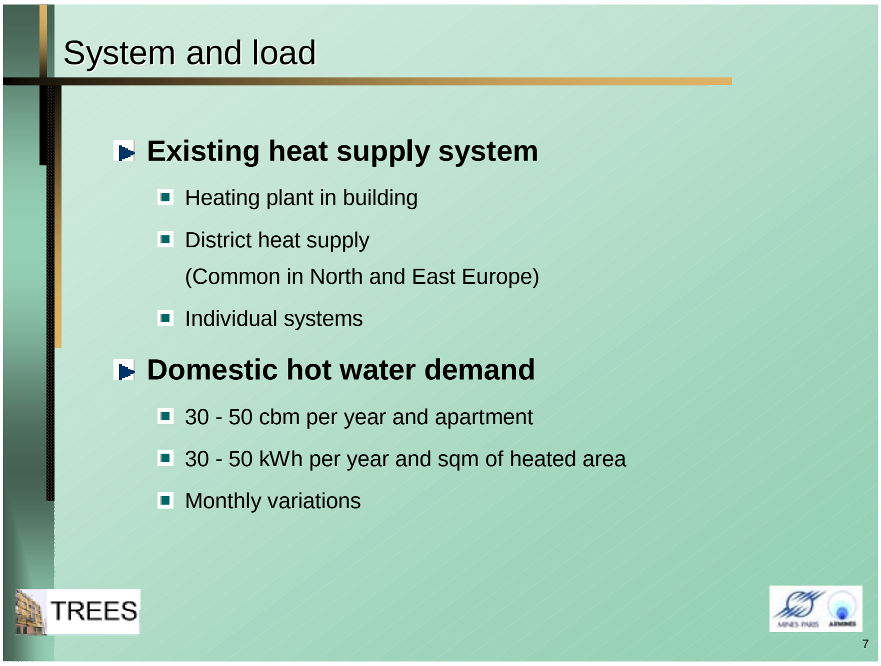


The best economic conditions occur when the solar collectors can replace existing roof (and façade) materials and work as a water-proofing building component to achieve only a marginal cost for the collectors. Most systems so far comprise ordinary module collectors placed on or integrated into the roof, while a number of larger systems are designed with so-called solar roofs. A solar roof is a building roof designed with large collector modules specially designed for mounting on roofs, e.g. to include roof trusses or to be placed directly on the roof trusses. See Facts for more details about solar collectors.

It is further important to avoid shading (especially on façade mounted collectors) and minimize the distance between the solar collectors and the buffer storage and the heating plant due to pipe heat losses.

The annual thermal yield varies between 300 and 600 kWh/sqm of solar collector depending on climate and system design. The solar collectors should be tilted and oriented to the south. Orientations between SE and SW as well as tilts between 15 and 45 are acceptable and result typically in less than 10% reduction of the useful solar heat in relation to the best orientation. A solar collector placed on the façade gains about 70% as much solar heat as a tilted south facing collector in a typical application.

SYSTEM AND LOAD



Most multifamily buildings have either a boiler heating plant or a district heat substation in the building. Some multifamily buildings have individual heating systems in the apartments.

The most favourable application for solar collectors is to pre-heat domestic hot water, including the hot water circulation necessary for the required hot water comfort in large buildings.

Depending on the layout of the existing system the solar system can also be designed to cover parts of the space heating demand during Spring and Autumn (as well as the Winter in Southern countries).

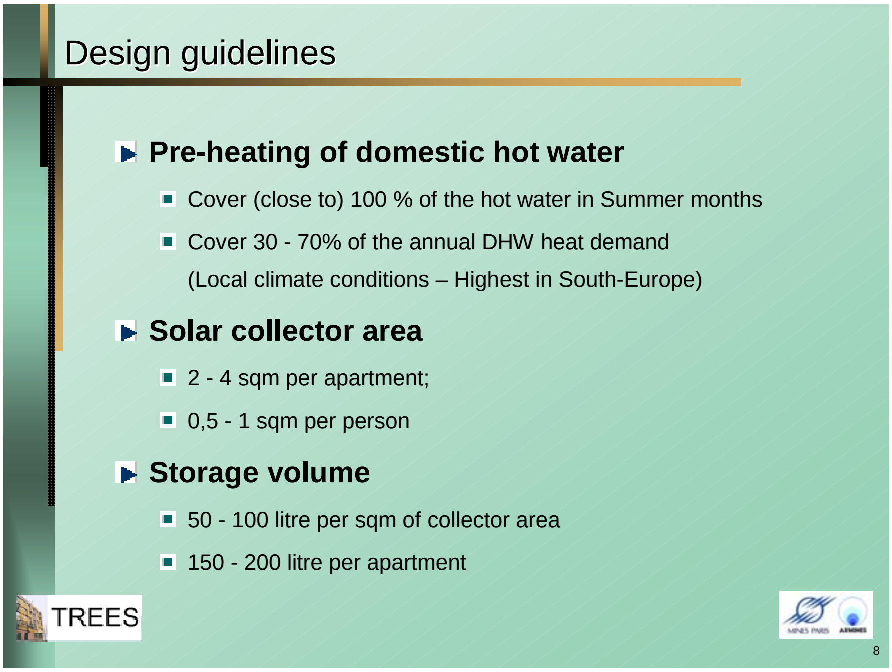
An alternative in multifamily buildings supplied by district heat is to connect the solar system to the primary district heating system.

The design of the solar system should if possible be based on the measured demand for hot water. The alternative is to use key numbers based on number of people or heated area.   The use of hot water varies typically from 30 to 50 cbm per year and apartment or between 30 and 50 kWh per year and sqm heated floor area.

Typical solar fractions (See System Design) ranging from 30 to 80 % will thus result in solar contributions from 10 to 40 kWh per year and heated floor area.

In the case it is possible to implement water savings measure, it is very important to consider these to be carried out <u>before</u> the solar system is designed in order not to have a too large solar system.

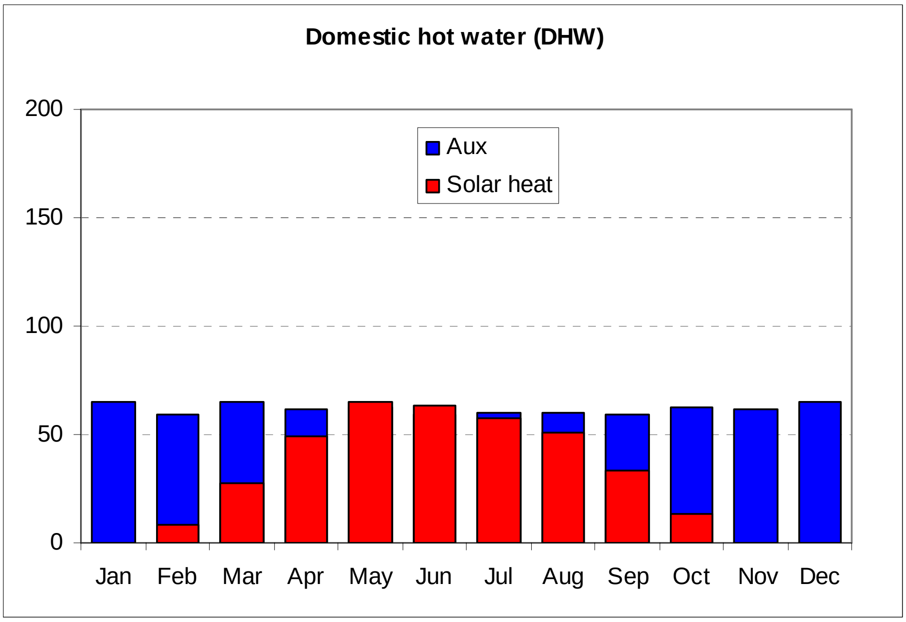
DESIGN GUIDELINES



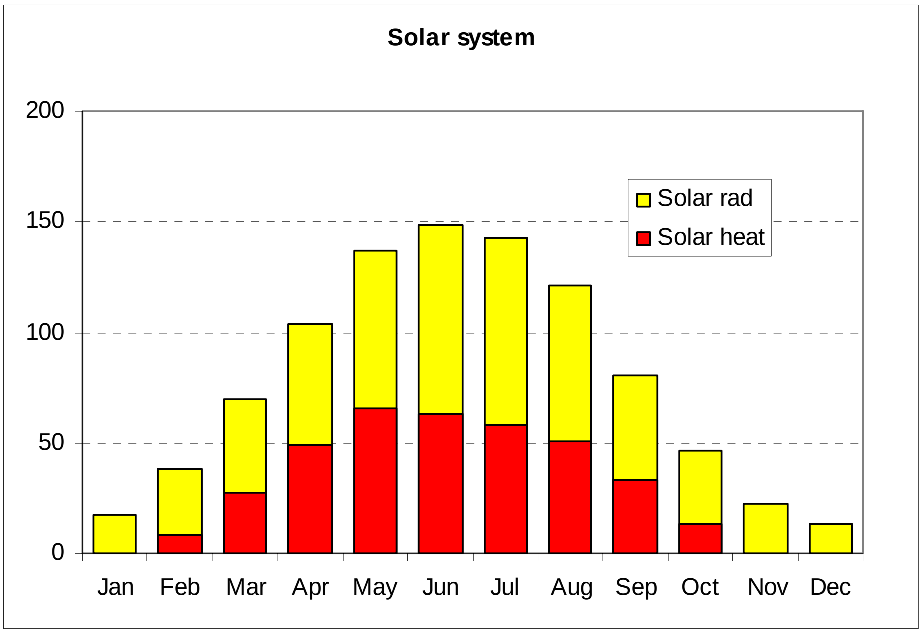
A solar system for heating domestic hot water should be designed to cover 100% or close to 100% of the demand during the Summer months. Here it is important to consider that this demand might be considerably lower than during the rest of the year. This is due to the fact that the cold water temperature is increased during the Summer and that it is more common to have vacations and use less hot water during the Summer period.

The above design criteria will result in different solar fractions (i.e. relations between solar heat and domestic hot water load) mainly depending on the climate of the site. Typical solar fractions in North Europé are 30-50% while they are 60-90% in Southern Europé.

A rough estimate of the size of the solar system is thus to determine the demand for hot water and estimate the size based on a suitable solar fraction. The required solar collector varies from 2 to 4 sqm per apartment depending on the climate and the type of collector used.



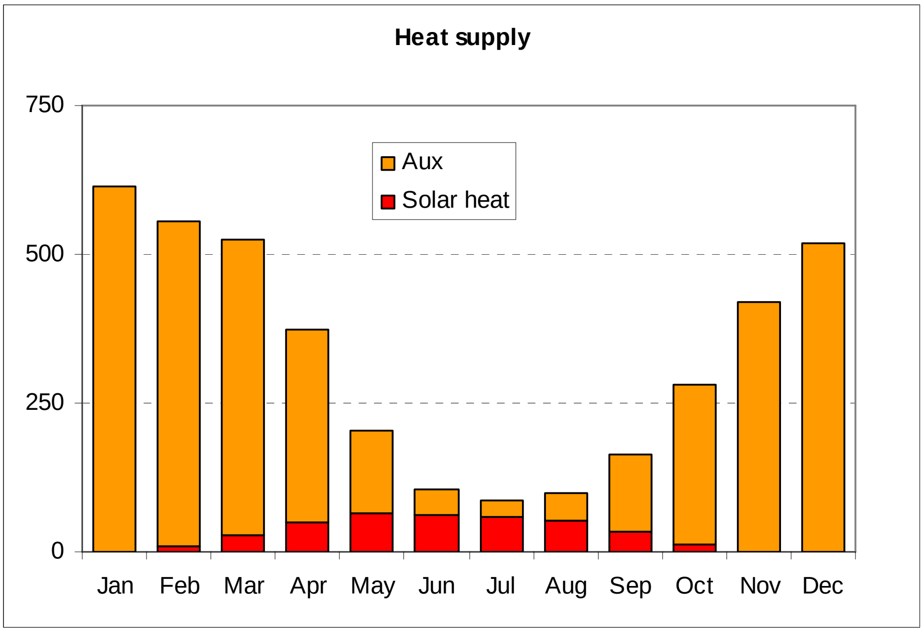
Solar heat and required supplementary (aux) heat for hot water in a sample existing residential building in north Europe.



Solar radiation and useful solar heat for a sample solar system in an existing residential building in north Europe.

The upper diagram shows the relation between the useful solar heat and the domestic hot water and the lower diagram shows the relation between useful solar heat and the available solar radiation on the collector for one and the same solar domestic hot water system in north Europe.

The solar fraction is about 40% and the annual efficiency of the solar system is about 40%. The solar fraction could be up to 80-90% in a more southern climate but the annual efficiency of the solar system will only be slightly higher using the same solar collector in a more southern climate.



Solar heat and required supplementary heat for a sample existing residential building in north Europe.

The diagram shows the relation between the useful solar heat and the total heat demand in the building for the solar system exemplified in previous diagrams. A better insulated building or a building in a warmer climate would mean that the useful solar heat will cover a larger part of the total heat demand.

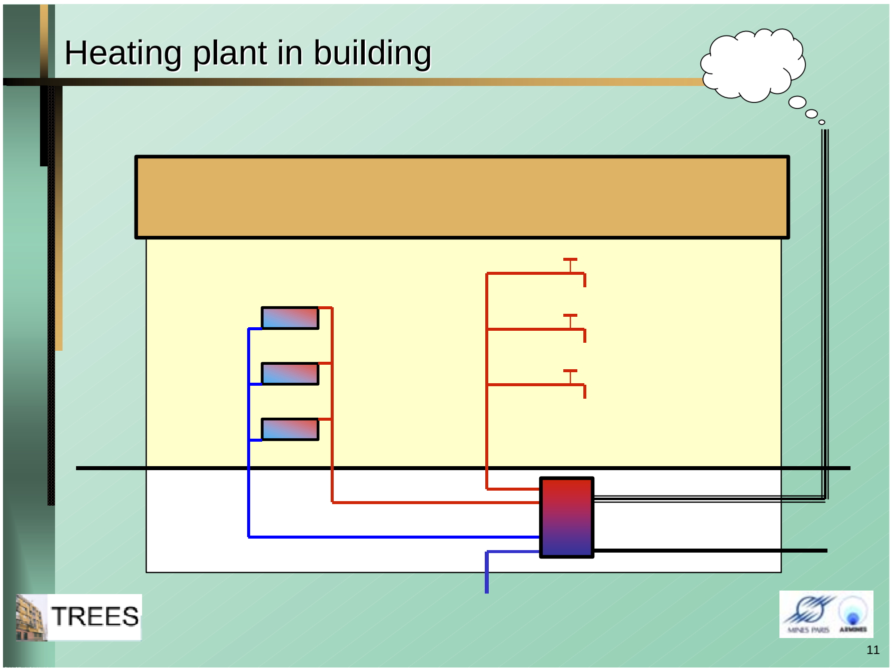
The solar system requires a buffer storage to take care of the mismatch between the use of hot water and the available solar system output (time of day and between days with varying solar radiation). The required volume has a fairly good relation to the daily hot water use, i.e. 150 - 200 litre per apartment or 50 – 100 litre per sqm of collector area.

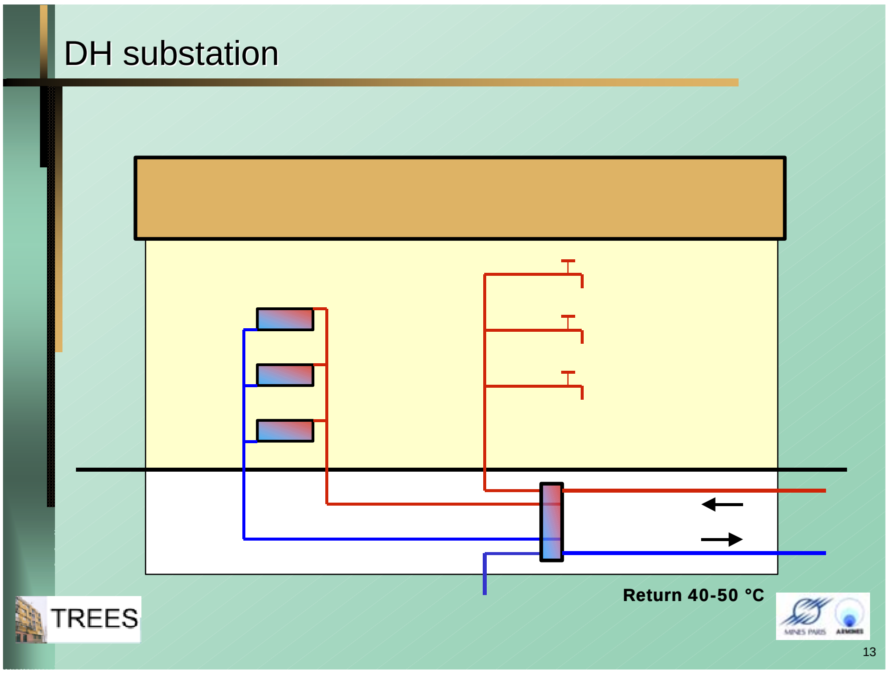
The detailed design of the solar system should be left to an engineering consultant, preferably one with experience from designing solar systems.

There are a number of different programs to be used by a consultant to design a solar system more in detail. A soft ware commonly used in Europe is T*Sol from Valentin that includes a database with solar collectors.

SYSTEM SCHEMATICS

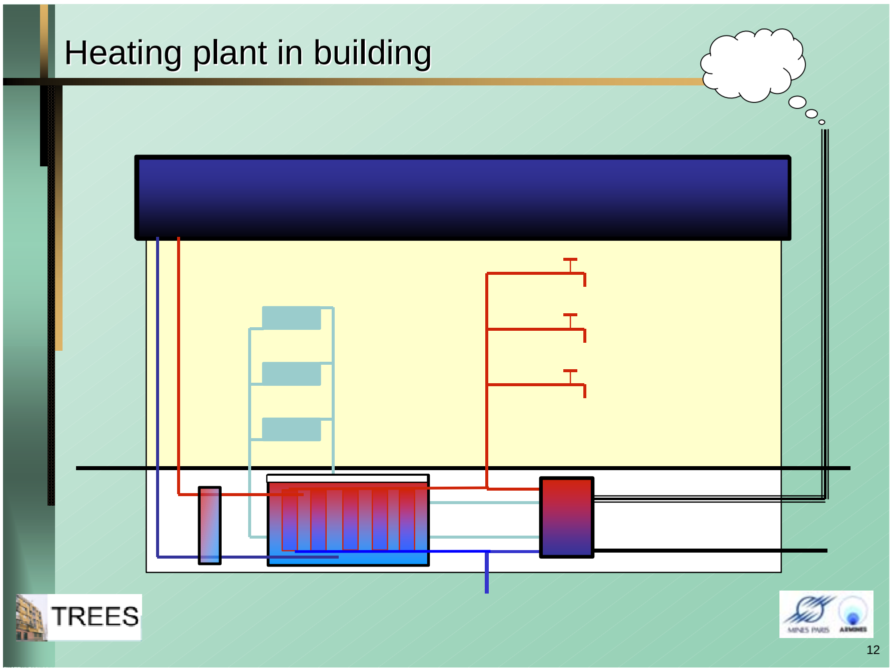
Existing multifamily buildings are typically supplied with heat via a local boiler heating plant or a central district heating plant (more common in Northern Europe). They comprise further a heating system, typically using hydronic radiators, and a domestic hot water system.

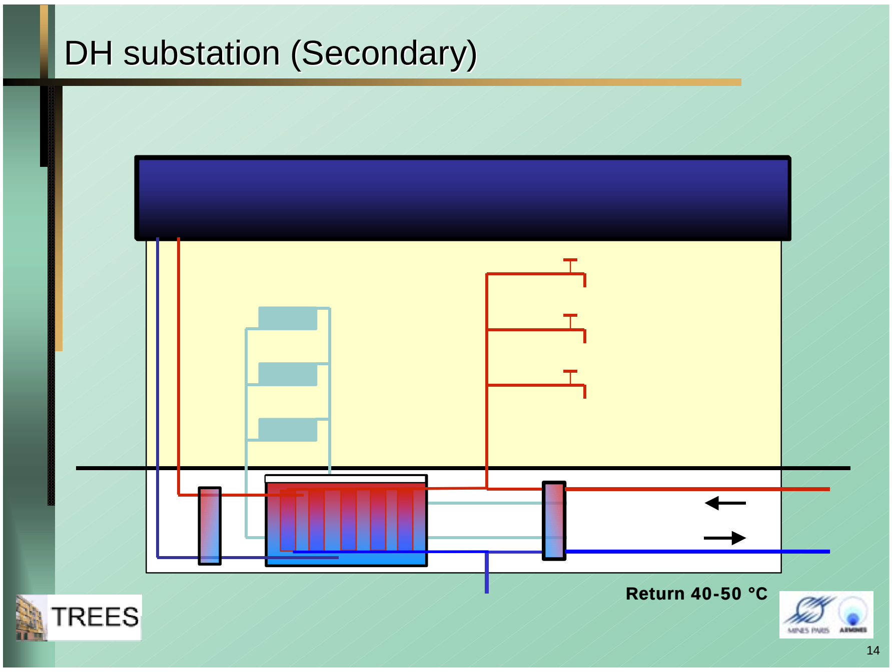




Schematic diagrams showing a heating plant (Top) and
a district heating sub station (Bottom) in a multifamily building.

The solar system has typically roof-mounted or –integrated solar collectors and a buffer storage tank placed in a suitable location in the building designed for the local domestic hot water load. The solar collector circuit is separated from the buffer storage by a plate heat exchanger and contains a freeze-protected fluid (typically glycol and water).

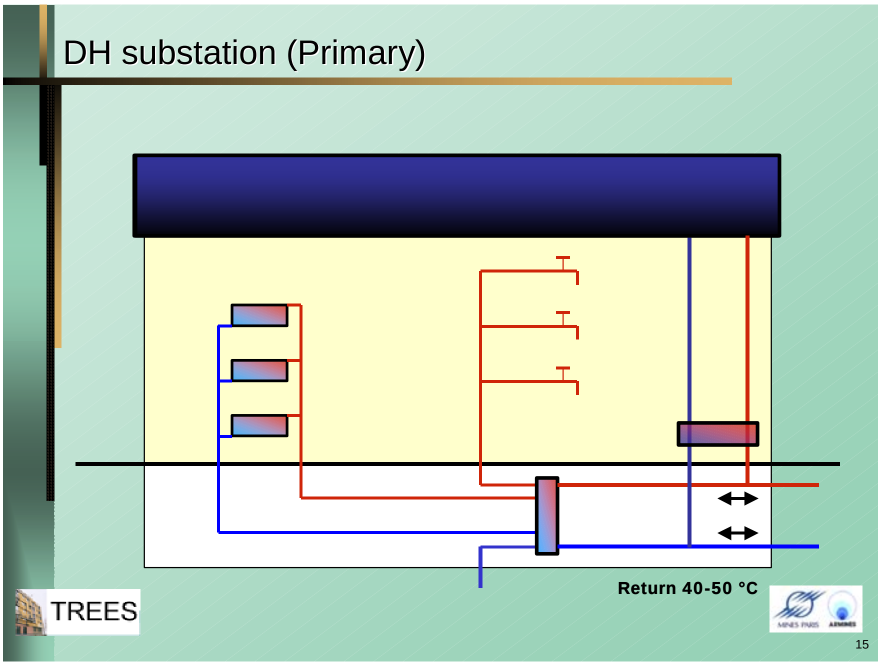




Schematic diagrams showing a heating plant (Top) and a district heating sub station (Bottom), both complemented with a solar domestic hot water system.

The solar heating system is typically designed to pre-heat domestic hot water by connecting the buffer storage in parallel to the existing boiler (heating plant) or heat exchanger (district heating). The buffer storage is heated by the solar collectors whenever there is enough solar radiation and the buffer storage is pre-heating the hot water when used. During periods with less solar radiation the domestic hot water is heated by the existing boiler or the existing heat exchanger.

These schematic diagrams show systems with buffer storage tanks at ambient pressure with immersed heat exchangers. It is also possible to use pressurized tanks and more ordinary plate heat exchangers.

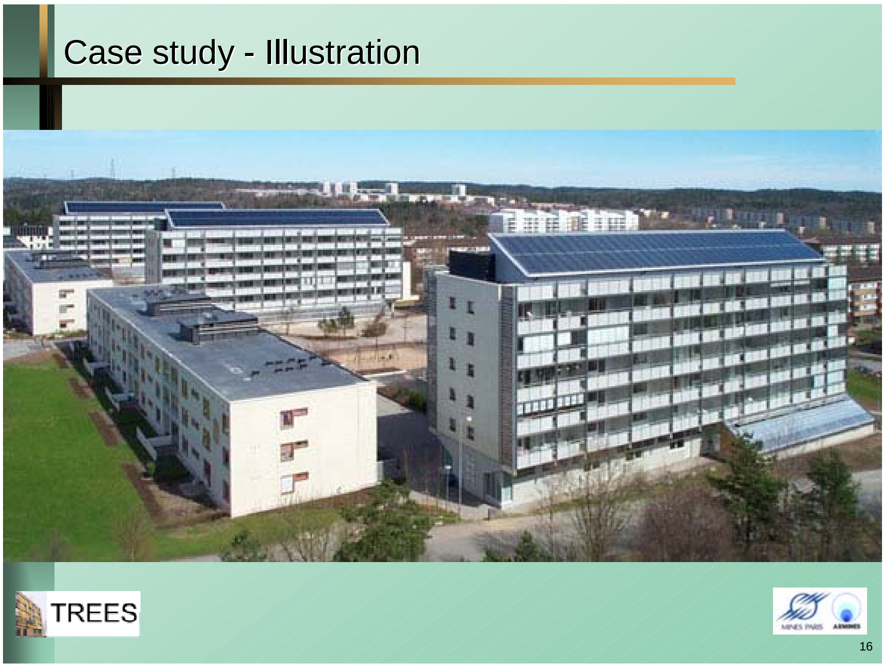


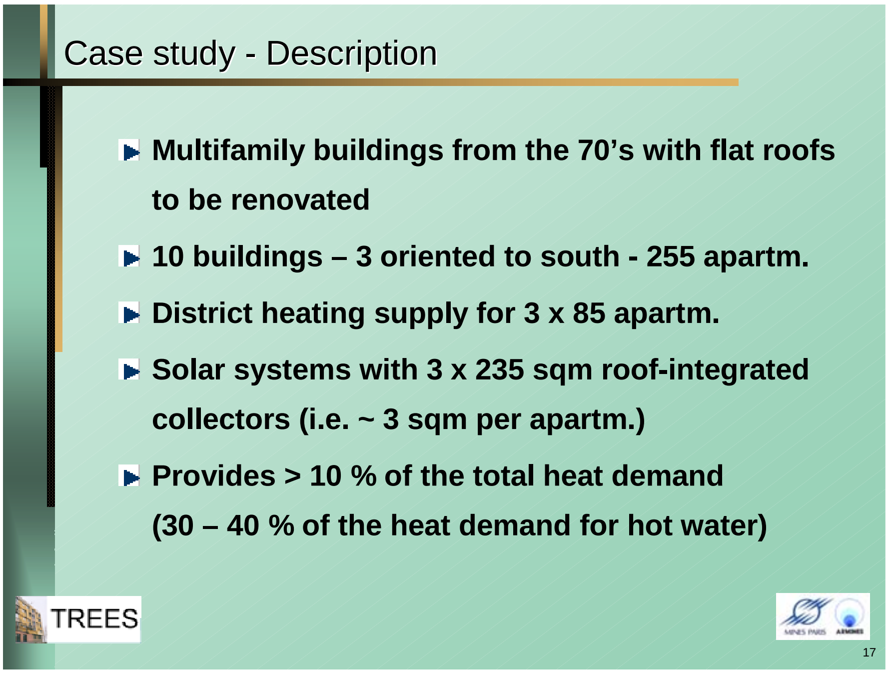
In the case with district heat supply and district heating sub stations it is also possible to connect the solar system to the primary district heating system via a plate heat exchanger. The advantage is that the solar collectors can be located on the most feasible roof and the solar heat can be used for connected buildings. The disadvantage is that the solar collectors have to work on a slightly higher temperature, as they have to meet the district heat supply temperature (typically 60-70 degC) using a constant temperature (variable flow) control.

The case with individual domestic hot water heaters in every apartment requires the installation of a central hot water system or at least a heat distribution system in the building. The installation of individual solar systems may be feasible in some cases but is not recommended in general.

CASE STUDY

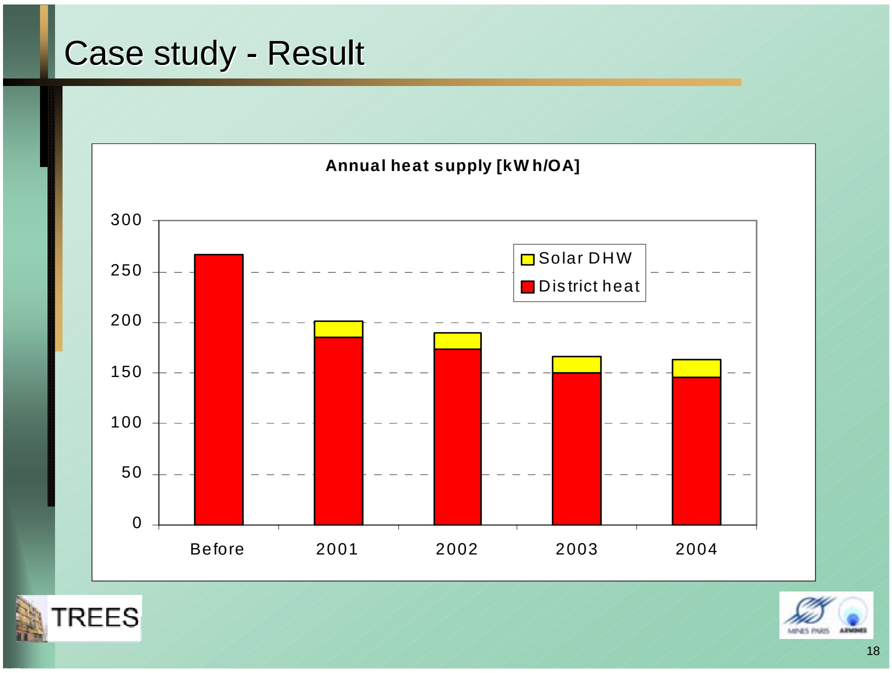
The case study describes a residential building area from the 1970's with 255 apartments in 10 multifamily buildings.



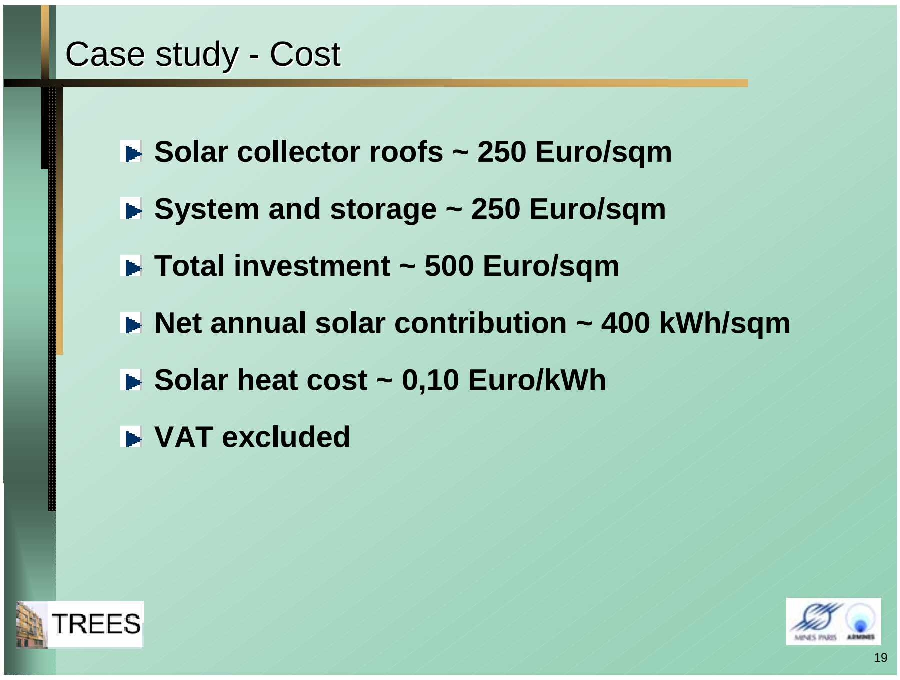


The building area is heated by district heating connected in three sub stations, each supplying 85 apartments. Three out of 10 buildings are oriented to the south and equipped with 235 m^2 roof-integrated solar collectors each for pre-heating hot water, i.e. 235 m^2 of collectors per 85 apartments or about 3 m^2 of collectors per apartment.

The district heating supplied before renovation amounted to 270 kWh per year and m^2 heated floor area. The renovation measures have gradually lowered the required district heating supplied to 145 kWh per year and m^2 heated floor area.



The influence the solar heating system amounts to 17 kWh/m^2 heated floor area. The solar system yields about 100 MWh per year or 400 kWh per year and m^2 of collector area.



The marginal cost for the solar collector roofs amounts to 250 Euro/m^2 collector area. The extra cost for the solar heating system with buffer storage, heat exchangers, pumps and controls amounts also to about 250 Euro/m^2, i.e. the total cost is about 500 Euro/m^2 collector area (excl. VAT).

There are different ways to calculate the solar heat cost, one way is to use the annuity method and calculate the average annual cost of the system and relate the average annual cost to the average annual thermal yield of the system.

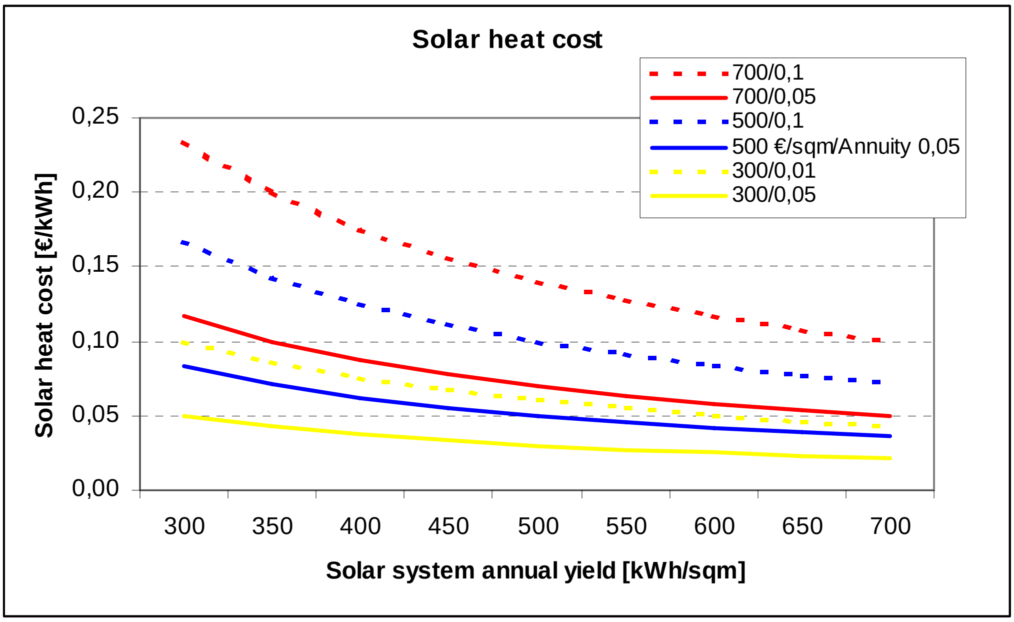
The average annual cost is calculated by multiplying the investment cost with the annuity factor, e.g. 0,0872 with 20 years depreciation time and 6% interest (See Table). The average annual cost for the investment cost in the case study is thus 500 x 0,0872 = 43,6 €/sqm of collector area.

The average annual thermal yield is 400 kWh/sqm of collector area and the average solar heat cost is thus 43,6 / 400 = 0,109 €/kWh.

Table. Annuity factors.

Year	2%	4%	6%	10%
15	0,0778	0,0899	0,1030	0,1315
20	0,0612	0,0736	0,0872	0,1175
25	0,0512	0,0640	0,0782	0,1102

The solar system is cost effective if the solar heat cost is less than the average annual cost of the alternative heat supply. As the alternative heat cost probably will increase over time, this should be taken into account. This can be done in an approximate way by reducing the interest rate with the expected annual heat cost increase, e.g. if we expect 2% annual increase and the interest rate is 6 %, we can use the annuity factor for 6 – 2 = 4 % and use the present alternative cost in the comparison. In this case the average solar heat cost would be 500 x 0,0736 / 400 = 0,092 €/kWh.

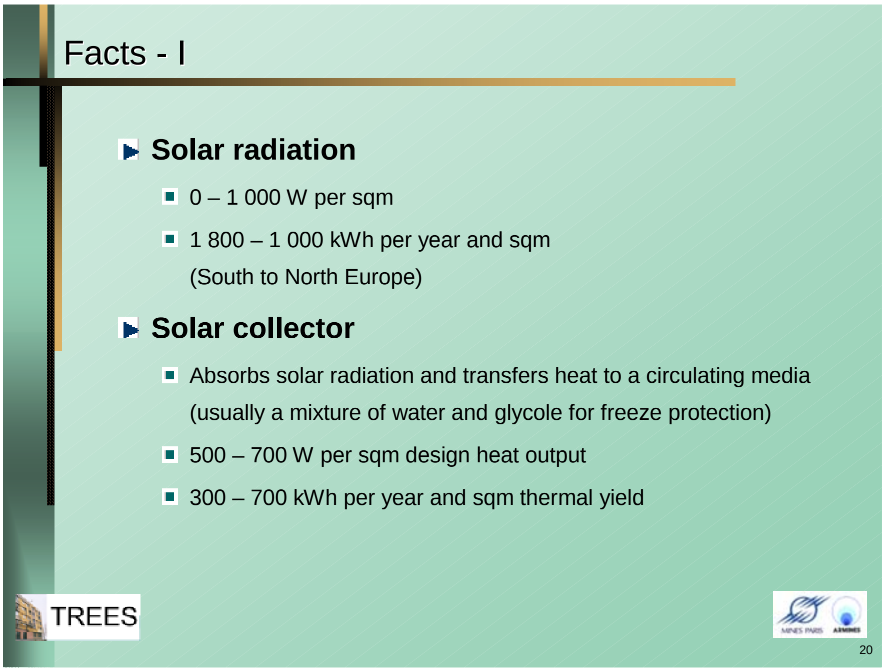


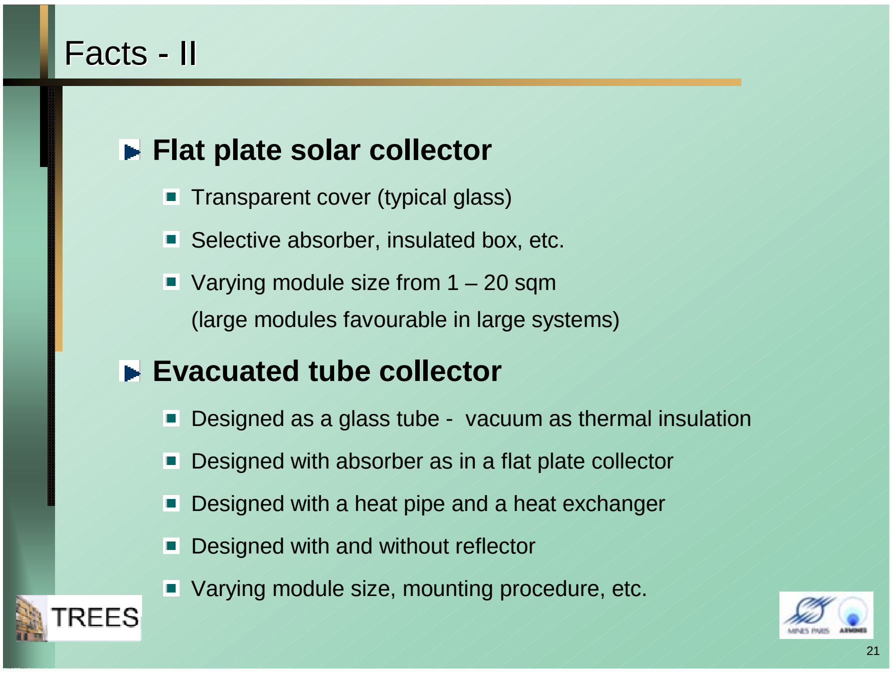
Solar heat cost as a function of specific investment cost, annuity and thermal yield.

The solar heat cost is strongly related to the cost of the system, the thermal yield and the economic conditions (depreciation time, interest rate and alternative heat cost).

The diagram shows the influence of investment cost, thermal yield and economic conditions (annuity) on the solar heat cost. Lowering the investment cost from 700 to 300 €/sqm collector area will have a similar influence on the solar heat cost as increasing the thermal yield from 300 to 700 kWh/sqm collector area. The applied annuity will have an even stronger influence on the solar heat cost.

FACTS



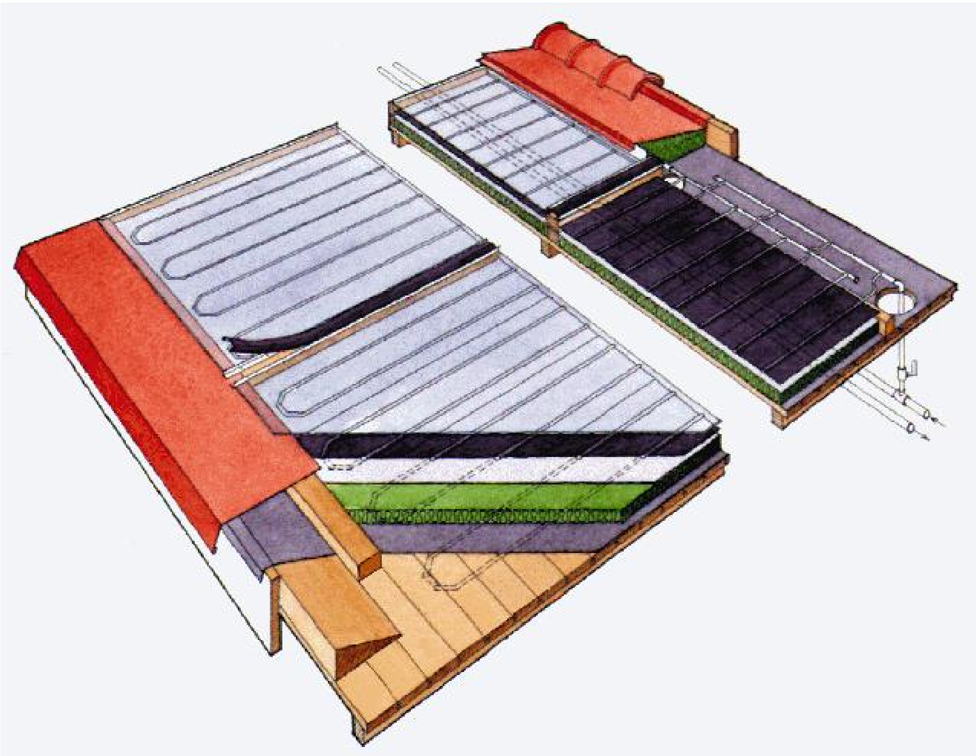


The solar radiation has in principle the same intensity all over the globe with a maximum of about 1 000 W/m^2. The annual solar radiation varies in principle with the latitude but also with the local climate from about 1 000 to close to 2 000 kWh/m^2 on a tilted south-facing surface.

The steady state efficiency of a glazed solar collector is of the order of 50-70%, i.e. the steady state thermal yield of a glazed solar collector is of the order of 500-700 W/m^2 collector area, depending on the solar radiation and the operational conditions.

The annual efficiency of a glazed solar collector is of the order of 40%, i.e. the annual thermal yield is of the order of 300 to 700 kWh/m^2 of collector area, depending on the location, the local climate and the operational conditions.

Flar plate collector (FPC) module. Photo: Wagner&Co/ESTIF



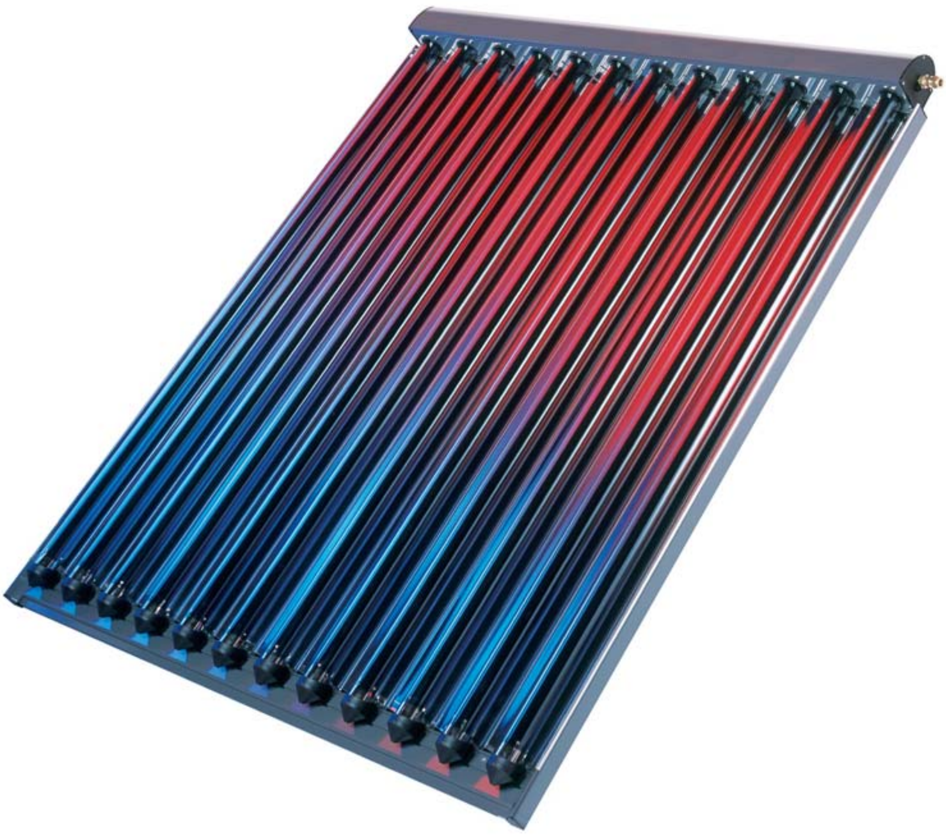
Roof module collector or solar roof module. Derome©.

There are two main types of glazed solar collectors, so-called flat plate collectors (FPC) and so-called evacuated tube collectors (ETC). The FPC can be ordered in different sizes from 1 to about 20 m^2 (for large systems).

The FPC consists of a transparent cover and an absorber (typically cupper or aluminium) mounted in an insulated box. The absorbed heat is transferred from the collector using a heat transfer fluid that is circulated in the pipes in the absorber.

The solar roof module used in the case study is designed as a typical flat plate collector designed as a roof module that can be placed directly on the roof trusses. The width of the roof module is 2 400 mm (standard distance between roof trusses in Sweden) and the length of the module can vary in steps of 600 mm.

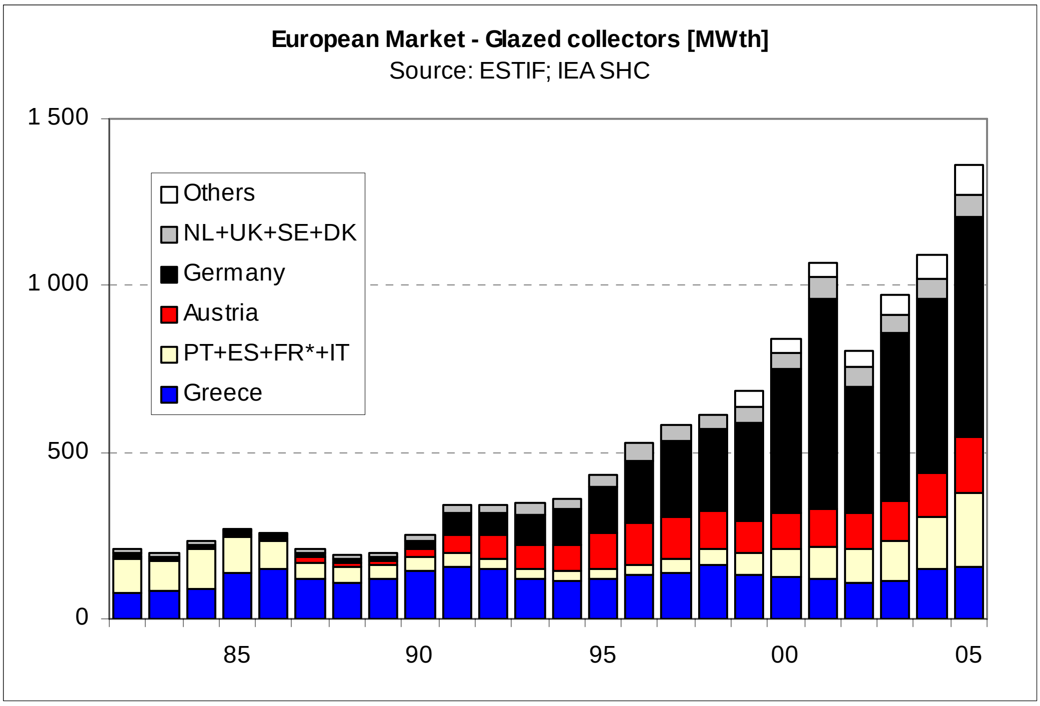
The ETC consists of one or two glass tubes and an absorber. Thermal insulation is provided by keeping vacuum in the glass tube. The absorbed heat is either transferred from the collector using a heat transfer fluid circulated in the absorber or using a refrigerant and a heat transfer fluid circulated through a heat exchangers placed in the top of the tube. The ETC is mounted in frames with varying length.



Evacuated tube collector (ETC) module. Photo: Ritter/ESTIIF.

The best ETC may have a slightly higher annual thermal yield than the best FPC, but the choice of collector type should mainly be based on the aesthetics and the cost of the system.

The European market for glazed solar collectors shows about 10% increase per year the last decade. The market is dominated by Germany but the market penetration is highest in Austria and Greece.



European market for glazed solar collectors. 1 000 MWth ~ 1 430 000 sqm

The market is dominated by solar domestic hot water and combi systems for single family buildings but the number of systems for multifamily buildings, hotels, etc. is increasing.

There are several hundreds of solar heating systems for multifamily buildings in Europe. The following table shows those with > 500 sqm of roof mounted or integrated solar collectors on new and existing multifamily buildings.

There are two other types of solar collectors, unglazed flat plate collectors (typically rubber or plastic) used for pooling heating and concentrating collectors used in high temperature applications (> 100 degC).

It is recommended to require and apply solar collectors certified with Solar Keymark, a European product quality label based on tests according to CEN-standards.

Table: 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
Hågaby, 1998-	Uppsalahem AB, SE	Exist	930
Henningsdorf, 2002-	Stadtwerken Henningsdorf, DE	Exist	856
Hammarkullen, 1985-	Gbg Bostads AB, SE	Exist	850
Ekerö, 1997-	Ekeröbostäder AB, SE	Exist	800
Attenkirchen, 2002-	Gemeinde Attenkirchen, DE	New	800
Ostrava, 2004-	Ostrava Health Centre, CZ	Exist	761
Brandaris, 1999-	Patrimonium WS Amsterdam, NL	Exist	760
Carlsheim, 2003-	Stadtwerke Carlsheim, DE	New	750
Särö, 1989-	EKSTA Bostads AB, SE	New	740
Kruitberg, 2003-	Patrimonium WS Amsterdam, NL	Exist	720
Nordhausen, 1999-	SK GmbH Nordhausen, DE	New	717
Oederan, 1994-	SWG Oederan mbH, DE	Exist	700
Echirolles, 1999-	OPAC 38 - FR	Exist	689
Henån, 1997-	Orust kommun, SE	Exist	685
Älta, 1998-	HSB Brf Stensö, SE	Exist	600
Heemstede, 1998-	Stichting De Hartekamp, NL	Exist	520
Steinfurt-Borghorst, 1999-	W & T Bau GbR - DE	New	510

ADDRESSES

European Solar Thermal Industry Federation – ESTIF – www.estif.org

System design software T*Sol – www.valentin.de

SOLARGE – EC project with examples and guidelines related to solar heating systems in multifamily buildings etc – www.solarge.org