Task 38
Solar Air-Conditioning
and Refrigeration

Solar Cooling Position Paper

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1. Introduction and background

It is important to mention that using solar energy in combination with active heating and cooling is not an alternative to energy efficiency measures and passive systems, which make use of environmental heat sources and heat sinks, respectively. In contrast, application of active solar heating and cooling technology should always go hand in hand with energy efficiency measures and a holistic overall design of the building and the solar assisted heating, ventilation and air-conditioning (HVAC) system will lead to an optimal solution in terms of energy balance and cost.

The introduction defines the different technical principles to convert solar energy into useful cooling and gives a brief overview on the most important thermally driven cooling technologies available on the market. Also the main arguments are summarized, which provide the motivation for the application of Solar Air-Conditioning and Refrigeration technology (in the following abbreviated as SAC technology).

1.1 Scope

Solar energy can be converted into cooling using two main principles (see Figure 1):

- Electricity generated with photovoltaic modules can be converted into cooling using well-known refrigeration technologies that are mainly based on vapour compression cycles.
- Heat generated with solar thermal collectors can be converted into cooling using thermally driven refrigeration or air-conditioning technologies. Most of these systems employ the physical phenomena of sorption in either an open or closed thermodynamic cycle. Other technologies, such as steam jet cycles or other cycles using a conversion of heat to mechanical energy and of mechanical energy to cooling are less significant.

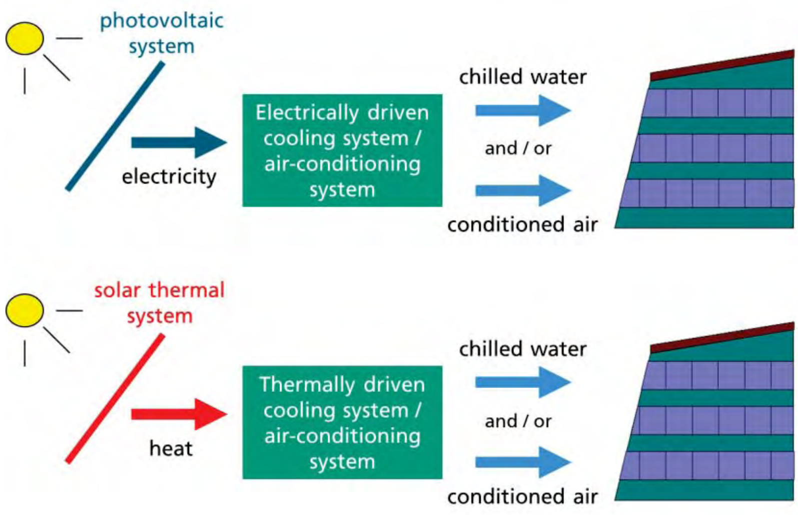
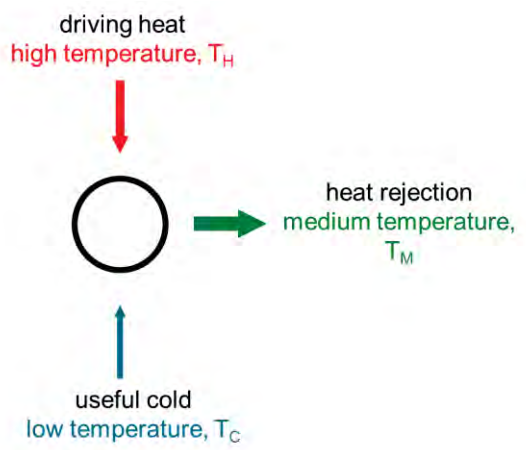


Figure 1. Principles for solar driven cooling

Today, the first principle – solar electricity driven cooling – is mainly used for solar driven refrigerators for cooling medicine in remote, sunny regions, while the second principle – solar thermally driven cooling – is mainly applied for comfort cooling and air-conditioning in buildings and first pilot installations have been realized for large capacity refrigeration applications. The first principle installed in buildings is normally not considered a “solar cooling system” today since most photovoltaic plants are connected to the electric grid and are operated completely independent from the HVAC installations used in buildings or the refrigeration machines used in industrial applications. This may change in future, for instance when the price of electricity produced with photovoltaic systems will be lower than the price that has to be paid for electricity from the grid.

Nevertheless, this position paper focuses on the dominating technology using the second principle – heat driven air-conditioning and refrigeration systems using solar thermal energy as the main driving energy. Figure 2 shows the heat fluxes and temperature levels of a thermally driven cooling system and is used for the definition of the thermal Energy Efficiency Ratio $EER_{thermal}$ (often also denoted as thermal Coefficient of Performance, $COP_{thermal}$), which is a key figure to characterise thermally driven cooling systems. Table 1 provides a brief overview on systems using sorption technology and their main characteristics.



$$EER_{thermal} = \frac{\text{useful cold at low temperature}}{\text{driving heat at high temperature}}$$

Figure 2. Heat fluxes of a thermally driven cooling system and definition of the thermal Energy Efficiency Ratio, $EER_{thermal}$. The useful cold is produced at a low temperature level, T_C. The driving heat is supplied at a high temperature level, T_H. Both heat fluxes flow into the machine and have to be rejected at a medium temperature level, T_M.

Table 1. Overview on market available thermally driven cooling systems based on sorption technology

Type of system	Water chillers (closed thermodynamic cycles)						Direct air treatment (open thermodynamic cycles	
Physical phase of sorption material	Liquid			Solid			Liquid	Solid
Sorption material	Water	Lithium-bromide		Zeolite	Silica gel	Lithium-chloride	Lithium-chloride	Silica gel (or zeolite), cellulose matrix with lithium-chloride
Refrigerant	Ammonia	Water		Water	Water	Water	Water	Water
Type of cycle(1)	1-effect	1-effect	2-effect	1-effect	1-effect	1-effect	Cooled sorption process	Desiccant rotor
$EER_{thermal}$ range	0.5-0.75	0.65-0.8	1.1-1.4	0.5-0.75	0.5-0.75	0.5-0.75	0.7-1.1	0.6-0.8
Driving temperature range, °C	70 … 100 120 …180(2)	70 … 100	140 … 180	65 … 90	65 … 90	65 … 90	60 … 85	60 … 80
Solar collector technology(3)	FPC, ETC SAT(2)	FPC, ETC	SAT	FPC, ETC	FPC, ETC	FPC, ETC	FPC, ETC, SAHC	FPC, ETC, SAHC

Comments:

1 1-effect: single-effect thermodynamic cycle (no internal heat cascade); 2-effect: double-effect thermodynamic cycle (with internal heat cascade)

2 Valid for production of cold at temperatures significantly below the freezing point of water, i.e. < 0°C

3 Abbreviations for solar thermal collector types: FPC = flat plate collector; ETC = evacuated tube collector; SAT = single-axis tracking solar collector (e.g. parabolic trough collectors or Fresnel type collectors); SAHC = solar air heating collector

1.2 Motivation

Why use solar thermal energy for air-conditioning of buildings or refrigeration applications? As a first observation it can be said that there is a large interest from end users. Making cold from heat seems to be a magical technology that appeals to many end-users.

Main arguments for solar assisted cooling (SAC) originate from an energy saving perspective:

- Application of SAC saves electricity and thus conventional primary energy sources.
- SAC also leads to a reduction of peak electricity demand, which is a benefit for the electricity network and could lead to additional cost savings of the most expensive peak electricity when applied on a broad scale.
- SAC technologies use environmentally sound materials that have no ozone depletion and no (or very small) global warming potential.

Other arguments originate from a more technical perspective:

- Solar energy is available almost at the same time when cooling is needed; this argument holds for both, solar thermal and solar electric based systems.
- Solar thermal systems used for production of sanitary hot water and heating (solar combi-systems) have large collector areas that are not fully used during summer. They can be used for SAC and thereby reduce risk of stagnation situations of the solar collector system.
- Comparatively low noise and vibration-free operation of thermally driven chillers.

After ten years of numerous activities in the field of SAC, in particular within the IEA Solar Heating & Cooling Programme but also in many other national and European R&D projects, the market penetration of SAC remains small. Therefore, it is important to take a look at the achievements and the recent position of solar cooling technology. It is also important to understand the future perspective of this technology and formulate the needs related to both R&D and market stimulation in order to exploit the potentials. This is also important in order to understand the potential of solar heating and cooling technologies (SHC) to contribute to the achievement of politically set targets in the reduction of energy consumption. The 20-20-20-targets of the European Commission are an example and it is important to identify the role of SHC within the concert of activities to achieve these targets.

This paper describes the recent position of solar cooling technology and develops an outlook about the potential and needed actions.

2. Status

The status of SAC technology is described looking at the technical maturity, energy and cost performance, and the status of market deployment.

2.1. Technical maturity

The key components of SAC systems are the solar collector subsystem and the thermally driven cooling subsystem. Additional key components are a heat rejection unit to reject the waste heat of the thermally driven chiller and storages (hot, cold).

Solar collectors and solar collector systems are common and have achieved a good status of technical maturity. For SAC systems that operate with temperatures below approximately 110°C there exists a good supply of robust, cost effective solar collectors. In the last years some new concepts of solar collectors have been developed that lead to increased safety and enhanced efficiency of the solar collection for solar cooling: examples are solar collectors operated with water and have a drainback system or night recirculation.

Solar collector systems for higher temperatures as needed for SAC that require those higher driving temperatures are still scarce, but also here an increasing number of manufacturers are entering the market. Nevertheless, solar collector systems for operation at temperatures above approximately 130°C – typically single-axis tracking with optical concentration – are still a young technology and not yet broadly applied.

Large thermally driven chillers and open sorption cycles have existed for many decades and are introduced in the market; their main operation today is with waste heat (e.g., from a co-generation system or industrial waste heat) or directly gas-fired. Typically, they are designed for operation to provide base load cooling and not specially adjusted for operation with solar energy.

In the last decade, the main progress was made in the field of small capacity thermally driven chillers and SAC has significantly contributed to stimulate this development. Today, numerous systems from various manufacturers are offered on the market and have reached a considerable technical maturity. However, most of the manufacturers are small start-up companies. Some of those companies achieved a status where they set up a manufacturing capacity on an industrial scale and others are on the way to follow.

Installation of buffer storages is quite common in SAC installations. Sizes range from small buffers to overcome short-term fluctuations up to large buffer stores used to save solar gains for a number of hours (e.g., from noon to afternoon). Storages are applied on the hot and/or cold side and are usually filled with water. In few applications, ice storages are applied on the cold side in order to increase the storage density (or in applications with cooling demand at temperatures below 0°C). Other phase change materials are still not common in solar cooling.

The main shortcoming of SAC from a technical perspective lies today on the system level. Many systems fail to achieve the planned energy savings because of shortcomings in proper design and energy management of systems that result in a high overall electricity consumption of auxiliary components. A particular area where mistakes are made is the heat rejection subsystem, which often has not received sufficient attention in the past. Another mistake made is that many systems were far too complex and as a result created non-optimal control and big maintenance efforts.

Main fields of problems from practical experiences in realized installations are:

- Heat rejection: cooling towers often need too much electricity and are not controlled for part load. Small capacity wet cooling towers are relatively expensive and need an inappropriate high effort for maintenance. Dry cooling towers need more electricity and often the re-cooling temperatures are too high for the solar thermally driven chillers. Hybrid systems (dry/wet) seem to be a promising solution, but very few systems are available on the market and they are not adjusted for combination with thermally driven chillers.
- High efficient auxiliary components and a careful hydraulic design are essential. This is particularly important as solar cooling systems need more hydraulic loops than standard solutions.
- Another technical barrier concerns the integration of all components into a complete system. The overall system design requires various professional skills for the different subsystems: solar energy at medium temperature (but higher when compared to standard sanitary hot water application), hydraulics with pressurized and medium temperature water, and air-conditioning or industrial cooling.

2.2. Energy performance

Solar cooling systems have proven to be able to save energy in comparison to conventional standard solutions. The amount of achieved energy saving strongly depends on system design and operation. Key figures that determine the achieved energy saving are the solar fraction for the heat needed to drive the thermally driven cooling and the overall electricity demand for auxiliary components, such as the fan (e.g., the fan in the cooling tower) and the pumps in the hydraulic circuits.

Figure 3 shows the dependence of the saved (primary) energy of a solar cooling system in comparison to a standard system as function of the solar fraction of the driving heat. Two types of technologies are represented: single-effect machines achieve a lower coefficient of performance, that is they produce less cooling per amount of driving heat. But, they also need a low driving temperature, typically 70-110°C, and thus allow using simple solar collector technology such as flat plate or evacuated tube collectors. Double-effect machines achieve a higher coefficient of performance, but need higher driving temperatures, typically 130-180°C, and thus require more sophisticated solar collector technology, such as single-axis tracking solar systems. System design should aim at achieving a high solar fraction, that is use almost no heat from conventional sources, such as natural gas to operate the thermally driven cooling.

In Figure 4 the influence of the electricity demand of auxiliary components on the achieved (primary) energy saving is demonstrated. Today, systems are found on the market that work with a relatively high electricity demand and thus do not save much energy or – even worse – lead to a negative energy balance, that is they consume more (primary) energy compared to a conventional system.

All the relations shown here are valid for cooling only. Typically, the overall energy balance is getting even more in favor of solar thermal systems if other heat needs are covered, such as heat for heating or sanitary hot water.

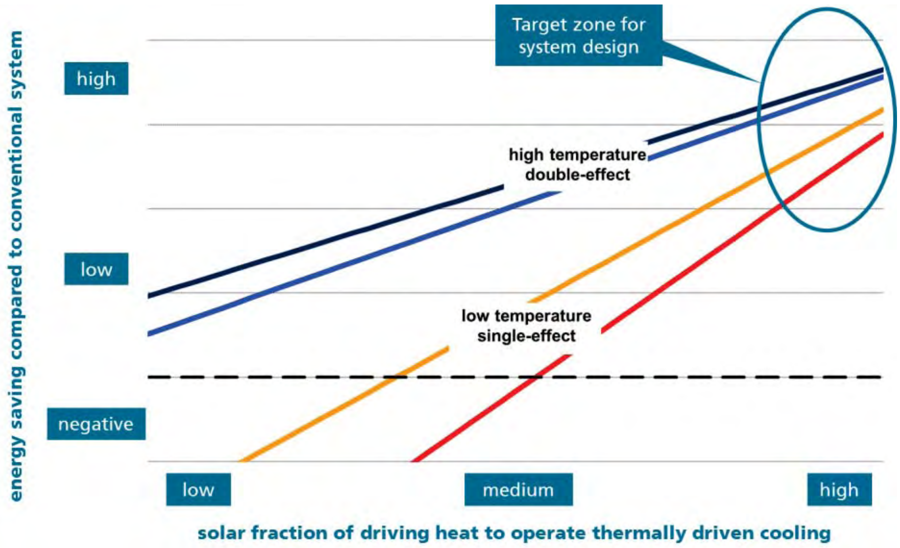


Figure 3. Energy saving compared to a conventional system versus the solar fraction of the driving heat needed to operate the thermally driven cooling

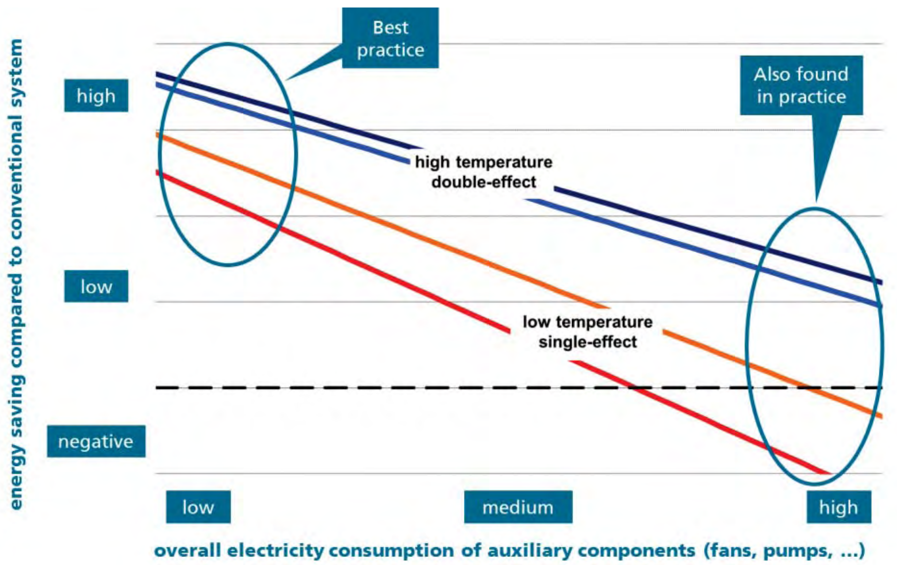


Figure 4. Energy saving compared to a conventional system versus the overall electricity consumption of all auxiliary components of the solar driven cooling system

In summary, it turns out that SAC has the ability to realize an energy efficient solution and lead to significant energy savings. Main requirements to achieve this are:

- Before the choice is made for SHC/SAC it has to be compared to other solutions in terms of energy saving and cost.
- An important design item is to keep systems as easy as possible in order to reduce risks of errors in implementation, operation, and maintenance.
- A careful design and planning is needed in order to define an optimal sizing of key components and an appropriate design fitting to the actual load structure.

- All auxiliary components have to be highly energy-efficient.
- An operation strategy has to be developed that leads to the most energy-efficient operation under full and part load conditions and best reliability on long-term operation.
- A careful commissioning phase of the system is necessary to ensure a system operation as planned.
- An ongoing monitoring ("continuous commissioning") is helpful in order to enable long-term operation at highest possible performance.

2.3. Economic viability and environmental benefits

First cost (investment cost including planning, assembly, construction and commissioning) for SAC systems is significantly higher than corresponding cost of best practice standard solutions – this is a very well-known fact for almost all solar energy systems and many other systems using renewable energies. The first cost of realized SAC installations is between 2 and 5 times higher compared to a conventional state-of-the-art system depending on local conditions, building requirements, system size, and of course on the selected technical solution. In recent studies, first cost for total systems ranged from 2000 € per kW_{cold} to 5000 € per kW_{cold} and even higher in some particular cases. This large range is due to different sizes of systems, different technologies, different application sectors, and other boundary conditions.

A recent trend is the development of (solar) cooling kits, that is pre-engineered package solutions that consist of all-important components of a system and where the components are well adjusted to each other. These kits are mainly developed for small capacities up to about 35 kW cooling capacity. Prices excluding installation cost and distribution system to the building for the package solutions dropped from about 6000 € per kW in 2007 to about 4500 € per kW in 2009 and are expected to reduce further to about 3000 € per kW in 2012.

The cost saving during operation very much depends on the boundary conditions. Boundary conditions in favor of a low payback time are:

- High solar radiation sums lead to high gains of the solar system.
- A long cooling season leads to a large number of hours where the system is used.
- Other heat loads such as for sanitary hot water and/or building heating increase the usefulness of the solar system.
- High prices of conventional energy make a solar alternative more competitive.

Looking at the overall life cycle cost of an SAC system (excluding any incentives or funds) in comparison to a conventional standard solution the situation looks much better than in the case of first cost. Depending on the particular conditions SAC systems will in many cases amortize within their lifetime. Under promising conditions even payback times of ten years and less can be obtained. However, commercial companies often expect a payback time of five years and less in order to justify an investment. Such low values of payback time will only be achieved under very special conditions.

SAC application has some other advantages that are often difficult to translate in an economic advantage, but may be important to be considered by policy makers:

- Application of SAC systems may lead to (primary) energy savings and thus help to reduce the dependence of finite energy fuels, which have to be imported in many countries.

- Correspondingly, application of SAC systems will lead to reduced CO_2 emissions and thereby contribute to a reduction of climate change and related effects.
- SAC systems using thermally driven cooling cycles show additional environmental benefits since they typically employ refrigerants with no ozone depletion potential and no or a very small global warming potential.
- SAC systems can be used also for all heating applications in a building or industry. The large solar collector field also provides heat for other purposes than cooling and thus helps to avoid consumption of fuel (or electricity) for heating applications.
- SAC systems can contribute to grid stability in regions with a considerable share of daily electricity consumption from the grid for air-conditioning with conventional techniques.

2.4. Market status

Close to a thousand SAC plants have been installed worldwide, which cover all types of technologies and sizes. This is of course a very early market in comparison to the tens of millions of compression air-conditioning systems sold worldwide every year. Recently, a number of large and very large installations have been realized or are under development. And – even more important – a number of projects are completely driven by private investors without major incentive or funding programmes to support these projects.

The numerous SAC RD&D activities initiated many of those installations and also led to the establishment of a SAC community. An international bi-annual conference focusing on R&D of SAC has been established and held three times already with an increasing number of participants and papers.

Today, still only very few companies exist that offer complete SAC solutions. Most systems are still composed of components or subsystems that are put together by a planning office for the particular project. In addition, there is still a great need for increased expertise and experience on the side of planners, installers, and other involved professionals.

Regarding the market for thermally driven chillers, a significant number of companies have been created in the last ten years that offer machines in the small capacity range (up to approx. 35 kW_{cold}). Most of these companies were start-ups that entered into an almost nonexistent market. Therefore, a significant increase in production rates, in particular for these small capacity systems, can be expected and correspondingly significant reductions in cost can be expected here. These systems, which can be operated with relatively low driving temperatures, are not only operated in combination with solar thermal energy, but also as co-generation units, district heat networks and industrial waste heat. Thus, the overall market for these thermally driven chillers will be much larger than for solar cooling only. Today, there are mature products available and first companies started to establish a manufacturing capacity on an industrial scale. More companies will follow to enlarge their production capacity and thereby develop more automated production processes.

The next important step is to develop today's low volume market channels into a mass market and, at the same time, drive costs down further through standardization of concepts and design methods and development of reliable package solutions.

Recently, a number of countries are considering special stimulation programs for a larger market deployment of SAC technologies. One of the most encouraging programmes has been installed in France; SAC installations here will be supported by substantial investment funds in order to overcome the existing cost barriers if they prove high quality performance and a high level of reliability. However, in most countries incentive programs provide support schemes for solar thermal systems in general and do not put a particular focus on SAC.

3. Potentials

The potentials for a broader market penetration of SAC technology is composed of further development of the technology in terms of performance, development of cost and thus economic situation and on opportunities in the markets.

3.1. Technical potentials

Potentials on the technical level range from new and advanced materials through improved components to more efficient and more reliable systems.

Main ongoing R&D on the material level is aiming to improve materials for adsorption and absorption (tailor-made adsorbents or. e.g., Ionic liquids) or absorption cycles and composites mainly using adsorption materials. These materials and compounds have the potential to allow for more compact systems with advanced heat and mass transfer and thus will lead to lowering the cost for installation and broadening the application range. Completely different solutions, such as new thermo-mechanical cycles, promise a significant increase in efficiency are under development but have not yet left laboratory scale.

Work on components concerns advanced cooling cycles on the one hand and advanced solar collectors, which are well adjusted to the needs of thermally driven cooling on the other hand. Important R&D activities addressing advanced components are:

- Integration of the generator of a thermally driven cooling machine in the solar collector will lead to reduced heat transfer losses and to more compact systems. Also, space in a technical room will be saved. Overall, such concepts aim at high efficiency at reduced system cost.
- Double-effect cycle absorption technology, which achieves high efficiency at high operation temperatures, will be extended also for the small capacity range and thus offer solutions with high overall efficiency for applications in the range of small capacity.
- Single-axis tracking solar thermal collectors to produce heat at temperatures in the range of 150°C to 250°C are still a rather new technology and important cost savings may be achieved by development of advanced materials (e.g. for reflectors) and advanced production technologies.
- Non-tracking collectors have achieved a high level of technical maturity. However, improvements towards higher operation efficiency at temperatures of 80°C to 110°C are still possible and advanced production technologies will allow for reduction of cost.

Important work on the system level is required in order to achieve more reliable systems and a high quality in the whole chain of projects ranging from design over planning, construction, and assembly to operation. This work includes measures such as training and education to increase knowledge and experience among professionals active in design and installation of HVAC systems.

3.2. Costs and economics

Cost reductions are required in order to increase the cost competitiveness of SAC in comparison to conventional solutions and thus increase the market deployment.

On the component level, main cost reductions are particularly expected for small capacity thermally driven cooling machines. Both technology improvements and mass production on an industrial scale will certainly lead to a lower cost of this key component. In principle, a noticeable potential also exists for cost reduction of solar thermal collectors. However, prices of solar thermal collectors remained almost stable over the last decade, which is mainly due to unstable market development and market policies. Another major component is the heat rejection unit. Today, mainly units in the large capacity range exist. The development of heat rejection systems specially designed for their use in SAC will lead to reduced component cost, in particular for small capacity units (e.g., below 100 kW of cooling power).

On the system level two main market areas have to be distinguished:

- Pre-engineered systems: mainly for applications in the small capacity range, that is air-conditioning in residential buildings and systems for small commercial applications, pre-fabricated standard packages will be developed. This pre-fabrication minimizes the planning effort and reduces the effort on the construction side, which also leads to minimized risk of errors in assembly and installation. As was pointed out above a significant cost reduction of pre-fabricated systems, also called kits, has been observed and will certainly continue to take place with growing markets.
- Custom-made systems: for large buildings and industrial applications custom-made systems will remain the appropriate approach. However, also for custom-made systems cost reductions on the system level are possible.
- Increased experience among involved professionals is an important need and guidelines and software tools for the design and layout of systems will help to reduce the effort during design and planning. In particular, standardized measures to assure a high quality of installations is required in order to increase the certainty of energy savings and related operation cost savings.

In the following section some comments are made on the comparison of solar thermally driven SAC with solar electrically driven SAC using photovoltaic modules and electrically driven vapor compression cycles.

As was pointed out in the introduction, systems using electrically driven vapor compression cycles combined with photovoltaic systems may be an alternative of using solar energy for air-conditioning or refrigeration. Photovoltaic modules experienced a continuous cost reduction with a growing market during the last two decades. Under today's price conditions both solar solutions, that is a solar thermally driven heating and cooling compared to conventional heating and cooling system plus a photovoltaic system, lead to similar economic performance, if no funds or incentive are taken into consideration. Therefore, a decision on the one or the other alternative has to be made based on particular boundary conditions. In particular, when an attractive feed-in tariff for electricity produced by photovoltaic systems exists, most probably the economic outcome will be in favor of a photovoltaic system. In these cases, the photovoltaic system will operate completely separated from the heating and cooling system and deliver all electricity into the grid. However, this may change significantly with an increased share of electricity production from fluctuating renewable sources. Onsite solutions that lead to a minimum impact on the grid, such as photovoltaic driven heating and cooling systems using electrically driven vapor compression cycles, may become an alternative. It is difficult to assess which of the two main solar driven heating and cooling solutions – thermally driven or electricity driven – will be more competitive under such conditions. Obviously the thermally driven system always provides a local system solution and thus will always lead to a reduced dependence of conventional energy and has never a negative impact on the grid. Also the easier integration of thermal energy storages compared to electrical storages is in favor of thermally driven cooling systems from a grid point of view. Solar thermally driven systems allow the integration of buffer storage on the "hot" side of the thermally driven chiller and thus offer a degree of freedom in system design and operation, which is not given in the case of photovoltaic driven systems.

3.3. Market opportunities

Generally speaking most favorable conditions for a successful market implementation for SAC systems are:

- Applications with a high need for heating and cooling (and sanitary hot water).
- Places with a high solar energy potential, that is high solar radiation.
- Conditions characterized by a high coincidence of loads and solar gains since this reduced the need for storage.
- Places with high cost of conventional energy.

A major obstacle is that in many places that fulfill the above requirements no or very little experience with solar energy use exists and often HVAC and refrigeration installations have a comparatively low standard. Nevertheless, under such conditions best economic performance can be expected. Companies that offer overall solutions and have the capability to provide maintenance services (e.g., using remote control approaches) will be able to exploit this market opportunity.

A major argument for the installation of SAC systems is their environmental soundness due to reduced consumption of conventional energy and employment of environmentally friendly refrigerants. This can be an important argument for an investor even if the system is not yet economically competitive, that is the return on investment is above the normal expectations for commercial investments.

Concretely speaking, market opportunities are seen in the following:

- Tertiary buildings, such as office buildings and hotels, in regions with sufficient solar gains: here in particular technologies employing non-tracking solar collector technologies will be employed and the solar system will be used for heating, cooling and sanitary hot water (if needed).
- Production buildings in sunny regions that need cooling for industrial processes (e.g., in the food industry): depending on the required temperature level of the cooling process either non-tracking solar collectors or single-axis tracking solar collector technologies will be employed. Large factory roofs can serve to place the collectors but also systems installed on the ground will be usual, in particular in areas where ground is not a limiting resource.

- In sunny regions in particular a potential for application of SAC in residential houses exists. Heating and cooling solutions making use of solar thermal energy for single family houses as well as for multi-family houses are particularly interesting in new buildings and in combination with highly energy efficient buildings which allow for radiative solutions (e.g., using the floor and / or the ceiling for heating/cooling).

Overall, renewable energies will play an increasingly important role in future energy systems due to the strong need to limit CO_2 emissions originating from conventional energy sources. SAC technology is one of the important solutions applicable on the demand side. Thus, this technology provides a market opportunity for many involved stakeholders including building owners, planners, manufacturers, and installation companies.

4. Actions needed

Needed actions are addressing different target audiences: Policy makers in the field of energy research policy to address the design of RD&D programs focusing on technology development, quality procedures, and demonstration programs; manufacturing companies and industries to contribute to advancements in the technology development; policy makers in the field of energy policy to provide means and supporting measures for an accelerated market deployment; associations representing solar energy companies and HVAC companies to play an important role in both, training of professionals and raising the awareness about SAC technology and its potentials.

4.1. Technology development and quality procedures

As was pointed out above there is a significant potential for further improvement of SAC energy and cost performance, in particular on the system level. SAC technology is a complex technology and requires much more standardization for the coupling of the key components and the development of robust, standardized solutions in future. Therefore, R&D on system optimization and accompanying measures (e.g., development of tools for planners) is important in the future and has to be addressed by decision makers in energy R&D. Also the industry and installation sector has to contribute here and provide turn-key solar cooling installations with guarantee on the performance. Besides work on the system level, R&D on the component level will enhance overall performance in terms of energy and cost and has to be appropriately covered in national and international R&D programs.

A particular focus needs to be put on a quality procedure for designing, commissioning, monitoring, operating and maintaining solar heating and cooling systems. This is an extremely important step for overcoming most of the barriers that stand against the development of a mature market in the sector. Such quality procedure has to fix the steps towards uniform and consistent planning, providing information, recommendations, and minimum requirements for each of its steps. This, in consequence, would contribute to an increase in awareness and acceptance of the technology and positively impact the number of applications since it would strengthen the stakeholders' trust and thus enhancing the market potential of solar heating and cooling systems. Moreover, the introduction of concepts, such as guarantee of solar results or minimum energy consumption, would stimulate the interest of investors and create the boundary conditions of a correct financial risk assessment, crucial for contracting or energy service activities. The quality procedure could also work as a support tool for the policy implementation of the national renewable energy targets and being the base for subsidy mechanisms.

4.2. Measures to support market deployment

SAC technology can provide an interesting solution to reduce peak electricity consumption, particularly in summer when high cooling loads create high peak demands (e.g., in southern countries). And SAC provides a CO_2 saving solution that is realized on the demand side and avoids the consumption of conventional fuels and/or electricity. Thus SAC technology has the potential to provide a significant contribution to the transformation of future energy systems.

However, as was shown above, a major bottleneck for a broader and faster market growth is the well-known dilemma of many renewable energy systems: high first cost and a payback which is much longer than usually expected for commercial investments.

Therefore supporting schemes have to be implemented that assure sustainable market development. Such supporting schemes should be adjusted to the status of the market deployment, that is to provide a higher incentive in the early market status and provide reduced incentives after the market has started to take off. Supporting schemes can be investment funds, tax reductions or credit programs with reduced interest rates. However, it is important that the provision of any supporting funding be dependent on the fulfillment of minimum requirements regarding the energy and/or CO_2 saving.

In the early phase of market deployment significant and visible demonstration programs are needed for various reasons:

- Gathering experience on a broad scale and analyzing and documenting best practices is critical in order to identify best solutions and develop solid guidelines and technical standards.
- A high visibility of good references is important in order to raise the awareness of the technology.
- Demonstration installations with a reduced financial risk due to financial support are needed to allow for the increased effort for design, planning, and installation in an early market implementation status.
- Demonstration installations are an opportunity for all involved professionals to learn about the technology and their specific requirements and potentials and limits.

Again, provision of financial support in such demonstration programs should be made dependent on a proven energy performance of the installation and implementation of quality procedures to assure this energy performance.

Furthermore, it is very important to establish training programs for installers (installation of SAC systems) as well as planners (design and monitoring of SAC systems) and to provide design tools for them on different levels. Associations in the solar sector as well as in the HVAC sector have to play an important role in this area. They have channels to disseminate information and organize training courses and workshops to assure that information reaches the important target audiences.

5. Summary and outlook

SAC technology is at a critical stage. Mature components are available and many installations have been realized. The technology has shown that significant energy savings are possible, and it has reached a level of early market deployment. However, the financial risk for parties involved in SAC business is still too high:

- Due to no complete assurance on the quality of the system the user cannot be sure about the level of energy savings and related cost savings.
- Most planners and installers have little experience with SAC technology and thus the effort – and related cost – to install those systems is higher than for standard systems.
- Due to unstable and small markets, manufacturers cannot be sure about sale rates and thus cannot bear the risk to significantly increase their production scale.

Therefore, measures to support a sustainable market development are most important. This includes in particular establishment of large scale demonstration programs and implementation of adjusted incentive schemes to lower the risk for investments. In parallel establishment of quality procedures that cover all phases of a project are most critical in order to satisfy the expectations of all involved stakeholders.

Overall renewable energies will play an increasingly important role in future energy systems due to the strong need to limit CO_2 emissions originating from conventional energy sources and SAC technology is one of the important solutions applicable on the demand side.

The IEA Solar Heating and Cooling Programme

The Solar Heating and Cooling Programme was one of the first Implementing Agreements of the International Energy Agency (IEA) to be established. Since 1977, its members have been collaborating to advance active solar and passive solar and their application in buildings and other areas, such as agriculture and industry. A total of 49 projects (referred to as Tasks) have been initiated, of which 34 have been completed. Each Task is managed by an Operating Agent from one of the participating countries. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition to the Task work, a number of special activities - Memorandum of Understanding with solar thermal trade organizations, statistics collection and analysis, conferences and workshops - have been undertaken.

Current Members are Australia, Austria, Belgium, Canada, Denmark, European Commission, Germany, Finland, France, Italy, Mexico, Netherlands, Norway, Portugal, Singapore, South Africa, Spain, Sweden, Switzerland and United States.

More information can be found on the website of the IEA Solar Heating and Cooling Programe at www.iea-shc.org.