

**MicroCHeaP Literature Search: Solar Energie**  
**Investigation related to Solar energy**  
**Contributed by FHG-ISE**

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**MICRO-CHEAP LITERATURE SURVEY**  
**CONTRIBUTION OF FHG-ISE**  
INVESTIGATION RELATED TO SOLAR ENERGY

## 1. SOLAR ENERGY OVERVIEW

### *1.1. Photovoltaic (solar electric)*

#### 1.1.1. Description of technology and system

Photovoltaic (PV), as the word implies (photo = light, voltaic = electricity), converts sunlight directly into electricity. Once PV was used commercially almost exclusively for space applications and small appliances, such as pocket calculators. Now, higher power ranges have become technically and economically viable because of growing experience in PV system design and lower prices of modules. The output power ranges from milliwatts to megawatts due to the modularity of PV systems. Driven by large market introduction programs, an increasing share of PV capacity has been installed in grid-connected applications. Recently, these have exceeded 50% of the overall PV market in 20 International Energy Agency member countries. Due to strong interest in PV technology, further growth of grid-connected systems is expected although in the long term the larger economic potential may be found in off-grid power supplies. Indeed it has been estimated that approximately 2 billion people live remote from the electric grid. Reports show that autonomous power supplies based on PV or PV hybrid systems<sup>1</sup> run cheaper than diesel generator systems in many of these cases.

#### 1.1.2. System components

Grid connected PV systems usually comprise one or several PV modules, an inverter, a power metering system and systems related to safety of operation. The most common system is shown in Fig. 1. A number of PV modules are connected in series to form a string, typically with output voltages at the maximum power point MPP of 700V. One or more parallel strings are connected to one inverter feeding the power into the grid.

Modules consist of cells (e.g. 36 or 72) usually made of semiconducting materials such as silicon. Crystalline silicon solar cells constitute approximately 90% of the market share of PV modules. The sunlight into electricity conversion efficiency varies from several percent (for some thin-film modules) to approximately 16 or 17% for monocrystalline silicon solar cells. Typical module sizes for grid connected systems range from 50 to more than 300W. The performance of PV modules depends strongly on their operation temperature. Depending on the technology used, the temperature coefficient is between -0.2 and -0.5%/K. Therefore, factors such as the type of installation (e.g. roof integration or stand-off mounting) and the degree of rear ventilation play a great role for the system efficiency.

Inverters are devices that convert the DC output of PV or batteries in stand-alone systems to AC electricity, which is to be delivered to the loads or will be fed into the grid. There are many different types of power electronic concepts used for inverters in the market.

The daily and seasonal solar irradiation and therefore the generation profile of PV systems strongly depends on the geographic location. Since for central Europe times with medium or moderate irradiation are quite frequent, inverters are usually selected with high efficiency at partial load. Their efficiency value should exceed 90% at 5% of nominal load. For economy and efficiency reason, PV inverters are chosen with a nominal power rating near or slightly below the peak power of the PV generator. Depending on regulations and inverter power, either one-phase or three-phase inverters are used. They should deliver electricity with high voltage and current quality and be capable to bear an overload of 20-30% for short periods of time. They should display precise and robust MPP tracking abilities and must provide functions to supervise the grid as well as other safety mechanisms.

To meter the electricity generated, either an extra meter is installed or the electricity is fed, for example, into the house wiring that supplies existing loads. In the latter case, if PV generation exceeds the actual load, either the meter runs backwards or an extra meter measures the excess electricity (net metering). The generation cost of PV electricity in grid-connected systems varies between approximately 30 € in sunny regions and 60 € in northern

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<sup>1</sup> Autonomous electricity supply system based on at least two sources of electricity, such as photovoltaic, wind, or diesel generator, always including a battery storage.

Europe if good practice is assumed. In grid-connected systems, the PV modules contribute the largest share of life cycle cost.

Grid connected systems either might be installed at the roofs or facades of buildings with typical system sizes from 1 to 10 kWp (some even higher) or as open land installations with system sizes up to several megawatts nominal power. While the majority of smaller house installations is owned and operated by private people, the very large systems are mostly run by holding companies or other commercial actors, like utilities.

Regarding safety, technical standards, and thus system layouts and inverter concepts, differ from country to country. Whereas in the United States earthing of the generator is mandatory, in European countries the use of isolated modules (safety class II) is standard. In addition to earthing, protection against islanding as well as fault current detection in systems with transformerless inverters are mandatory. Islanding is a phenomenon in which during a power blackout or intended interrupt (e.g. for maintenance of the grid) distributed power sources such as PV systems keep a grid segment—an island—alive. This situation is quite unlikely, yet could pose a certain danger to users, maintenance personnel, and equipment. With certified hardware equipment and maintenance personnel following the safety rules, PV systems do not pose any danger.

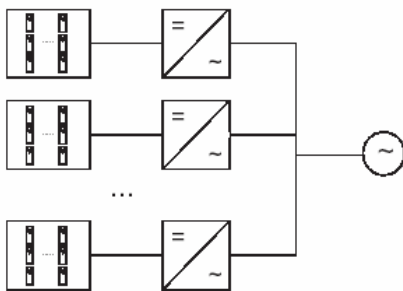


Fig. 1: Configuration of a grid-connected PV system consisting of several strings (Source: Fraunhofer ISE)

### 1.1.3. State of the art

#### *Silicon wafer solar cells*

This kind of solar cell is made of mono or multicrystalline silicon wafers. Commercial cells display an efficiency value between 13 and 17%, while laboratory cells achieve 24,7%. This kind of cells dominate the market place with more than 90% of share. Since 1991, costs have been reduced by approx. 60%. Nowadays, modules have a warranty of 20 years at least.

#### *Thin film solar cells*

This group encompasses mainly amorphous silicon, copper indium diselenide (CIS) and cadmium – tellurid (CaTe) cells. In this technology, the material is deposited on a low-cost substrate such as glass. Efficiency ratio achieve between 5 and 15%. This cell family has reached approx. 7% in share of the market place.

#### *Concentrator solar cells*

Photovoltaic concentrator systems offer the interesting option to significantly reduce the area of actual solar cell. Through the up to 1000 times optically concentrated sunlight, the need for cell area drops dramatically. As a consequence high-efficient but in the same time very expensive III-V semiconductors can become economically viable. Building upon experience gain from space applications, concentrating systems have reached a pre-commercial state.

#### *Module technology*

Module technology has reached high standards since the 90's. Warranty time awarded by manufacturers usually exceeds 20 years. Nowadays, mostly glass-glass or glass-foil laminate are used. Cells are encapsulated in EVA laminate.

### *Grid-connected systems*

Commercially available inverters display annual average efficiencies of up to 96%. Costs for inverters, wiring and erection systems have dramatically dropped in the last years. Mature products and system concept and proven business plans are now available.

#### 1.1.4. Trends and problems

##### *Bottleneck in the supply of solar silicon*

Feedstock of the solar cell production used to be the off-grade material from the electronic industry. However, the soaring growth rate of PV will probably lead to a bottleneck situation in 2005 in the silicon supply chain. Beside the usage of high-efficient manufacturing process in terms of material consumption, it is suggested to organise a specific supply branch for “solar silicon”. This problem may be alleviated in 2007 when new silicon factories will be operated.

##### *Price targets*

Price targets of 2 €/Wp have been set for the year 2010. In 2020, it is believed that the retail price will amount to less than 1 €/Wp. The prerequisites are:

- decrease of the wafer thickness while the conversion efficiency is increased thanks to better manufacturing processes,
- Improvement of the module's lifetime.
- Costs reduction through innovative mass production
- R&D efforts towards specific system components

##### *Fundamental research*

New cell concepts are expected to arise from today's fundamental research projects that will have a major impact on the performance ratio and the costs. Among them are innovative technologies such as dye and organic solar cells. Commercial maturity is not expected before many years.

## **1.2. Solar thermal energy**

### 1.2.1. Description of technology and system

The solar thermal system collects energy from the sun and converts it into heat and transfers it to water or air. Solar thermal systems are usually designed for automatic daily and year round operation. This chapter will primarily handle the active solar thermal systems with external water storage tank (see Fig. 1) since these are the most common system in homes in middle and north Europe and have been used for 30 years.

The technical economical potential for solar thermal is estimated at 1.4 billion m<sup>2</sup> (EU -15) of installed collector area. The energy amount delivered would then correspond to approx. 6% of the EU final energy consumption. At present, only 1% of this potential has been realised so far.

The commercial prospect of solar thermal energy in Europe is indeed very good. The markets have shown substantial growth over the past decade. On average the glazed collector area in operation increased by approx. 12% per year and the market volume (i.e. newly installed collector area) grew by 25% in 2003 compared to 2002. The collector area in operation is highly concentrated in three countries: Germany, Greece and Austria account for more than 80% of the EU total. Relating the glazed collector area in operation to the population, the leading role was taken on by Greece (264 m<sup>2</sup> per 1.000 capita) and Austria (203 m<sup>2</sup>). However EU average amounts only to approx. 26 m<sup>2</sup>. In recent years there has been a trend towards levelling the big differences between the frontrunners and the countries lagging behind. Spain, Italy and France have been growing faster than the EU average, whereas Austria and Greece have stagnated at a high level. With approx. 1 million m<sup>2</sup> of thermal collectors installed in 2004 and a growth rate expected to exceed 30%, Germany remains the biggest marketplace in Europe for this technology.

Solar thermal can be successfully implemented at all latitudes. Some of the strongest markets (Germany, Austria) are not situated in particularly sunny regions, whereas for instance Southern Italy is clearly lagging behind. Factors like general awareness of the environment, public support (financial, regulative, campaigns) and the quality of the products/services offered by the industry have proven to be at least as important as climatic conditions.

Systems are differentiated according to their application:

- System for domestic hot water (DHW) production: sized in order to meet the heat load for hot water during summertime, it usually covers between 15 and 25% of the total annual heat load of the building. This category is subdivided into DHW thermo-siphon systems that use gravity to circulate the heat transfer fluid (e.g. water) from the collector to the tank and into forced circulation systems where the fluid is pumped. DHW systems for a single-family house have typically a 3-6 m<sup>2</sup> collector area and a 150-400 litres tank.
- Combined DHW and space heating system: generally with a bigger collector area, it tends to cover between 25 and 35% of the total annual heat load of the building. The collector size of these so called combisystems is typically in the range of 7-20 m<sup>2</sup> and the tank in the range of 300-2000 litres. Its market share approaches 20% in Germany and 50% in Austria.
- Collective DHW systems: designed for multiple-family houses, apartment blocks, hotels, office buildings etc. their surface varies from ten to several hundred square meters.

### 1.2.2. System components

The main component of a solar thermal system is the collector that converts the incident radiation into useful heat. Glazed collectors are the most common type in Europe. Two different designs exist for glazed collectors: flat plate collectors and evacuated tube collectors. Fig. 2 illustrates the flat-plate design. These collectors are usually rectangular boxes covered by glass and containing a heat absorbing material inside. The absorber typically consists of copper or aluminium and is treated to better absorb the heat. Such treatment ranges from simple black paint to special selective coatings. Little tubes, which carry the heat transfer fluid are built in or welded on the absorber plate. The heat transfer fluid is typically water or a water/glycol solution, that prevents the collector from freezing. When striking onto the glass front, part of the sunlight is reflected (optical losses). The transmitted radiation is then caught by the absorber and transferred to the heat transfer medium (useful heat). The back of the collector is equipped with an insulation layer to decrease the heat losses with the ambient (thermal losses). In a evacuated tube collector, the thermal losses have been reduced by a quantum leap, since the absorber is enveloped by vacuum (see Fig. 3). The collector consists of long glass tubes which are usually mounted in parallel in one row. Reflectors devices concentrate the rays towards the absorber. This design is therefore suitable for higher temperatures.

Collector efficiency depends strongly upon both optical and thermal losses. Modern flat-plate collector displays an conversion efficiency of 80% that drops rapidly when the temperature difference between heat transfer fluid and surrounding increases. An evacuated tube collectors displays approx. 70% conversion efficiency but this value remains nearly constant against the growing temperature gap.

Unglazed collectors have been used for 30 years, mainly to heat open-air swimming pools. The collector consists of a set of long black thin tubes made of synthetic material (commonly EPDM). The solar system is directly connected to the hydraulic circuit used to filtrate the pool water, which is heated when flowing through the collector. Unglazed collectors for swimming pools are relatively cheap and easy to install.

Usually in forced circulation systems the collector is placed on the roof or on the facade while the hot water storage tank is placed in the boiler room. The collectors can be attached on the house's roofs, both on pitched roofs or on flat roofs. While a south-facing slope (on the northern hemisphere) would be ideal, a roof surface facing east or west will also be fine in most cases. In the latter case, special mounting systems, usually made of steel or aluminium, will typically have the collectors tilted at 45 degrees (in moderate climate zones like Germany). Similarly, the collectors can also be placed on the ground.

Collector and tanks are connected via insulated pipes. The heat transfer fluid is displaced by an electric pump that is control by a on-off controller, that surveys the temperature difference between collector outlet and tank bottom. The tank is equipped with an internal heat exchanger in order to avoid any contact between the water/glycol mixture and the drinking water. The heat exchanger is generally manufactured entirely from copper. It consists of several copper coils. All connections are brazed and are external to the shell.

In a regular household the solar system is perfectly capable of providing on its own the necessary heat to produce hot water during summertime even in moderate climate zones (like Germany). The water stored in the hot water

tank is enough to bridge some dull days in summer. In winter, an additional conventional boiler (usually running on heating oil or natural gas or wood) guarantees a constant supply of hot water, while making use of the solar collector as much as possible, thus considerably saving energy costs also during winter. Particularly low consumption of the back-up fuel can be reached when the burner is directly integrated into the solar tank.

The contribution of the solar thermal system is evaluated while considering the energy path depicted in Fig. 4. It is useful within a system analysis to express the solar contribution to a combined system in terms of fractional reduction in the amount of conventional energy usage. The solar fraction relates the effectively used solar heat, i.e. the solar system yield, to the total heat consumed.

$$\text{solar fraction} = \frac{\text{solar system yield}}{\text{solar system yield} + \text{auxiliary heat consumption}}$$

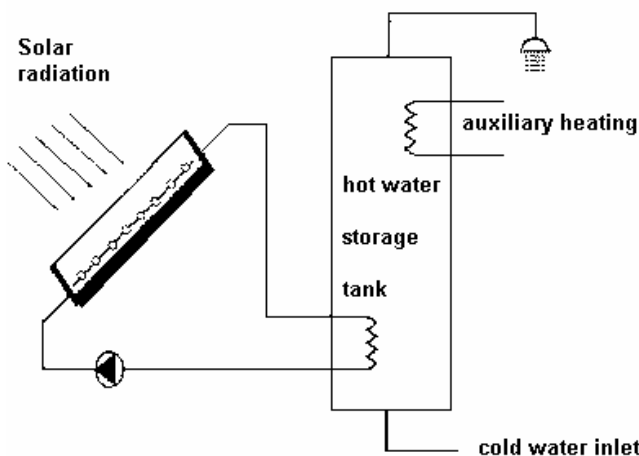


Fig. 1: Solar thermal system for hot water production with two circuits and internal heat exchanger (Source: Fraunhofer ISE)

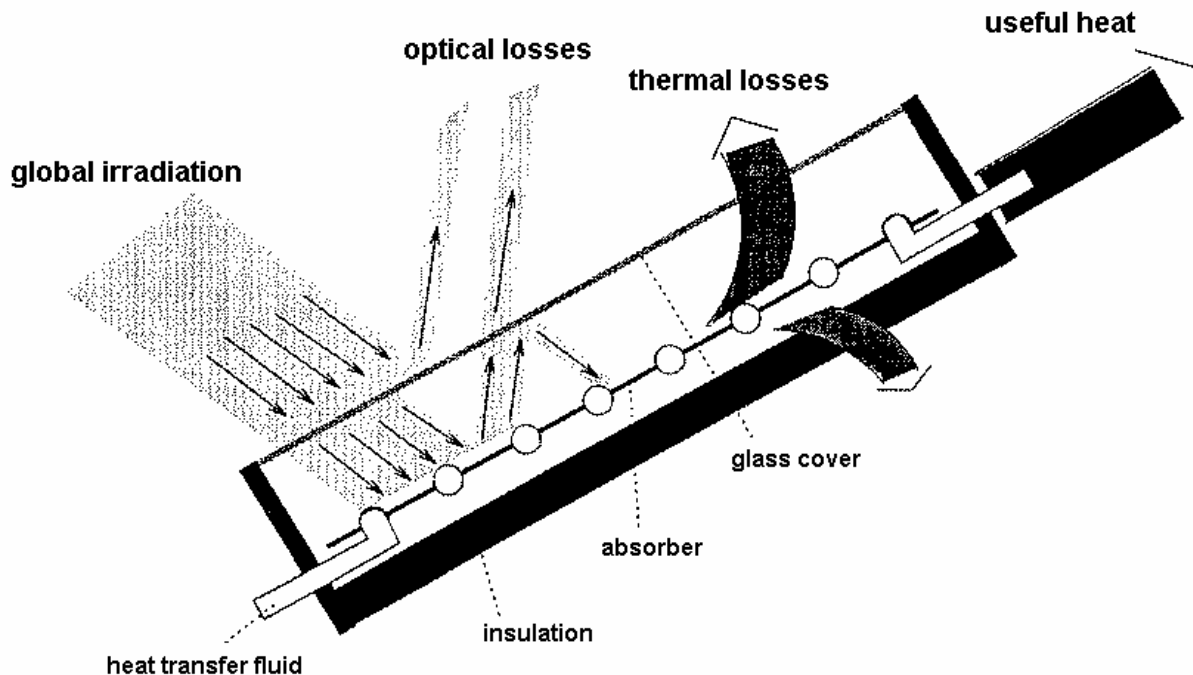


Fig. 2: Energy flow in a flat plate collector: Irradiation, optical and thermal losses, useful heat (Source: Fraunhofer ISE)

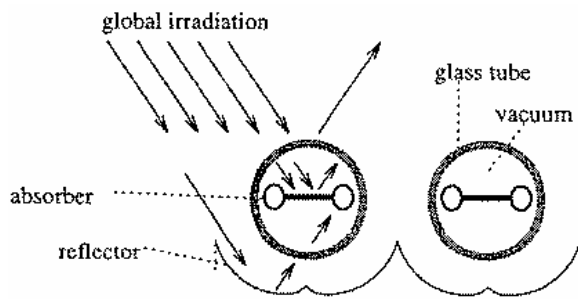


Fig. 3: Path of the irradiation within an evacuated tube collector (Source: Fraunhofer ISE)

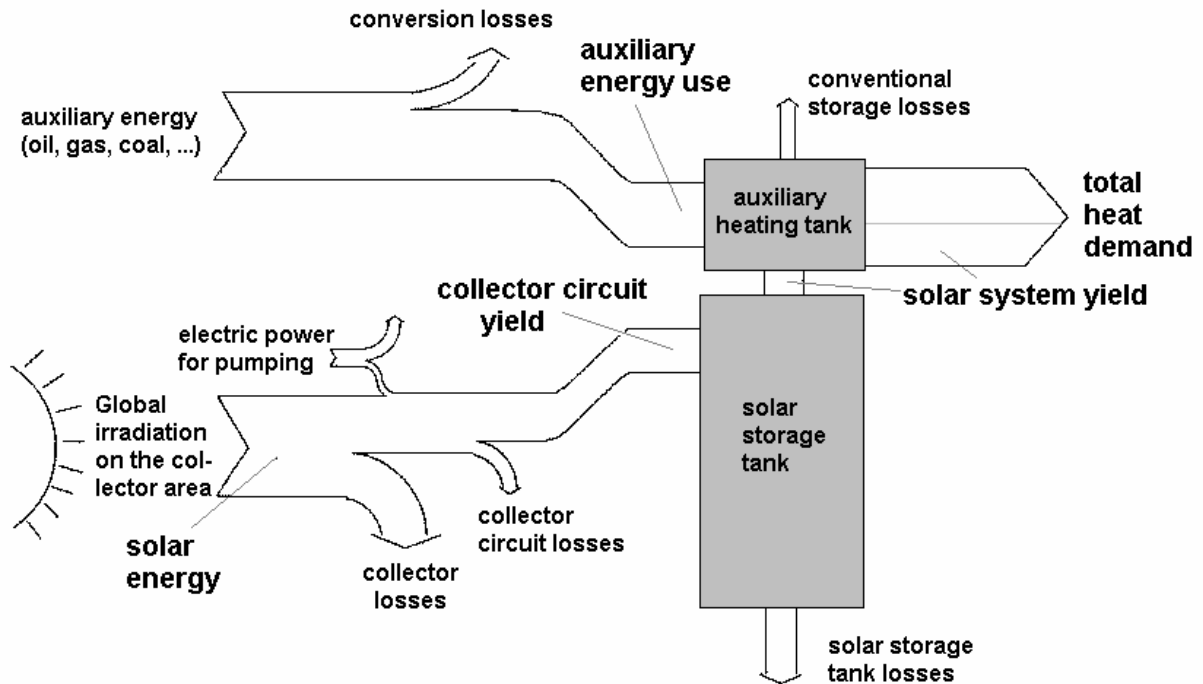


Fig. 4: Energy flow path from the sources to the user (Source: Fraunhofer ISE)

### 1.2.3. State of the art

#### *High-efficiency absorber coating*

Spectral-selective absorber coatings favour the absorption of the sun rays while diminishing the heat losses by re-radiation by lowering the emissivity of the absorber in the infrared bandwidth.

#### *Absorber production techniques*

High automation level in the production process from the copper foil coil up to the finishing of the absorber leads to low costs and high-quality products. High reliable bracing and laser or ultrasonic welding techniques are used to guarantee a lifetime of at least 20 years.

#### *Micro-climate in collector space*

Natural airing of the collector's inside avoids the condensation of steam on the front glass at low surrounding temperature, thus increasing the readiness for operation of the module, especially in the morning.

### *Backside heat insulation*

New mineral wool insulation material with low cement content is used as rear insulation layer. The concentration of cement in the insulation layer facing the absorber is very low. This reduces the vaporisation risk of the cement inside the collector box due to high absorber temperature. This removes the danger of condensation of the organic compound vapour on the front glass.

### *Module size and roof and facade integration*

Collectors can nowadays be produced in almost all sizes and shapes. They are lighter and easier to transport. They can easily be mounted and even integrated in roof tops and facades, replacing completely the roof tiles or the wall outer rendering.

### *Sun glazing*

Glass cover technology has reached high transmission efficiency. Less solar rays are absorbed by the front window and more radiation is transferred to the absorber.

### *European standards and testing procedures*

In many EU-countries, the granting of financial incentives for solar systems is bound to the installation of solar components that respond to the EN technical requirements and that bear a certification mark.

#### EN 12975 - Thermal solar systems and components - Solar collectors

The document specifies requirements on durability (including mechanical strength), reliability and safety for liquid heating solar collectors. It also includes provisions for evaluation of conformity to these requirements. It is not applicable to those collectors in which the thermal storage unit is an integral part of the collector to such an extent, that the collection process cannot be separated from the storage process for the purpose of making measurements of those two processes. It is not applicable to tracking concentrating solar collectors.

#### EN 12976 - Thermal solar systems and components - Factory made systems

The document specifies requirements on durability, reliability and safety for factory made solar systems. The document also includes provisions for evaluation of conformity to these requirements. The requirements apply to factory made solar systems as products. The installation of these systems itself is not considered, but requirements are given for the documentation for the installer and the user which is delivered with the system. Moreover, the document specifies test methods for the validating the requirements for factory made systems as specified in EN 12976-1. It also includes two test methods for thermal performance characterisation by means of whole system testing.

#### EN ISO 9488:1999 - Solar energy - Vocabulary

## 1.2.4. Trends and problems

### *Price targets*

A collector array of 4-5 m<sup>2</sup> and a hot water storage tank of 300 l is normally sufficient to satisfy the need for hot water of a family of four in summer. In winter, the solar system is used for pre-heating and the auxiliary heating system provides the major proportion. The system efficiency of such a real system can achieve 40%. The solar heat cost amounts approx. to 0,38 EUR/kWh (2000 prices). If the collector area is expanded to, say, 15 m<sup>2</sup> with the goal of assisting in room heating, the solar fraction may achieve 60% and the solar heat cost 0,24 EUR/kWh.

Larger DHW systems are generally designed for a low solar fraction (low solar coverage of the hot water demand) and operate on a lower temperature resulting in a high system performance (thermal output/m<sup>2</sup> of solar collector). Most large DHW systems are designed with forced circulation but multiple thermo-siphon systems are also used when the conditions are suitable.

### *Fundamental research*

The newly developed anti-reflex glazing displays very high transmission efficiency so that double pane cover glazing has become a viable option to reduce even more the heat losses by convection of the collector box. This

pave the way for low-cost glazed collectors to new application fields such as middle temperature process heat (water desalination, ...).

As a result, even flat plate collectors are able to reach temperature higher than 100 °C and therefore are subject to boiling. This leads to an increase of the stagnancy time of the system. A current topic of research is to better understand the boiling phenomenon inside the collector and to develop control strategies that prevent the collector from boiling but allow high outlet temperature.

## 2. PUBLICATIONS IN JOURNALS

In recent years, a vast amount of literature has been published, covering all aspects of Solar energy and associated technology. However, within the framework of MicroCHeaP, attention is set to focus on topics as thermal and electrical application, system design, converter technology, and some general aspects of solar energy.

Fruitful search words for a literature survey into the field of solar energy systems are ‘solar’, ‘PV’, ‘solar system’, ‘solar collector’ and ‘solar thermal’. A selection of journals, encyclopaedias or periodics are proposed below: :

### **Photovoltaic**

1. T. Meyer, “Photovoltaic Energy: Stand-Alone and Grid-Connected Systems”, Encyclopaedia of energy; 6 print volumes; ISBN 0-12-176480-x; Elsevier; 2004
2. *Solar Energy Materials & Solar Cells*, journal published by Elsevier B.V. It is devoted to Photovoltaic, Photothermal, and Photochemical Solar Energy Conversion

### **Solar thermal**

1. *Applied Thermal Engineering*, journal published by Elsevier B.V. The Journal deals with system designed of advanced processes related to a large range of equipment while economics plays a necessary role in the assessment of many thermal engineering projects.

*Solar Energy* is the official journal of the International Solar Energy Society (ISES) and is devoted exclusively to the science and technology of solar energy applications. It is targeted to engineers, scientists, architects and economists active in the fields of systems, components, materials and services for applications of solar energy.

*Journal of Solar Energy Engineering* is a journal of the American Society of Mechanical Engineers (ASME). It publishes technical papers and briefs on all aspects of solar-derived energy, including both active and passive solar applications.

The *Journal of Atmospheric and Solar-Terrestrial Physics* is an international journal concerned with the inter-disciplinary science of the Sun-Earth connection,

*Photon, Das Solarstrom-Magazin* (Solar Verlag) is a periodical in German that deals with all kind of issues related to PV.

*Solar today* is a bimonthly magazine — published by the American Solar Energy Society, [www.ases.org](http://www.ases.org) — that covers all solar and renewable energy technologies, from photovoltaics to climate-responsive buildings to wind power and biomass. Regular topics include building case studies, energy policy and community-scale projects.

The German association Solarenergie-Förderverein Deutschland e.V. (SFV) publishes regularly a info mail named *Solarbrief* (more at <http://www.sfv.de/> )

*Solar Energy Materials* was a journal published between 1980 and 1991.

### 3. PUBLICATIONS IN CONFERENCES

The following conferences deal with solar energy topics on a regular basis:

#### **Photovoltaic**

1. OTTI Kolleg Photovoltaische Solarenergie (<http://www.otti.de>)
2. IEEE Photovoltaic Specialists Conference (<http://www.ieee.org>)
3. European Photovoltaic Solar Energy Conference
4. World Conference on Photovoltaic Solar Energy Conversion
5. International Photovoltaic Science and Engineering Conference
6. E.C. Photovoltaic Solar Energy Conference
7. Symposium Photovoltaische Solarenergie (in German)

#### **Solar thermal**

1. OTTI Kolleg Thermische Solarenergie (<http://www.otti.de>)
2. National Passive Solar Conference, organised by American Solar Energy Society
3. The European Solar Thermal Industry Federation *ESTIF* publishes on a regular basis market and trend information for Europe (<http://www.estif.org/>)

*EuroSun* is a conference organised by the ISES and held every two years. It combines an extensive congress programme with a major renewable exhibition. ([www.eurosun2006.org](http://www.eurosun2006.org))

The largest trade fair in Europe dedicated to solar systems is named *Intersolar* and takes place annually in Freiburg, Germany ([www.intersolar.de](http://www.intersolar.de)).

### 4. BOOKS

A number of books giving a good introduction into solar energy are:

#### **Photovoltaic**

1. A. Luque, S. Hegedus, "Handbook of photovoltaic science and engineering" John Wiley and Sons, 2003
2. A. Bubenzer, J. Luther, "Photovoltaics guidebook for decision makers" Berlin: Springer, 2003
3. M. D. Archer, R. Hill, "Clean electricity from photovoltaics" London: Imperial College Press, 2001
4. W. Berger, "Photovoltaics in Europe in the year 2020" Wien: Verlag der Österreichischen Akademie der Wissenschaften, 2001
5. International Energy Agency -IEA-, Solar Heating and Cooling Programme, "Photovoltaics in buildings" London: James & James, 1996
6. F. Bisschop, "Building with photovoltaics" Ten Hagen & Stam, The Hague, 1995
7. S. R. Wenham,; M.A. Green, M.E. Watt, "Applied photovoltaics", Centre for Photovoltaic Devices and Systems, Univ. of New South Wales, ISBN: 0-86758-909-4, 1994
8. F. Lasnier, T. Gan Ang, "Photovoltaic engineering handbook" Bristol: Hilger, ISBN: 0-85274-311-

4 ,1990

### **Solar thermal**

1. J. Duffie, W. Beckman, “Solar Engineering of Thermal Processes” John Wiley and Sons, 1992
2. W. Weiss (editor), “Solar heating systems for houses, a design handbook for solar combisystems”, International Energy Agency, Solar heating and cooling programme; ISBN 1 902916 46 8; James & James; London; 2003
3. A. Marko, P. Braun (editors), “Thermal use of solar energy in buildings”, Course book for the Comett project “SUNRISE” seminar, Fraunhofer Institute for Solar Energy Systems; Freiburg, Germany, 1994
4. A. Rabl, “Active Solar Collectors and Their Applications”, Oxford University Press, 1985
5. “Sun in action II - a solar thermal strategy for Europe”, European Solar Thermal Industry Federation ESTIF, volume 1 and 2, download at [www.estif.org/](http://www.estif.org/), 2003
6. W. L. Dutré, “Simulation of Water Based Thermal Solar Systems”, Boston: Kluwer, ISBN: 0-7923-1236-8, 1991
7. F. Peuser, K.H. Remmers, M. Schnauss “Langzeiterfahrung Solarthermie” Berlin: Solarpraxis, ISBN: 3-934595-07-3, 2001

## 5. SOLAR SYSTEM MANUFACTURERS AND SYSTEM INTEGRATORS

Manufacturers of solar systems suited for energy supply to buildings are (list not exclusive):

### **Photovoltaic**

1. Solar-Fabrik AG (Germany)
2. RWE Schott Solar GmbH (Germany)
3. Solar World AG (Germany)
4. Solarwatt Solar-Systeme GmbH (Germany)
5. Shell Solar (The Netherlands)
6. Alpha Solar Vertriebsgesellschaft mbH (Germany)
7. Q-cells AG (Germany)

### **Solar thermal**

1. Wagner & Co. (Germany)
2. Elco Klockner Heiztechnik GmbH (Germany)
3. Paradigma GmbH & Co. KG (Germany)
4. Solvis GmbH & Co. KG (Germany)
5. Buderus Heiztechnik (Germany)
6. Viessmann (Germany)
7. S.O.L.I.D. GesmbH (Austria)
8. MEA – Maschinen- und Energieanlagen GmbH (Austria)
9. Clipsol (France)

10. VELUX (Denmark)

11. De Dietrich Thermique (France)