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IEA SHC Task 48 - market support measures

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Abstract

Within IEA SHC Task 48 "Quality assurance and support measures for Solar Cooling" market support measures have been analyzed and developed for different purposes. A review of relevant international standards, rating and incentive schemes has been carried out. A methodology for performance assessment, rating and benchmarking for SHC-system has been developed and tested with 10 best practice examples. Three selected solutions for small, medium and large scale SHC plant designs are described in detail and will be published as design guide [3]. Further work investigated measurement and verification procedures, labelling possibilities and contracting models.

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Keywords: IEA SHC Task 48, market support, incentive scemes, rating and benchmarking, best practice, contracting

1. Introduction

IEA SHC Task 48 deals with quality of solar cooling systems with different approaches on component level, system level and support measures. This paper explains market support measures and how they are created. These measures use the results of quality assurance investigations on component and system level and explore the possibilities to identify, rate and verify the quality and performance of solar cooling solutions. The resulting tools and reports provide a framework that enables policy makers to craft suitable interventions (e.g. certificates, label and contracting, etc.) that supports solar cooling on a level playing field with other renewable energy technologies.

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Three scenarios are identified and different support mechanisms apply to them. (1) Engineered Design of Large (>20 kW) Systems, (2) Measured Performance of Large (> 20 kW) Systems and (3) Deemed Performance of Small (<20 kW) Systems. Although the completion of all tools is not fully achieved, this work permits to initiate market support measures for solar heating and cooling systems.

Nomenclature

f_{sav_NRE}	Fractional savings of non-renewable primary energy
$PER_{\_NRE}$	Primary Energy Ratio
SPF_{el}	Seasonal Performance Factor with respect to electricity
SPF_{th}	Seasonal Performance Factor with respect to thermal energy

Subscripts

$_{C}$	Cooling (overall performance of the cooling system)
$_{DHW}$	Domestic hot water (including backup)
$_{SH}$	Space heating (including backup)
$_{sys}$	Overall system (including cooling, domestic hot water and space heating)
$_{thC}$	Thermal cooling (performance of the ab-/adsorption chiller)

2. Review of relevant international standards, rating and incentive systems

Market support policy successes and failures were categorized and analyzed in order to understand the lessons learned from prior experience. In this activity, work relevant to known market transformation options that are, or have been, implemented in various forms around the world was contributed by member countries in the form of a survey template. The virtues of each measure are compared and contrasted in this activity [1].

A range of policy interventions are identified in 6 countries worldwide that can potentially be used to support solar cooling. Many of these policy incentive schemes focus on awarding subsidies to systems based on technical parameters such as solar collector area. These incentives, created with solar hot water applications in mind are not targeted to the cost/performance situation of the emerging solar cooling industry.

There has been some policy foray into system quality support through performance-based incentives. However, given the maturity of the solar cooling industry this approach has risks for industry actors as it is difficult to accurately predict performance during the design/investment phase. Measurement and verification costs may also create undue administrative burden and project risk for actors including the system designer or developer and the proponent.

There is a need for non-technical policy support addressing characteristics such as system quality, user interface, risk, market education, industry training and support, attractive business models and general market appeal. These less tangible, but critical policy strategies could be those that influence consumer choices by targeting, informing, motivating and empowering consumers.

This database and the above findings are intended to provide insights into the needs of alternative policy interventions and hence guide the development of the standards, guides and rating framework being delivered in the subsequent work packages. It will also contribute to the work of Subtask D.

One issue identified during this activity is that many of the responding members appear to mainly consider direct incentive measures such as subsidies on capital cost, tax deduction and access to capital. However, many other more subtle measures including compliance standards and planning approval may have been overlooked. It is recommended that the survey exercise is repeated with other industry actors.

3. Methodology for performance assessment, rating and benchmarking

To compare technical and economic key figures of monitored or simulated Solar Heating and Cooling Plants an Excel tool was designed [2] and is used here to analyze 10 realized and operating SHC plants. Three of the analyzed plants are located in Austria and P.R. China, as well as one in France, Germany, Italy and Singapore. Each plant and its solar usage as well as its ambient surroundings are unique.

The plants mainly provide chilled water to fan coils. Only one plant is equipped with a chilled celling. Four plants have a nominal cooling capacity lower than 30 kW. Cooling capacity between 30 and 50 kW is provided by 5 plants. One plant has a nominal cooling capacity greater than 150 kW. Mainly flat plate collectors are installed. A parabolic trough, a Fresnel collector and one evacuated tube are used once. These three technologies are in use in the plants in the P.R. China. The solar energy is used for “cooling only” in 2 plants. All other 8 plants have a multiple-use of the solar thermal energy. Two plants combine cooling and domestic hot water and 4 plants combine cooling and space heating. Two plants use the solar energy for cooling, domestic hot water and space heating. All plants have hot water storage tanks. Just two of ten plants have a cold water tank.

If the heating and cooling loads are not fully satisfied by solar thermal energy, various possibilities for a (hot) backup are in use. Two plants use pellets boiler and 4 natural gas boiler. One plant has no hot backup at all. Three plants have other specific hot backup’s (e.g. heat pump, electrical backup). Only 2 plants use hot backup to supply the thermal chiller. The backups are mainly for heating purpose (space heating and domestic hot water). Additionally cold backups are used in 5 plants. One plant has a water cooled and 4 plants have air cooled cold backups (vapor compression chiller). 50% of the plants have no cold backup at all. 8 of 10 plants use a wet cooling tower for heat rejection. The two last use a dry or a hybrid cooling tower.

Three selected results are presented below. The main key figures are (i) Seasonal Performance Factor with respect to electricity (SPF_{el}), (ii) Seasonal Performance Factor with respect to thermal energy (SPF_{th}), (iii) Primary Energy Ratio with respect to non-renewable primary energy ($PER_{\_NRE}$), (iv) Fractional savings (f_{sav_NRE}) and (v) Relative Levelized costs of energy.

All key figures are calculated with respect to a given system boundary. The main boundary systems are listed in Table 1.

Table 1. Boundary systems according to subtask B7

Overall system (including cooling, domestic hot water and space heating)	- sys
Cooling (overall performance of the cooling system)	- C
Thermal cooling (performance of the ab-/adsorption chiller)	- thC
Space heating (including backup)	- SH
Domestic hot water (including backup)	- DHW

Figure 1 displays the average monthly electrical efficiency for thermal cooling $SPF_{el.thC}$ on the vertical axis and the corresponding thermal efficiency of ab-/adsorption chiller ($SPF_{th.C}$) on the abscissa. The better the component performance (high $SPF_{th.C}$) the less energy is needed for heat rejection and thus less parasitic electricity is necessary and the electrical performance is higher.

Figure 2 presents the dependency of average annual thermal performance of the chiller ($SPF_{th.C}$) and the system ($SPF_{th.sys}$) on the system design (storage and control strategy), represented on the x-axis by the ratio of hot water storage volume (liter) to collector area (m²). Two trends are displayed. (i) red, dashed line: component efficiency – $SPF_{th.C}$ (ii) blue, dotted line: system efficiency – $SPF_{th.sys}$.

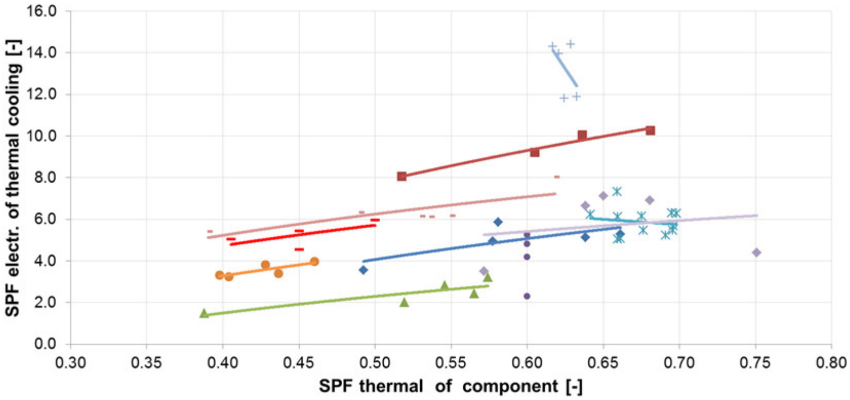

Fig. 1. Electrical efficiency ($SPF_{el.thC}$ (-)) vs. thermal efficiency of the chiller ($SPF_{th.C}$ (-))

The trend lines present the relation of the thermal efficiency and the specific hot water storage volume. The bigger the storage volume, the lower the thermal efficiency. With regard to the efficiency of the component (chiller itself) the influence of storage and control might end up in different supply temperatures for the generator and thus lower thermal efficiency. Main influence of the storage volume is reflected in the difference between the upper and lower trend line. The difference of component and system efficiency gets maximized with increasing specific volume. The bigger the storage volume is, the higher are the heat losses and the lower is the system efficiency. There is also an influence of the control strategy (standby, part-load, etc.) and of the system configuration (use for cooling only or multiple-usage) onto these two trend lines.

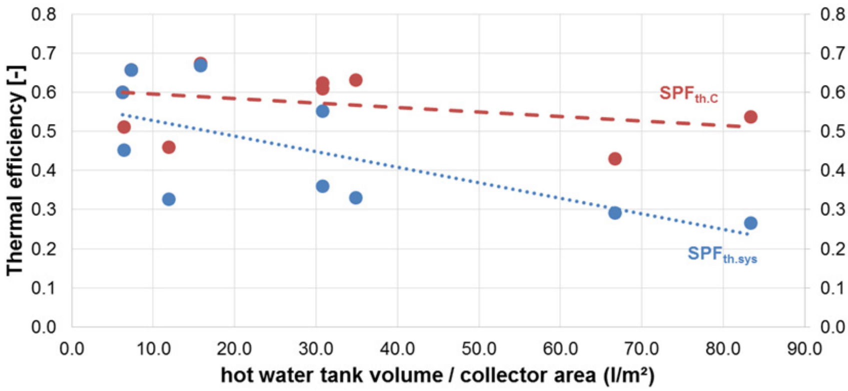

Fig. 2. $SPF_{th.C}$ (component) and $SPF_{th.sys}$ (system) vs. ratio of hot water tank volume to collector area (l/m²)

Levelized costs of useful energy (SH+DHW+C) are calculated under consideration of standardized investment, maintenance, replacement cost and fuel costs for each plant and the theoretical reference system respectively. The input data consists of best known mean values. The aim of these calculations is to generate reasonable cut-off values. The results present best known averages and may differ from specific values in countries or projects with special boundaries.

To avoid a discussion about absolute values, the results are presented as ratio of the levelized costs of the SHC system to the reference system (vapour compression chiller and natural gas boiler). Figure 3 shows the results depending on the overall capacity (SH+DHW+C) of the plants. Two main distinctions regarding the size have to be made: (1) the SHC system works as base load systems and supports a conventional system, (2) the SHC system is the only system installed and therefor it serves full load capacity. If a system is built to cover base load and the conventional system isn't monitored, the system is treated as full load example.

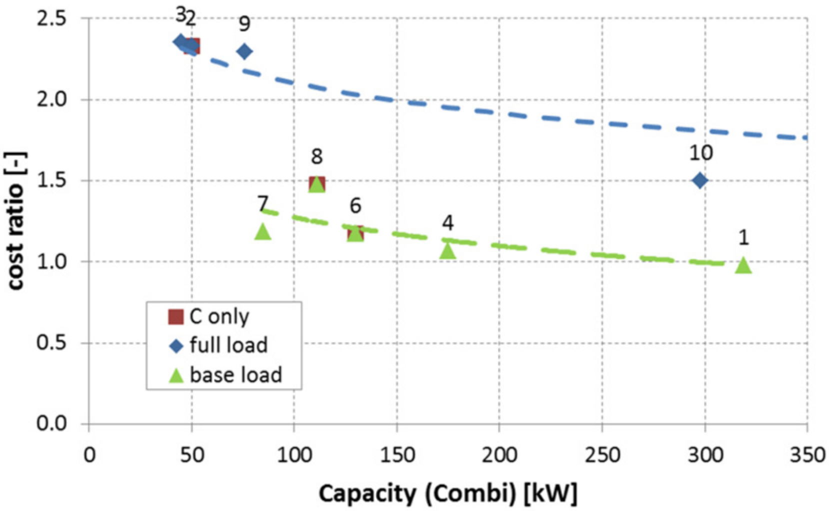

Fig. 3. Cost ratio (-) vs. capacity of the system (cooling + space heating + domestic hot water)

Two trends can be observed. The full load systems (blue, dashed line) represent cost ratios between 2.4 (no. 3) down to 1.2 (no. 5 @ 1,5MW). The lower, red dotted trend line represents the base load and shows values from 1.8 (no. 8) down to 0.98 (no. 1). Lowest cost ratios can be obtained by systems with high space heating and domestic hot water demands respectively (plants no. 1, 4 & 7). Under these specific conditions (more details in [2]) SHC system can be competitive with reference systems.

Electrical efficiencies alone are insufficient for the rating and assessment of SHC systems. Nevertheless for subsystems only (SH, DHW, C) rated minimum and maximum SPF_{el} can be defined with view on best practice and theoretical boundaries. If the overall system needs to be evaluated, the solar fraction and the conventional systems have to be included in the evaluation. Unfortunately, not all conventional parts are monitored enough detailed to be included in the overall system evaluation. Therefore it is more likely to rate the solar parts separately.

The 10 analyzed examples show interesting trends and some rules of thumb can be derived out of the results. Effects of solar fraction, subsystem efficiency on the overall savings can be observed. Some conclusions for the labelling are possible.

Labelling the overall system only is not enough. In that case solar and conventional performance, but also space heating, cooling and domestic hot water production get mixed up and the results for different systems can hardly be compared among each other's.

Non-renewable Primary Energy Savings ($f_{sav.NRE}$) are a reasonable value to be shown in a labelling. Care needs to be taken, that a standardized system is taken as reference system, as this influences the calculation directly. Only if subsystems are characterized, the tremendous advantages of Solar Heating and Cooling Systems related to Primary Energy Savings can be illustrated appropriately.

The economic analysis showed that under advantageous conditions SHC systems can be feasible and competitive with conventional systems. The configurations should focus on base load applications and all year solar usage.

4. Selection and standardization of best practice solutions

From the past and present experience with small, medium and large size solar air-conditioning systems, within the framework of this activity, a reduced and documented set of system design schemes and control schemes was selected, which exhibit favorable system operation in terms of optimized performance and reliability. Initially, case study configurations were selected and were used to define and standardize the engineering criteria which lead to target reliability, efficiency and cost competitiveness. High attention was drawn to the standardization of the system design schemes and defining the constraints of applicability of these standardized designs. Therefore 10 principles are defined:

Principle 0: Reduction of energy demand before substitution by renewables
Principle 1: Keep the design simple and compact
Principle 2: Choose applications with high annual solar utilization
Principle 3: Avoid fossil fuels as backup in systems with single effect ab-/adsorption chillers
Principle 4: Use wet (or hybrid) cooling towers whenever possible
Principle 5: Ab-/adsorption chiller design for long daily operation time
Principle 6: Design the system assuming that solar collectors will typically operate at average solar radiation only
Principle 7: Minimise parasitic power
Principle 8: Minimise heat losses
Principle 9: Apply appropriate design resources
Principle 10: Allow adequate resources for monitoring and commissioning

Three systems (small, medium and large scale) have been chosen to be included in the "Solar Thermal Cooling Design Guide: Case Study Examples" [3] (The Guide). The design guide is intended as a companion to the IEA Solar Cooling Handbook [4]. A detailed description how to follow the 10 principles and how to design reliable and successful solar cooling plants will be given there.

The content and function of the two companion books are as follows

- The IEA Solar Cooling Handbook (The Handbook) provides a comprehensive, but general overview of the various technologies and equipment components, which convert solar heat into useful cold. It aims to provide comprehensive information and advice on all aspects of solar cooling, in order to enable engineers to design their own solar cooling system from first principles. In this way, it focuses on the broader principles involved, and it leaves full design flexibility for engineers to respond to the wide range of possible applications that may be encountered. While it contains examples, it does not provide prescriptive designs for specific applications.
- The Guide aims to provide more detailed and specific engineering design information than in The Handbook. By focusing on a limited number of specific case study examples, The Guide aims to provide additional useful information relevant to specific embodiments of solar cooling, which are not necessarily general to all forms of solar cooling. In this way it aims to provide a limited number of more prescriptive design solutions that reduce the number of decisions required by the engineer, and more clearly codifies the art of solar cooling design in the light of specific application experience.

Compendiously The Handbook aims to give foundational design understanding across the breadth of alternative solar cooling solutions, and The Guide aims to supplement this information with more detailed advice for a limited number of specific applications.

The form of The Guide follows an engineering design description for three specific designs with the rationale for each key design decision explained. The system flow sheet is described and the application conditions under which the system selection is appropriate are discussed. Where appropriate, numerical constraints are suggested for the selection and sizing of parameters of key equipment items.

It should be noted that there are many other attractive solar cooling technology solutions. The absence of a given solar cooling technology from The Guide does not mean that it is not appropriate or less attractive than the solutions provided in The Guide. The Guide is merely a positive statement on a small number of solutions rather than a negative statement on other solutions.

While The Guide aims to more completely elucidate a set of specific solutions, it is not intended as a substitute for good design by a qualified engineer based on full understanding of the principles of solar cooling as described in The Handbook.

5. Measurement and verification procedures

In this framework [5], the principal goal of this work is to define the procedure for in-situ verification of the solar cooling plant performances. While Measurement & Verification (M&V) procedures (e.g. IPMVP, ASHRAE and FEMP) exist for general energy conservation measures, it is desirable to have a more specific and targeted guide for solar cooling in order to simplify procedures, improve confidence in results and to assist M&V implementation with more detailed guidance.

Measurement and verification (M&V) aims to measure and verify energy savings from specific changes of infrastructure. M&V has a focused purpose, it is not simply traditional energy consumption monitoring. M&V is centered on quantifying the energy savings as a result of implemented energy conservation measures (ECM) within determined confidence levels. The determination of energy savings is central to the financial evaluation, quality and confidence between parties and their contractual arrangements. M&V must be disciplined, rigorous, credible and transparent.

A common and consistent approach for measurement and verification enables more reliable assessments of performance efficiency, enabling the reduction of savings risks and improving energy conservation investments.

Good M&V practice will:

- enhance confidence levels of energy saving mechanisms;
- improve project engineering for new and retrofit projects;
- monitor system performances;
- increase the understanding and management of project risks;
- improve efficiency;
- reduce maintenance problems and
- encourage further investment.

Accurate M&V determination allows greater persistence of savings and reduced variability of savings. M&V should be well defined and use generally accepted methods, this leads to greater and more reliable savings as well as improved investment and profitability.

Good monitoring methods are essential to reduce maintenance problems. The data recording instruments have to be of sufficient quality to meet objectives for the qualification of system performance levels, whilst keeping the costs at an acceptable level for the contractor. The method has to quantify the overall performance levels of the system being monitored and detect any drop in performance caused by problems occurring within that system.

6. Labelling possibilities investigation

This activity dedicates to the investigation on the creation of a solar cooling label itself or (more probable) on the creation of specific solar cooling extension(s) to existing “Green quality” labels such as LEED or Green Building Council tools. First an overview of the state of the art of the labelling process is gained and then investigations on how to integrate them or even how to create an independent solar cooling label are investigated and theorized.

The different approaches to define a system for labelling of solar cooling systems are the following two options [6]:

- Option A is a structured process, which base on existing labels, like (i) EU Solar Keymark, (ii) Eco-design, (ii) Energy Star, (iv) Eurovent and further labels for components of solar cooling systems. The labels are used to rate the different system components. The results of the rating are summarized in a software program which gives a preliminary label of the system. The final label is given after testing the system by monitoring.
- Option B base on existing and new defined standards only. The content of existing standards can be used to define new chapters which are necessary to create a standard for solar cooling systems. A selection of standards, that can be applied, are (i) EN 12975, (ii) DIN V 18599, (iii) AS 4238:2008 and other international standards.

The labelling of option B is therefore adapted on calculations by standards and a given method of simulating the solar cooling system with TRNSYS (e.g. AS5389).

As a first draft in [2] the labelling from the European Energy Consumption Label (2010/30/EU) was used. The rating levels start from A^{+++} in dark green (best rating) to G in red (worst rating). The rating takes the fractional saving factor f_{sav}, which is defined as the non-renewable primary energy savings of the investigated system compared to a predefined reference system. This factor f_{sav} can be calculated according to equation (1).

$$f_{sav.NRE.PER.i} = 1 - \frac{PER_{NRE.ref.i}}{PER_{NRE.i}} \quad (1)$$

If the considered renewable system has a lower primary energy demand than the reference system, the f_{sav} value is greater than zero. The energy label is calculated for the four different subsystem boundaries (see table 1: cooling, thermal cooling, domestic hot water and space heating) and the total system. The rating levels are kept in ten percent steps. The position of the black arrow depends on the value of the fractional savings; the highest and lowest position is on the arrowhead of the A^{+++} and G respectively.

The above described 10 best practice examples (see chapter 3) are rated as follows. 7. It can be observed that subsystems and the entire system can achieve significant different labels. Plant no. 6 and no. 10 show negative values (Table 2) indicating that the solar system consumes more primary energy than the reference system. Plant no. 10 has negative savings of the cooling subsystem ($f_{sav\_NRE.PER.C}$ and $_{fsav\_NRE.PER.thC}$) but in total as complete system the savings are positive.

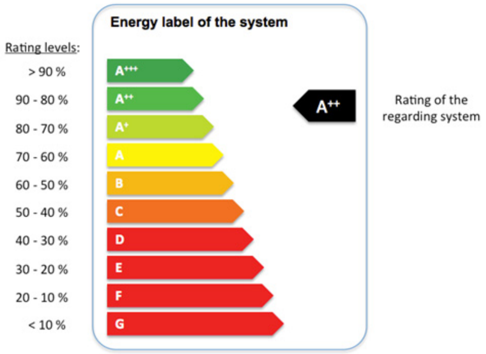

Fig. 4. Energy label

Table 2. Overview of energy labels for all boundaries and all 10 SHC plants

Plant no.	1	2	3	4	5	6	7	8	9	10
Energy label of the system	A+++	A+	F	A+	A	G	D	E	C	D
fsav_NRE.PER.sys	0.91	0.75	0.18	0.74	0.62	-0.14	0.35	0.22	0.46	0.39
Energy label for cooling	B	A++	F	E	C	G	C	E	E	G
fsav_NRE.PER.C	0.51	0.81	0.18	0.29	0.49	-0.14	0.45	0.22	0.23	-0.24
Energy label for thermal cooling	B	A+	F	D	C	F	A++	B	C	G
fsav_NRE.PER.thC	0.55	0.80	0.15	0.32	0.48	0.18	0.85	0.53	0.43	-0.24
Energy label for domestic hot water	no	no	no	A+	A+++	no	D	no	A	no
fsav_NRE.PER.DHW	0.00	0.00	0.00	0.76	0.98	0.00	0.34	0.00	0.67	0.00
Energy label for space heating	A+++	B	F	no	no	no	D	no	D	A
fsav_NRE.PER.SH	0.94	0.59	0.17	0.00	0.00	0.00	0.32	0.00	0.40	0.70

7. Collaboration with T45 for contracting models

This activity emphasizes contracting models for solar cooling systems. For that purpose, a narrow collaboration was established with IEA SHC Task 45 on large systems for district heating and cooling systems. This analysis [7] focuses on details, such as investment models, contracts and other relevant issues with regard to which information an Energy Service Company (ESCo) is limited and dispersed in the EU and worldwide.

An Energy Service Company (ESCo) is a professional business partner. The partner offers consumers the opportunity through a wide range of energy services to reduce energy consumption as well as related costs.

Worldwide experiences can be shared and background information from solar thermal ESCos were gained. At the moment, a lot of perceived risks and uncertainties are blighting the prospect for change to sustainable energy methods. These methods could stimulate the generation of clean energy for air conditioning in small buildings and facilities as well as in large scale applications.

Lessons learned from several ESCo projects are presented in the current report [7]. The report contains a lot of information for future solar thermal energy application possibilities. Summarized, main findings of the analysis presented in this report are:

- Energy agencies are crucial in providing expertise and assistance in implementing ESCo projects for increasing the uptake of contracting schemes.
- A well-organized, international ESCo business sector would be beneficial to provide information on different energy service schemes, chosen based on project requirements.
- The establishment of a clear, international legislative framework, which is capable to regulate all contract related details, would support multinational project activities.
- Systems should facilitate operations for contractors offering the whole supply chain for solar thermal air conditioning, including operation and maintenance.
- Standardized measurement and verification procedures are necessary in order to support innovative solar cooling technologies; like provided by IEA SHC Task 48
- Before plants can be realized, project risk forecasts and clear risk analyses are necessary in order to realize ESCo projects.
- The analysis identified a need to increase the public awareness of ESCo project opportunities and their economic and environmental benefits.

The analysis identified that various international opportunists for solar cooling ESCo projects exist, and that further cooperation and realization in the field of financial project backgrounds would be highly beneficial. To keep risks on a minimum, standardized measurement and verification procedures, such as the one of IEA SHC Task 48 and presented above, are crucial criteria's for a successful realization.

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