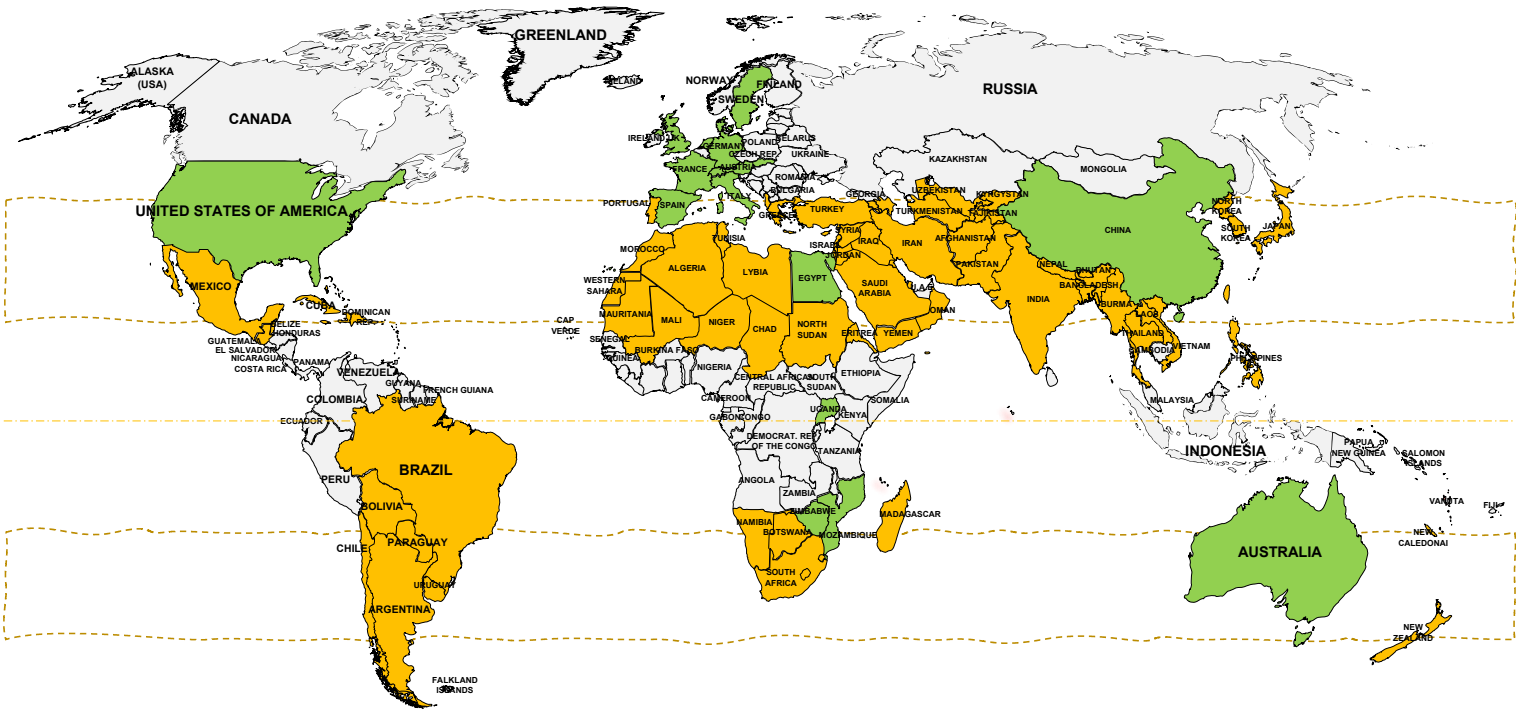
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

# Adapted Systems




**IEA SHC TASK 65 | SOLAR COOLING FOR THE SUNBELT REGIONS**

Technology Collaboration Programme
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SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

# Adapted Systems

## This is a report from SHC Task 65: Solar Cooling for the Sunbelt Regions and work performed in Subtask A: Adaptation

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Cover photo credit: World map with Sunbelt regions (marked yellow) and the 18 countries of the participating Task 65 experts (marked green), source: Neyer Brainworks & JER

## Solar Heating & Cooling Technology Collaboration Programme (IEA SHC)

The Solar Heating and Cooling Technology Collaboration Programme was founded in 1977 as one of the first multilateral technology initiatives ("Implementing Agreements") of the International Energy Agency.

**Our mission** is *"Through multi-disciplinary international collaborative research and knowledge exchange, as well as market and policy recommendations, the IEA SHC will work to increase the deployment rate of solar heating and cooling systems by breaking down the technical and non-technical barriers."*

**IEA SHC** members carry out cooperative research, development, demonstrations, and exchanges of information through Tasks (projects) on solar heating and cooling components and systems and their application to advance the deployment and research and development activities in the field of solar heating and cooling.

**Our focus areas,** with the associated Tasks in parenthesis, include:

- Solar Space Heating and Water Heating (Tasks 14, 19, 26, 44, 54, 69)
- Solar Cooling (Tasks 25, 38, 48, 53, 65)
- Solar Heat for Industrial and Agricultural Processes (Tasks 29, 33, 49, 62, 64, 72)
- Solar District Heating (Tasks 7, 45, 55, 68)
- Solar Buildings/Architecture/Urban Planning (Tasks 8, 11, 12, 13, 20, 22, 23, 28, 37, 40, 41, 47, 51, 52, 56, 59, 63, 66)
- Solar Thermal & PV (Tasks 16, 35, 60)
- Daylighting/Lighting (Tasks 21, 31, 50, 61, 70)
- Materials/Components for Solar Heating and Cooling (Tasks 2, 3, 6, 10, 18, 27, 39)
- Standards, Certification, and Test Methods (Tasks 14, 24, 34, 43, 57)
- Resource Assessment (Tasks 1, 4, 5, 9, 17, 36, 46, 71)
- Storage of Solar Heat (Tasks 7, 32, 42, 58, 67)

In addition to our Task work, other activities of the IEA SHC include our:

- SHC Solar Academy
- *Solar Heat Worldwide*, annual statistics report
- SHC International Conference

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# Contents

# 1 Executive Summary

The goal of the IEA SHC Task 65 “Solar Cooling for the Sunbelt regions” is to focus on innovations for affordable, safe, and reliable Solar Cooling systems for the Sunbelt regions worldwide. Countries located between the 20th and 40th degree latitudes in the Northern and Southern Hemispheres, placed in the Sunbelt, face increasing cooling needs on the one hand and higher solar irradiation on the other a compelling solution.

This document is the final report on activity A3 “System adaption”. The main parts are a description of a literature review on adapted systems to Sunbelt regions and a short summary on selected projects related to that.

The literature review focuses on adapted systems in solar cooling for Sunbelt regions. It outlines the methodology for conducting the review, including defining keywords, searching sources, preprocessing data, and coding information. The review aims to analyze qualitative data from various sources, utilizing Computer Assisted Qualitative Data Analysis Software (CAQDAS) like MAXQDA. The process involves steps such as working with word clouds, exploring full texts, highlighting important passages, and writing excerpts. After detailed data evaluation of 187 sources, the results will be synthesized and summarized for publication. Preliminary analysis shows trends in publication years (2012 followed by 2014 and 2020), types of references (mostly journal papers), titles, keywords (more than 500), and abstracts, providing insights into the state of the literature on solar cooling systems. Results of the literature review are presented as word clouds, showing the frequency of terms in different aspects of the literature, e.g., title or abstract.

In the SolarHybrid project, a solar-hybrid concept combining solar-thermal absorption cooling with conventional compression cooling was developed and analyzed. This concept was adapted for Sunbelt regions and tested using hardware-in-the-loop measurements. Building upon previous experiences, the project focused on optimizing the hybrid refrigeration system under various climatic conditions, achieving dynamic regulation and high efficiency. Functional models of refrigeration machines were tested in the lab to validate the concept's feasibility.

In the "sol.e.h.2" project, an adapted system for solar-hybrid cooling in hot/humid climates was developed. Key aspects include addressing climatic challenges, designing adapted systems, and optimizing loads to achieve technical and economic efficiency. The project utilized a modular container-based office building and emphasized the importance of reducing building cooling loads for the effectiveness of solar-hybrid cooling systems.

The ongoing SunBeltChiller (SBC) project, led by Industrial Solar GmbH and ZAE Bayern aims to develop solar thermal cooling and heating for the Sunbelt region. The SBC uses solar thermal energy and a double lift absorption chiller to operate efficiently at high re-cooling temperatures (~90°C). Waste heat from this process drives a single effect absorption chiller. Operation can be shifted to the night hours, enabling efficient cooling without the need for water-intensive wet cooling towers. This system can also provide additional heat, making it suitable for warm regions with water shortages or high humidity.

# 2 Introduction

The knowhow capitalized in OECD countries (Europe, US, Australia, etc.) on Solar Cooling Technology (both thermal and PV) is already very relevant, but very few efforts have been made to adapt and transfer this knowhow to Sunbelt countries such as countries in Africa, MENA, and Asia which are all dynamic emerging economies. Therefore, the present project is aimed at the development of innovations for affordable, safe, and reliable cooling systems for the Sunbelt regions worldwide by using solar energy either solar thermal or solar PV.

The innovation driver and the keyword is Adaptation of existing concepts to the Sunbelt regions, which is investigated within Task 65, Subtask A under Activity A3 - Adapted Systems.

To show the relevance, a literature review was conducted. This report provides in Chapter 3 an overview of the

- method;
- initial relevant data and facts;
- a short summary on the status.

Moreover, three projects are highlighted in Chapter 4 of the report. In previous projects of the University of Innsbruck (UIKB) different solar-hybrid systems were investigated. The adaptation to different boundary conditions (also for Sunbelt regions) was investigated and also tested through hardware in the loop measurements - some results are shown. In another project this concept was investigated/adapted to hot and humid climates for different building types. An ongoing project led by ZAE Bayern shows the adaptation of a SE/DL absorption chiller to enable efficient operation in Sunbelt regions.

# 3 Literature Review on Adapted Systems

The main part of the work done is a literature review on adapted systems in solar cooling for Sunbelt regions. Therefore, the methodology, the chosen parameters/boundaries and the first outsights are presented.

## 3.1 Methodology for the Literature Review

Working with academic literature is essential in many scientific fields and crucial for systematically reviewing existing research. With more publishers offering online access to their journals and publications, conducting literature reviews has become easier and more efficient.

This chapter describes the used methodology including the tools for the literature review. The following steps are carried out:

1. It is necessary to carry out the work in a structured manner in order to achieve results efficiently. The first step is to clearly define the topic and objectives. Based on this the main keywords and terms related have to be defined.

2. The next step is to determine the sources where the relevant literature is listed and available. This also includes the extent of the search (time required and completeness) and how it is carried out.

3. The bibliographic data of the found literature will be collected in reference management software (Citavi). This software utilizes project files containing databases of collected bibliographic information. Projects consist of individual literature entries containing author, title, potential links, keywords, abstracts, full texts, and further details. The collected data has to be screened on relevance (title, abstract, actuality) and completeness.

   This also contains pre-processing in terms of rejection, completion of missing data, and supplementing full texts. This data is finally exported in RIS data format inclusive the full texts as extra file. RIS data is a standard for bibliographic citations, they contain "tags," consisting of two letters each, followed by corresponding information. Key tags include:

   - TY: Type of literature entry, initiating each new entry.
   - ID: Unique identification number of the entry.
   - AU: Author(s).
   - TI: Title.
   - PY: Publication date.

4. In this type of literature research, qualitative data is analysed. The term "qualitative data" encompasses non-numerical, unstructured data originating from social sciences. While numerical data is easily understood, qualitative data presents diverse forms such as interviews, photographs, and documents. Methodologically, various types exist, while technically, data can be recorded in multiple formats and transcribed into text files. This is also necessary for the different type of literature, especially if you want to investigate the state of the art and don’t have comparable numbers.

   Therefore, Computer Assisted Qualitative Data Analysis Software (CAQDAS) is used to go further with the literature review – in this case the software MAXQDA. Qualitative data analysis software is particularly effective for managing excerpts and creating summaries, supporting the writing process. Such software is essential for analysing qualitative data, which presents diverse challenges compared to quantitative data analysis. Quantitative researchers deal primarily with numerical data, whereas qualitative researchers face a myriad of data types and collection methods, akin to biodiversity in the natural world. MAXQDA can cooperate with any reference management program exporting their databases in the RIS data format.

5. After the data import, these must be critically checked and cleaned up again and the links to the full texts checked.

6. Next step is the review itself. The process of conducting a literature review varies based on research questions, objectives, source scope, and available time. When time is limited, focus may be on abstracts rather than full texts, and criteria may be more narrowly defined. There are various features for conducting literature reviews:

- Working with word clouds: Identifying central themes and key terms by exploring full texts and creating word clouds. Non-relevant words can be transferred to a stop list.
- Exploring full texts and working with memos: Using context search in the Document Browser to find occurrences of search words, thus narrowing down the reading scope. Ideas, core statements, and questions can be recorded as memos linked to specific text passages.
- Highlighting important text passages: Colour coding significant text passages for easier identification and later thematic coding.
- Exploring word frequency: Analysing word frequencies in one or multiple texts.
- Writing excerpts: Creating document groups for excerpts and linking them to the primary text.
- Automatically coding text passages: Searching for and automatically coding interesting keywords in texts.
- Manually thematically coding significant text passages: Coding relevant text passages with thematic codes that align with research questions. Utilizing comments or weighting for future citation identification.
- Differentiating, coding, and statistically analysing various dimensions: Identifying dimensions for a specific content area and statistically analysing their frequency.
- Visual representations of themes and sources: Utilizing visual tools like the Code Matrix Browser, Code Relations Browser, One-Case-Model, and One-Code-Model for thematic analysis.
- Writing thematic summaries and creating summary tables: Using the Summary Grid function to write thematic summaries and present them in comparative tables.
- Quantitative analysis of themes: Analysing sources based on variables like publication year, answering questions about distribution over time or topic trends. Statistical tables and graphs can be generated for thematic codes and subcodes.

7. The synthesis of results and writing of the review is the final phase after the initial groundwork. It involves summarizing the findings and crafting a well-structured text. Two types of reviews can be distinguished: descriptive literature reviews and quantitative meta-analyses.

   Both should include sections on objectives, methods, results, and conclusions. For quantitative meta-analyses, the methods section should detail the statistical procedures used. Tools like coding search, memos, summary tables, word frequency analysis, and graphical representations can be valuable aids in the writing process, facilitating the organization and integration of findings into the final review. (Raediker et al., 2019)

To carry out the described methodology properly, the definition of the search criteria and boundary conditions are essential. The following chapter describes this process and the main parameters.

The goal of this methodology is to show the current status on adaption of solar cooling systems for ‘Sunbelt regions. This includes different aspects, for example such as “what are the boundaries at Sunbelt”, “which systems are relevant” and “which control strategies fit the needs”.

## 3.2 Detailed Review on Adapted Systems in Sunbelt Regions

As for components adaptation, activity A3 assesses existing solar cooling systems and points out necessary adaptation on existing layouts, while suggesting and developing innovative solutions. In focus are systems both driven by solar thermal collectors (single/double effect sorption chillers and desiccant systems coupled with concentrating and non-concentrating collectors, free cooling systems, etc.) and by photovoltaic panels (direct expansion and hydronic vapor compression chillers coupled with PV panels).

Local solutions adapted to cover one single building’s load will be accounted for together with large systems suitable to provide cooling to a number of buildings, such as district loops distributing chilled water or neutral temperature water used as a heat rejection medium. This is supported by the literature study on the state of the art of solar cooling in Sunbelt regions with a focus on system adaptation.

Based on the described review methodology the main steps of this literature review are briefly described as:

1. Definition of
    - main topic
    - main sources
    - main keywords
2. Literature search
3. Literature preprocessing and cleaning
4. Definition of codes (specific keywords)
5. Coding of data
6. Evaluation of the data with usage of different features
7. Derivation of results

### 3.2.1 Definition

The main topic and research question is defined as

"**State of the art of solar cooling systems adapted to Sunbelt regions**".

After the examination of the available sources and the scope/relevance of them, it was decided to use two sources:

- **Web of Science**
- **Google Scholar**

The definition of the main keywords was done by brainstorming and led to the following terms:

- **Solar cooling**
  to include the most relevant sources in the overall topic
- **Solar cooling adaptation**
  as the activity is an adaptation, it is necessary to investigate these sources in detail and show the actual status/developments on the component and system level.
- **Solar cooling climate**
  the combination with climate is crucial to have the connection to the Sunbelt. It crosses different climates (i.e. tropical, dry and temperate climates), which need to be respected. The corresponding combination of solar irradiation, ambient temperature, relative humidity, wind and other parameters (sandstorms, water availability, etc.) influence the choice and the efficiency of all components and thus the performance of the solar cooling systems.
- **Solar cooling system design**
  this should focus on different designs for different boundaries and also the possible different use cases.
- **Solar cooling control**
  should provide the knowledge to optimize the control strategy to the different locations and conditions.

### 3.2.2 Literature Search

Based on the defined literature sources and keywords the main literature collection was done. For the first phase the search criteria was to find the most relevant literature, ranked by the search algorithms of the sources. For each keyword, the 30 most relevant works were taken from both sources, see Figure 1. The collection resulted in a number of 300 citations, which were part of the investigation.

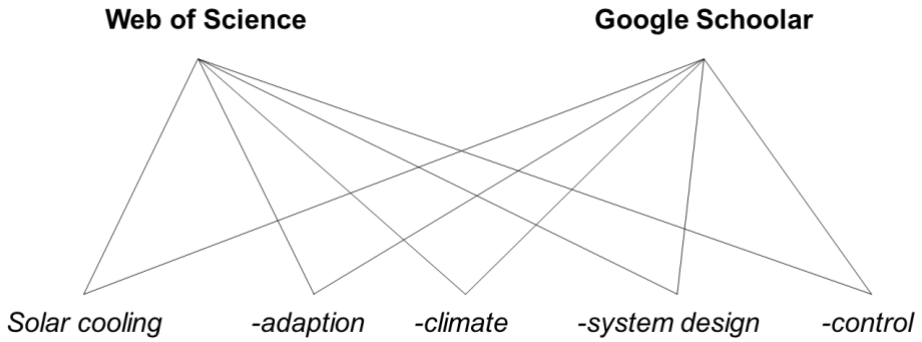


**Figure 1: Sources and main keywords of literature review**

### 3.2.3 Literature Preprocessing and Cleaning

The identified literature was directly loaded into the reference management software Citavi. It was necessary to check, clean and preprocess all of the data. Therefore, the following steps were done:

- Add an extra tag to each literature and add the source and keywords to which they belong.
- Find duplicates and match them (also the tags for the source and keyword).
- Check all of the abstracts and supplement the missing ones. Within this step delete literature with no relevant content.
- Unify keywords (capitalization, plurality, similarity, …)
- Add all available full texts and decide how to deal with missing ones. Rename all full texts the way "author, year, title"
- Cross-reference between literature data, abstracts, keywords and full texts

This preprocessing and cleaning led to 187 titles out of 300 searched ones!

Keywords are minimized from 628 to 501!

For all the relevant sources the full texts are available!

After this all of the data was exported as RIS file with the additional renamed full texts as PDF files. These data are further imported to MAXQDA software to perform the qualitative review itself.

### 3.2.4 Definition of Codes (Specific Keywords)

There were various codes and subcodes defined to enable the investigation of the files with respect to the different topics. These are some examples of them:

- Solar PV & solar thermal cooling
- Boundaries: hot dry/hot humid climates
- Focus on components and present system performance
- Hydraulic and system design
- System optimization (economic, efficiency, primary energy, …)
- Control strategies
- Heat rejection

### 3.2.5 Coding of Data

The coding of the data was done within MAXQDA and could be compared with highlighting of the different texts fitting to the different codes. These excerpts can then be shown in relation to the different topics.

### 3.2.6 Evaluation of the Data

The evaluation is a steady process at the moment and there are also always steps back to add literature and so an. Within this also the different features like word clouds, memos, word frequencies and so on are used to get a good overview and work on the results. Some of them are shown in the next chapter.

### 3.2.7 Derivation of Results

The detailed analysis of the results has to be done once the evaluation is finished.

A short summary in form of word clouds is shown in the following chapter. They represent some numbers, data types and most common topics represented by the frequency of the words occurring.

## 3.3 Summary Literature Review

Within the literature review a lot of different sources are analyzed. Following word clouds show some excerpts of the work out of the 187 literature sources and 501 keywords.

### 3.3.1 Publication Year

The shown words and its size represent the frequency of the different publication years (Figure 2). The threshold was chosen to be a minimum of 5 representations (~3%). Most cites are from 2012, followed by 2014 and 2020.


**Figure 2: Word cloud on publication years of literature sources.**

### 3.3.2 Type of Reference

The types of reference (Figure 3) have the same threshold as the publication year, also 5 times. Most sources are journal papers (jour), followed by conference papers (cpaper) and books.


**Figure 3: Word cloud on reference type (jour - journal paper, cpaper - conference paper, book).**

### 3.3.3 Titles

This word cloud represents the most occurring words within the titles (Figure 4). The threshold is in this case a minimum representation of 8 times (~5%).

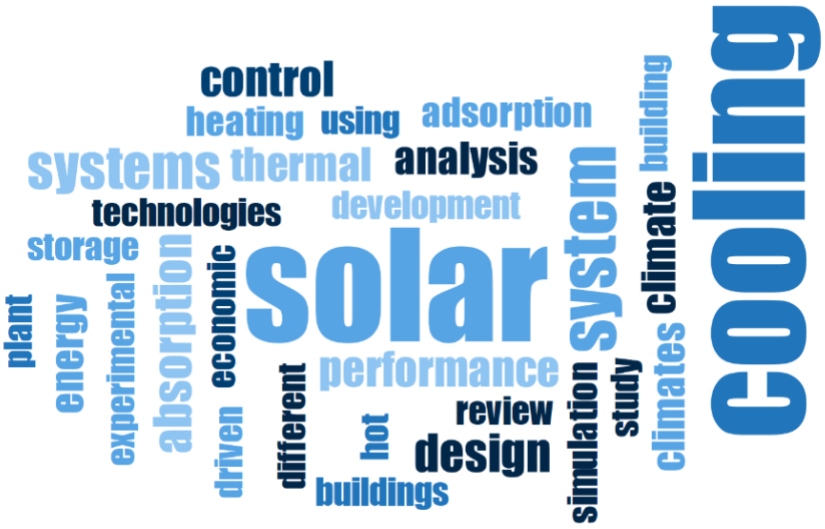


**Figure 4: Word cloud of the most frequently occurring words in the titles.**

The main used words are based on the search terms themselves:

- Solar cooling
- -adaptation
- -climate
- -system design
- -control

On the other hand, based on the analysis of the titles, the following highest numbers are coming up with:

- Thermal
- Ad-/Absorption
- Performance
- Buildings
- Experimental
- Hot

### 3.3.4 Keywords

This word cloud represents the most occurring words out of the keywords (Figure 5). The threshold is in this case a minimum representation of 8 times (~5%).

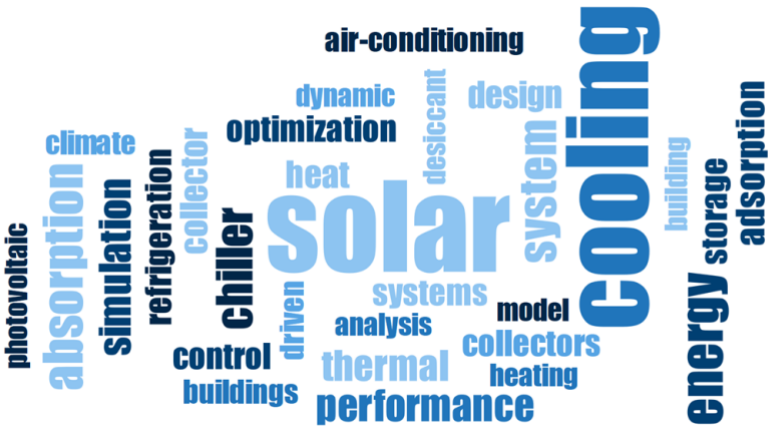


**Figure 5: Word cloud most frequently occurring keywords.**

They are based on the search terms and on the other hand the analyzes shows the highest numbers at

- Ad-/Absorption
- Desiccant
- Photovoltaic
- Air-conditioning
- Optimization
- Storage

### 3.3.5 Abstracts

This last word cloud represents the most occurring words out of the abstracts (Figure 6). The threshold in this case is set to a minimum representation of 8 times (~5%). There the variation of the words is much higher and shows the extensive data available in the literature.

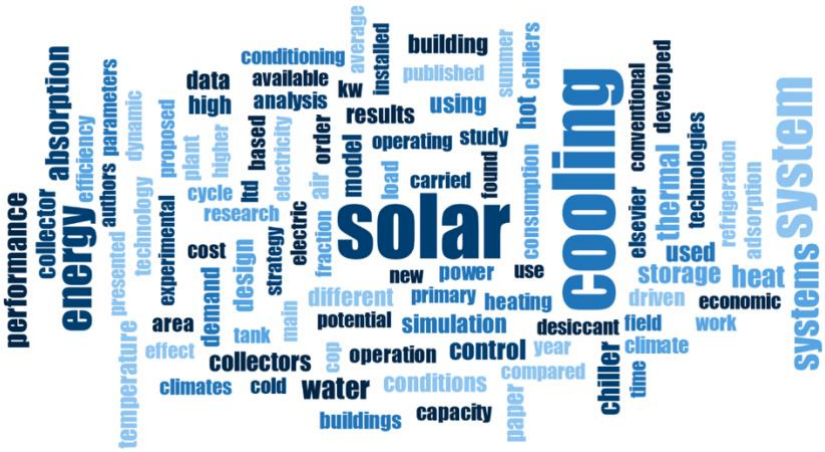


**Figure 6: Word cloud of the most frequently occurring words in the abstracts.**

The presented data shows a small overview of the knowledge presented in the different sources. The main goal of the review is a detailed overview of the status on necessary adaptions for solar cooling in Sunbelt regions.

The following chapter shows some projects in the sector of solar cooling. These show such adaptions, and their results are also included in the review, according to the published data.

# 4 Projects Related to Adapted systems

This chapter presents a small number of solar cooling projects that have investigated the system adaptation to different climates and boundary conditions appropriate to the Sunbelt regions. Their results are also part of the literature review.

## 4.1 SolarHybrid

Within the Austrian funded FFG project “SolarHybrid” a solar-hybrid concept (solar in combination with a vapor compression and absorption chiller) for various cases was developed and analyzed (Figure 7). These concepts were further investigated to be adapted for the Sunbelt regions and to demonstrate their functionality through hardware-in-the-loop measurements. Building upon the laboratory and simulation experiences the hybrid refrigeration concept was further investigated under different climatic conditions using various tools for evaluation and comparison. This concept combines a solar-thermal absorption cooling system with a conventionally powered compression cooling system, dynamically adjusting between solar and backup power to achieve a dynamic regulation and $SPF_{sys.C}$ >12. The system can also operate as a heat pump, with the option for parallel usage of both sides (cooling and heating). Functional models of ammonia/water absorption and compression refrigeration machines have been installed in the lab for testing in various operational modes.

Within the FFG project SolarHybrid a solar-hybrid concept for various cases was developed and analyzed. Based on that the solar-hybrid concept was adapted for various cases in Sunbelt regions and demonstrated feasibility through hardware-in-the-loop measurements.

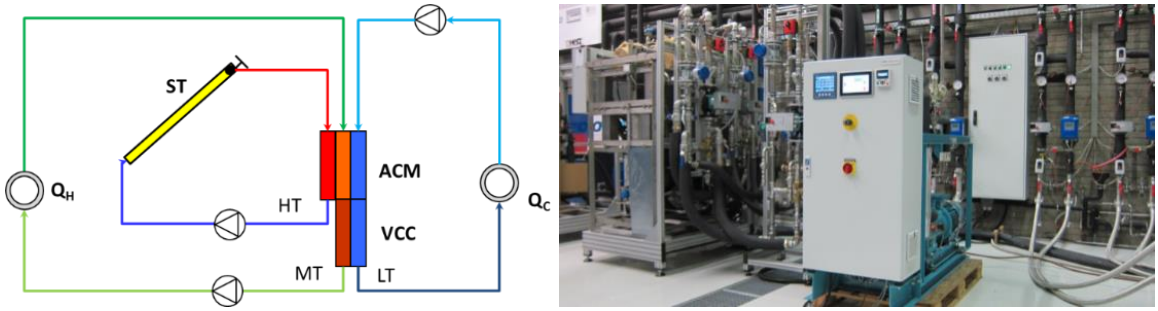


**Figure 7: Solar hybrid scheme (left) and test setup in lab (right)**

The concept of hybrid refrigeration provision was further investigated under different climatic conditions and evaluated and compared with different tools. The “sol.e.h.²” project incorporates a combined building-system optimization approach, first reducing the building's energy demands to a minimum (cooling/heating load and energy requirement), followed by the implementation of the solar-hybrid system concept developed by UIBK (chapter 4.2). This combines a directly solar thermal-driven absorption cooling system with a conventionally powered compression cooling system, dynamically adjusting between solar and backup power to achieve a dynamic regulation and $SPF_{sys.C}$ >12. The concept can also function as a heat pump, with the condensers serially connected. Parallel usage of both sides (evaporator-cooling, condenser-heating) is also possible.

The basis for the work is the functional models of an ammonia/water ($NH_3/H_2O$) single-/half-effect absorption refrigeration machine and an ammonia compression refrigeration machine. These functional models have been installed in the laboratory of the University of Innsbruck and subjected to stationary and dynamic tests in individual and hybrid operating modes. The functional models and a typical daily profile can be seen in Figure 8 below.

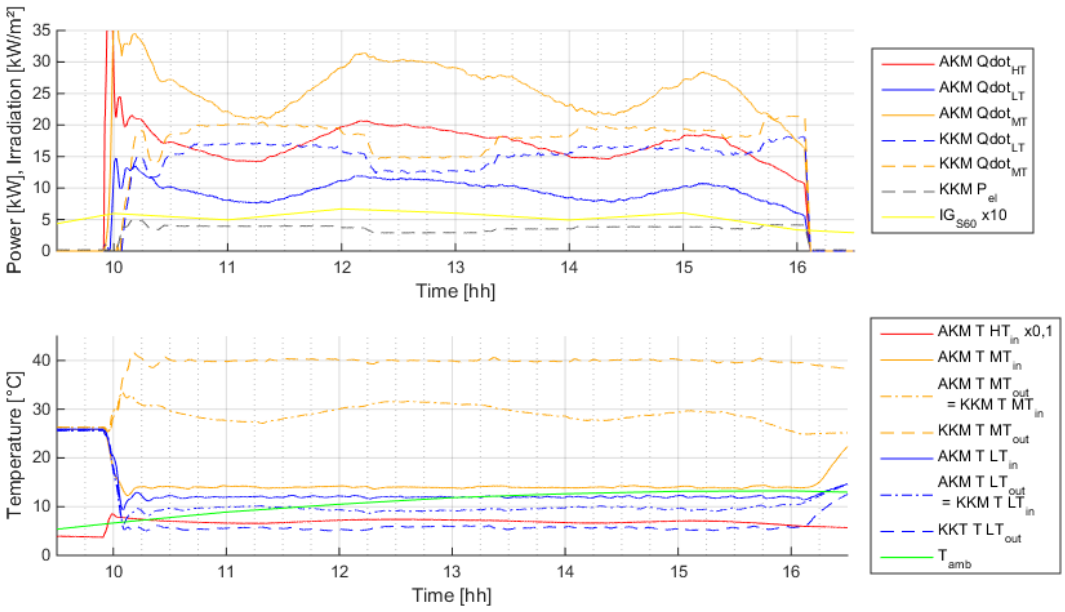


**Figure 8: Dynamic measurements of a real chiller in hybrid operation.**

## 4.2 sol.e.h.²

The FFG funded "sol.e.h.2" project presents an adapted system for solar-hybrid cooling in hot/humid climates. Concrete points for three activities were derived from the presentation and results, and documented accordingly:

- Climatic Conditions: Hot/humid climates pose challenges for dehumidification and cooling due to reduced solar radiation. However, through passive architectural measures and optimized solar energy provision, significant technical and economic results can still be achieved.
- Adapted Systems: The system design includes collector size, storage capacity, compression versus absorption refrigeration, and integration of cooling towers or coupling with domestic hot water for cooling. Hybrid systems combine solar thermal collectors with absorption and compression refrigeration, using natural refrigerants like $NH_3$ or $LiBr/H_2O$ for improved efficiency and redundancy.
- Load Optimization: Primary reduction of building cooling load, followed by covering the remaining demand with solar refrigeration, demonstrated excellent technical and economic performance.

The project utilized a modular container-based office building with open outdoor corridors, causing significant cooling and dehumidification loads. Closing these corridors and minimizing leaks proved essential for separating indoor spaces from external climate influences. Further optimization of the building envelope, including insulation, cool colours, reduced transparency, sun protection glass, and moisture recovery in mechanical ventilation, helped smooth cooling load peaks (Figure 9). Drastically reducing building cooling loads is key to the cost-effectiveness of solar-hybrid cooling systems.

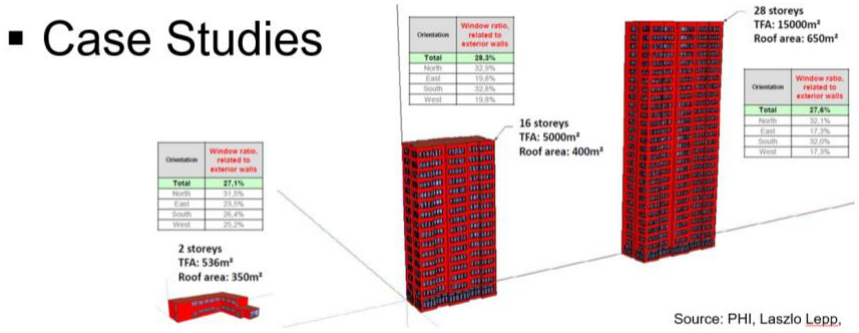


**Figure 9: Case study on different building types within sol.e.h.2.**

## 4.3 SunBeltChiller

The results of the ongoing research project “Solar thermal energy system for cooling and process heating in the Sunbelt region – “SunBeltChiller (SBC)” have been included into this work. The project is led by the Bavarian Centre for Applied Energy Research (ZAE Bayern). It was funded by the German Federal Ministry for Economic Affairs and Climate Action (BMWK) under the project number 03ETW026. The developed method was used to determine possible locations and potentials for the SBC system as a first example.

There are different ways of solar cooling. Table 1 shows a selection of the most common and well-known variants. In addition, the SBS is presented. It is powered by solar thermal energy and uses absorption technology to generate cold. A major challenge for all (solar) cooling systems is the ambient temperature and the associated re-cooling conditions. The higher the re-cooling temperature, the lower the efficiency of a compression chiller or the lower the cooling capacity of an absorption chiller. If the re-cooling temperature is too high, the absorption chiller can no longer be operated.

**Table 1: Different ways of solar cooling (Gurtner et al., 2023).**

CCh: Compression Chiller
AbCh. AbsorptionChiller
SE: Single Effect
DE: Double Effect
SE-DL: Single Effect / Double Lift

| | Ambient temperature | PV + CCh | Solar thermal cooling | | |
|---|---|---|---|---|---|
| | | | AbCh SE | AbCh DE | AbCh SE-DL |
| System‘s efficiency of solar plant η | | 13,5% | 55% | 45% | 45% |
| COP of chiller | 25 °C | 4,6 | 0,75 | 1,35 | 1,35 |
| | 35 °C | 3,4 | | | |
| **Conversion efficiency** „Sun to cold“ = η·COP | 25 °C | 0,61 | 0,41 | **0,61** | **0,61** |
| | 35 °C | 0,46 | (0,41) | (0,61) | **0,61** |

This problem can be solved or at least reduced by using a wet cooling tower. The disadvantage of this re-cooling technology is the high-water consumption. Wet cooling towers can therefore not be used (or only to a very limited extent and at high cost) in regions with water shortages. Furthermore, wet cooling towers by design only work to a limited extent at high humidity. This means that solar cooling systems using absorption chillers can only be used to a very limited extent in warm regions with a lack of water or high humidity. Solar cooling systems with compression chillers are less efficient in these regions.

The SBC solar cooling system offers a solution to this problem. The SBC is powered by concentrating solar collectors at temperatures higher than 160 °C. In the first step, the solar collectors drive a special absorption chiller called Double Lift (DL) machine which can be re-cooled at very high temperatures (approx. 90 °C). In the second step, the waste heat from the DL machine drives a "classic" single effect (SE) absorption chiller, which is re-cooled against the ambience. The overall efficiency of these two steps is equivalent to a Double Effect (DE) absorption chiller (Figure 10).

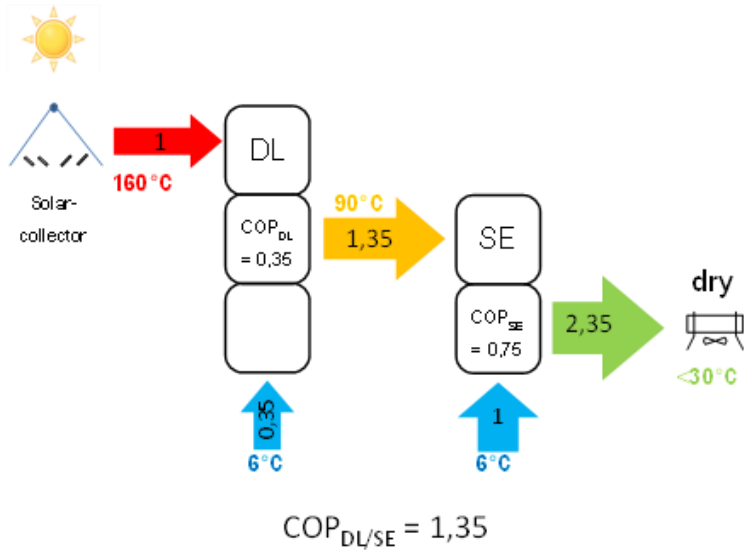


**Figure 10: SunBeltChiller - A combination of a double lift and a single effect chiller (Gurtner et al., 2023).**

Thanks to the two-stage generation of cold and by using heat and cold storages, the operation of the Single Effect can be shifted to the night hours and thus to periods with lower outside temperatures. This eliminates the need for a wet cooling tower. In addition, the SBC system can provide additional heat at around 90 °C (Figure 11).

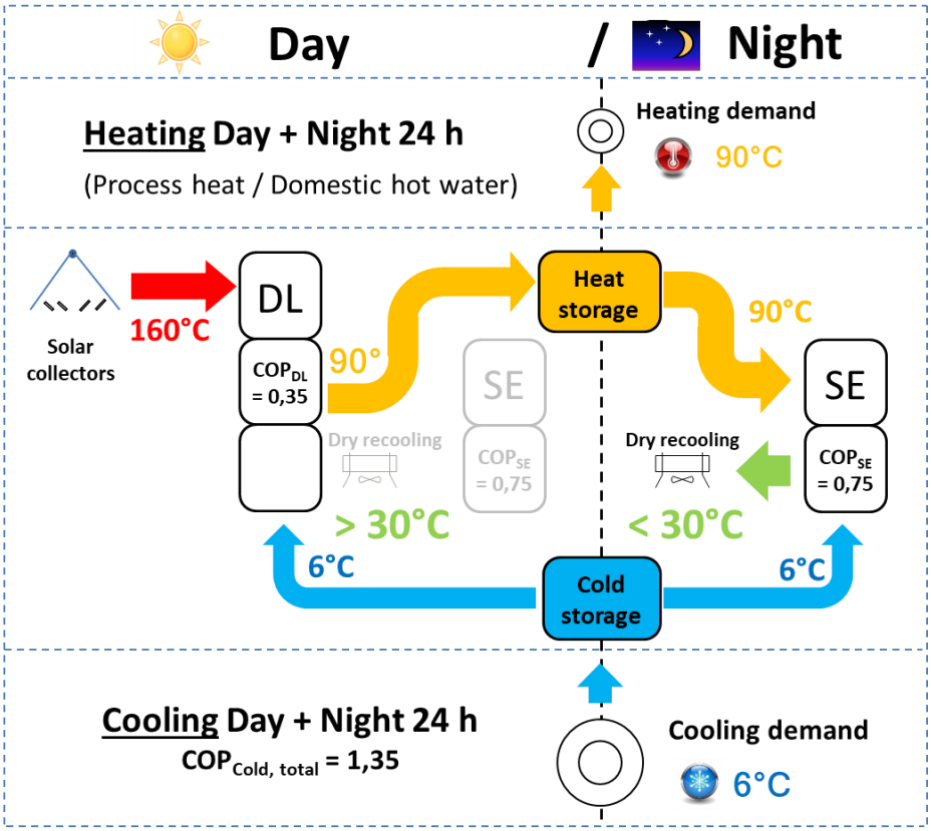


**Figure 11: The SunBeltChiller System (Gurtner et al., 2023).**

The SunBeltChiller is therefore an adapted solar thermal cooling (and heating) system that, despite high ambient temperatures, does not require a wet cooling tower and promises high efficiency.

# 5 Publication Bibliography

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