Adapted components and showcases on solar cooling systems in sunbelt region countries

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Abstract

As global temperatures are hitting new heights, demand for air-conditioning is increasing. In this light, the improvement of solar cooling systems and their actual performance need to be investigated. IEA – SHC Task 65 Solar Cooling for Sunbelt regions focuses on innovations for affordable, safe, and reliable Solar Cooling systems. The project focuses on solar energy, either solar thermal or solar photovoltaic, in the Sunbelt region, taking into account the different boundaries worldwide (sunny and hot, and humid climates, between the 20th and 40th degrees of latitude in the northern and southern hemisphere). The task consists of four main subtasks to investigate different aspects of the study: adaptation, demonstration, assessment & tools, and dissemination. This paper presents the results of a survey conducted within the activities of two subtasks: adapted components (A2) and showcases on system and component level (B1).

Keywords: solar cooling, adapted component, case study, Sunbelt region

1. Introduction

The population is growing, the incomes are rising, the rise in global temperature, and the increase in comfort standards are causing the increase in air-conditioning demand. Nowadays, air conditioners and electric fans account for about a fifth of the total electricity in buildings around the world – or 10% of all global electricity consumption (IEA, 2018). If measures are not taken to counteract this increase, the space cooling demand will almost triple by 2050; it can reach 6,200 TWh or 30% of the total electricity use in buildings. Such estimations are generally based on the most recently available conventional technologies for air-conditioning and refrigeration.

While the OECD (Organisation for Economic Co-operation and Development) countries in Europe, the US, Australia etc., are taking the lead in solar cooling technology both in thermal and photovoltaic (PV), most of the countries in the Sunbelt regions need more momentum in terms of technology and funding to propel this further. Countries that fall between 20 and 40 degrees of latitude face an increase in cooling demand on one side and higher solar irradiation on the other, thus making it a one-stop solution to utilize the potential of solar cooling and try to invert the current trend. The Green Cooling Initiative (Gloel et al., 2015) estimates a steep rise in the use of conventional air conditioning units from 918 million to 3.5 billion by 2050.

In this light, IEA Solar H&C PROGRAM task 65 focuses on innovations for affordable, safe, and reliable solar cooling systems. The project focuses on solar energy, either solar thermal or solar photovoltaic, in the Sunbelt region, taking into account the different boundaries worldwide (sunny and hot, and humid climates, between the 20th and 40th degrees of latitude in the northern and southern hemisphere).

Solar cooling systems have gained significant attention as an environmentally friendly and sustainable solution for meeting the cooling demands in Sunbelt region countries. These systems incorporate adapted components and are tailored to these countries' unique requirements and climatic conditions. By harnessing abundant solar energy and optimizing cooling technologies, solar cooling systems in Sunbelt region countries offer immense potential for reducing energy consumption, enhancing comfort, and mitigating climate change impacts.

The above-mentioned task consists of four main subtasks to investigate different aspects: adaptation, demonstration,

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assessment & tools and dissemination. This paper presents the results of a survey conducted within the activities of two subtasks: Adapted components (A2) and showcases on system and component level (B1). The expected goal of the project is to deepen the understanding of how varying climatic conditions and operating parameters affect the choice of components and identify the factors that enable or pose challenges to widespread application in the region. Indeed, solar cooling systems designed for sunbelt region countries incorporate components specifically adapted to the local climate and environmental conditions. These components are selected to optimize the system's performance and ensure its reliability in high-temperature regions. Some of the key adapted components include Solar Collectors: Solar collectors used in sunbelt region countries are designed to capture and convert a maximum amount of solar radiation into thermal energy. Furthermore, they are optimized to operate efficiently even in high ambient temperatures, ensuring optimal energy generation throughout the year.

Sorption Chillers: sorption chillers are commonly employed in solar cooling systems. These chillers use the heat generated by solar collectors to drive the cooling process. Adapted chillers have improved heat transfer capabilities, enhanced efficiency, and increased tolerance to higher inlet temperatures, making them suitable for sunbelt region countries.

Heat Rejection Systems: Heat rejection systems, such as cooling towers or dry coolers, are essential for dissipating excess heat generated during the cooling process. Adapted heat rejection systems are designed to operate effectively in hot climates, providing efficient heat transfer and reducing water consumption where applicable.

Thermal Energy Storage: To overcome the intermittent nature of solar energy availability, solar cooling systems in Sunbelt region countries often incorporate thermal energy storage solutions. These storage systems are optimized for higher ambient temperatures and offer effective energy storage and retrieval capabilities, ensuring uninterrupted cooling during periods of low solar radiation. To investigate how a solar cooling system must be adapted in such a severe climate area, scientists developed specific tools and conducted focused experimental campaigns. For example, (Ssembatya et al. 2014) evaluated the performance of solar cooling systems in the UAE climatic conditions by TRNSYS simulation. The system used for simulations was developed to assess the potential of solar cooling systems in this region. The tool developed showed that the system can operate with a thermal COP of 0.60 – 0.80. The experiments then validated such results on a typical day, thus proving that an adapted system can meet its cooling requirement for almost 2/3rd of the year without backup heating and/or cooling.

Litardo (Litardo et al., 2022) recently reviewed all the cooling strategies for warm and humid climates. The authors examined and identified possible solutions for space cooling in hot-humid climates (air system with heat recovery, radiant ceilings coupled with AHU, etc.), including an assessment of the application of these solutions on a case-study building in Mogadishu, Somalia, from the point of view of the cooling demand to the energy consumption of the selected cooling systems. The findings of this work provide helpful information about the performance of the cold delivery systems in harch climatic areas, thus allowing the extrapolation of data for solar-assisted systems. Also (Bentayeb et al.) provided valuable data about such a class of systems. In their study, the authors presented a model that considers the actual functioning of an adsorptive solar fridge that employs activated carbon-methanol pairs regarding weather conditions such as ambient temperature and insolation. The model simulates the cooling performance in two distinct Moroccan climates: Rabat (humid and temperate) and Marrakech (hot and arid). The numerical simulation reveals that the solar refrigerator operates differently in each climate. In Rabat, which has a Mediterranean climate, the cold room temperature can be sustained below 5°C; conversely, in Marrakech, which has a pre-Saharan climate, the system can overheat during the summer and the cold room temperature can reach 17°C. The simulation also indicates that the studied unit poses a problem in both climates as the cold room temperature can drop below 0°C, with a minimum of -15°C during winter.

2. Methodology

The survey was shared and sent to solar cooling experts, researchers and manufacturers. Moreover, to have a more extensive database of information, the survey was upgraded with other data from literature review studies. The survey was divided into two main parts. Each part included information related to one of the two subtasks. In particular, the first part was associated with a first exploratory survey of demonstration cases: it included information such as title, typology of the case (if implemented, detailed project, concept, etc.), the name of the implementer and the owner, the location, the related climate condition, the application sector (process industry, distribution of goods, fish industry, buildings, mining, etc.), technology information of the Thermal Driven Chiller (STD), Solar Thermal collectors (ST), of the PV panels, of the storage, of the heat and cold back up, and the Heat Rejection System (HRS), the description of the demo case, the profile of the energy needs, availability of space for the installation of renewable/energy-efficient technologies, the potential of replication, and availability of data/monitoring system. The second part included information regarding the actual performance of the components such as thermally driven chiller, electric chiller unit/backup, ST collectors, PV panels, storage, heat and cold backup, heat rejection system, and the description of possible precautions adopted for operation in climatic conditions of the Sunbelt area.

3. Solar Cooling System Types: an overview

This section provides a basic description of solar cooling technologies and focuses on identifying components suitable for different solar cooling systems based on weather profiles. The primary solar cooling systems are illustrated in Figure 1.
One prominent solar cooling system is the PV-assisted system, which primarily utilizes solar energy to generate electricity. This electrical energy is then used to power a conventional vapour compression system. In addition, hybrid Photovoltaic-Thermal (PVT) collectors are employed in cases where the thermal energy from solar radiation is extracted. This integration of PVT collectors has been shown to enhance the efficiency of PV panels.
The following subsections further elaborate on the specific details and workings of PV-assisted systems and PVT collectors.
Another significant solar cooling technology is Solar Thermal (ST) cooling, which encompasses various types and applications. ST energy is harnessed to drive chillers of multiple typologies. The section comprehensively describes ST cooling, including detailed discussions on system components such as solar collectors, thermal energy storage, chillers, and heat rejection methods. Each component is described, highlighting its functionalities and significance within the ST cooling system.
By categorizing the components suitable for different solar cooling systems and considering weather profiles, the section offers valuable insights into the design and implementation of solar cooling technologies. Furthermore, it emphasizes the utilization of solar energy in both PV-assisted systems and ST cooling, showcasing the potential of these systems to provide sustainable and efficient cooling solutions in various applications.
Overall, the section provides a foundational understanding of solar cooling technologies, offering a basis for further exploration and research in the field. In addition, it sets the stage for subsequent discussions on system optimization, performance analysis, and advancements in solar cooling systems for diverse climate conditions.

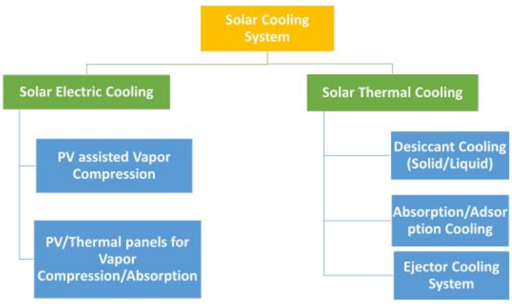

Fig. 1: Solar Cooling System Classification

3.1 PV-assisted Solar Cooling

Solar electric cooling utilizing the electric energy from a PV panel combined with vapour compression systems is an effective form of solar cooling technology in many scenarios because PV panels integrated into existing buildings do not need any additional allied parts to support the cooling process. Furthermore, with the current PV panel efficiencies at 15% to 20% and the use of Maximum Power Point Tracking (MPPT) to optimize solar energy utilization, PV-assisted vapour compression cooling is more economically and technologically viable.
Optimizing the effective utilization of solar fraction incident on the PV panel to meet the energy demand of a building, the ratio of peak-rated power of panels to the chiller-rated power is a critical design consideration (Li, Y., 2018). Also, different energy storage options, such as cold storage using phase change materials (PCM) and batteries, are considered to increase the overall system effectiveness (Wang and Dennis, 2015), Albatayneh et al. (2021a) made an experimental evaluation between PV air conditioner and ST cooling system. While ST cooling had a LCOE value of \$2.35/kWh, the value for the air conditioning system coupled with PV is under \$0.05/kWh for an Eastern Mediterranean region characterised by a hot, dry climate. When considering different techno-economic parameters,

the choice of appropriate solar collector technology and efficient solar cooling device are critical determining factors (Mokhtar *et al.*, 2010).

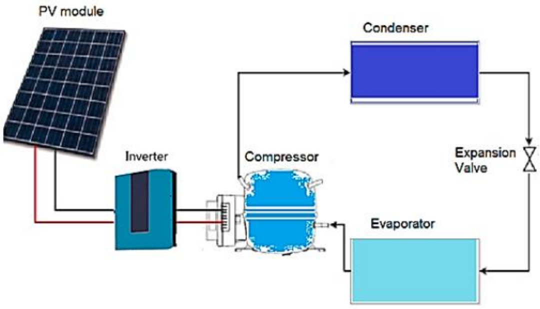

Fig. 2: PV-assisted solar cooling (Albatayneh *et al.*, 2021)

3.2 Vapor absorption Cooling

A vapour absorption cooling system consists of an absorber, generator and pump (the thermal compressor), a condenser, an expansion valve and an evaporator. The system can be divided into three circuits: a) Hot water flow; which supplies the heat to the absorber, b) Cold water flow; which is responsible for drawing heat from the space to be cooled and c) Cooling water flow; here the heat generated by both the above flows are removed by a cooling tower and released to the environment.

Various researchers developed and studied different systems configurations, demonstrating that systems could be enhanced at various stages to increase their overall performance. Alghool et al., (2020) studied to store the ST energy, a storage tank and/or an auxiliary heater are used to keep the hot water supply consistent and to compensate for any intermittency in solar insolation and prolonged usage over a day. They found that solar collectors covered 46% of the chiller's heat demand. Lòpez et al. (2020) employed a biomass boiler to account for hot water in the solar energy and a ClimateWell-CW10 absorption chiller. It has two different subsystems that can alternatively charge and discharge independently in the same project. The machine achieves good COP values that match the literature references, but results predict that extra use of auxiliary heating systems may be needed for applications with low insolation levels. Yu et al. (Yu *et al.*, 2019) showed that in high-rise building applications using a hybrid refrigeration system combining absorption and compression cycle, COP is improved by up to 22.2% and 19.8% on sunny days and cloudy days, respectively.

Another good action can be the integration in this kind of system of chilled water. This tank is usually a cold backup to ensure space cooling at all times of the day. E.g. for residential and multi-family building applications, domestic hot water (DHW) can be extracted from the cooling tower water circuit and heat extraction from the water to be cooled reduces the size of the cooling tower (Bilardo *et al.*, 2020).

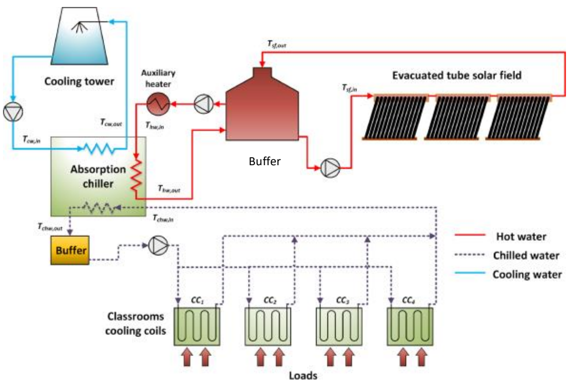

Fig. 3: Schematic diagram of an absorption cooling system (Aguilar-Jiménez et al., 2020)

3.3 Vapor Adsorption Cooling

Solar adsorption air conditioning system (SADCS) uses low-grade heat to power their adsorption/desorption cycle to bring about a cooling effect. SADCS can be broadly categorized as open and closed system adsorption cooling. In an open cycle adsorption cooling, the latent heat of cooling is reduced by adsorbing moisture to the adsorbant surface, and working air is in direct contact with the adsorbant. On the other hand, a closed system produces chilled water that brings about the cooling effect (Mat Wajid et al., 2021). An open cycle solar adsorption cooling comprises two main components a dehumidifier and cold storage. The working principle is detailed in the figure below. It entails an open adsorption heat pump with intermittent operation. Furthermore, an air solar-driven absorption system is designed with the additional use of an auxiliary heater and cold storage (Nielsen et al., 2022).

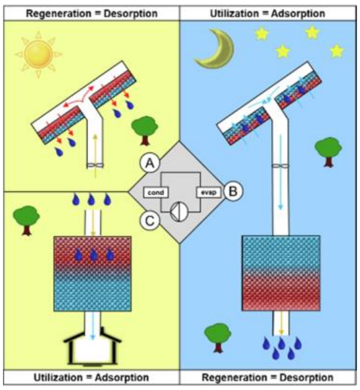

Fig. 4: Working principle of solar adsorption cooling (Nielsen et al., 2022)

In a closed system adsorption cooling, there are three independent water streams i) connected to the solar heating system to heat the adsorber beds ii) cools down the condenser and the bed iii) chilled water loop cooling the indoor space(Almohammadi and Harby, 2020). To enhance the adsorption cycle for more demanding applications, there are additional components with two adsorption chambers so that they can function alternately and get a continuous useful effect (see figure 5). When ads 1 is in cooling mode (adsorber) ads 2 will be in heating mode (desorber). Cooling towers like in the absorption cycle take away the heat from the condenser and are part of the heat rejection cycle of the refrigeration cycle.

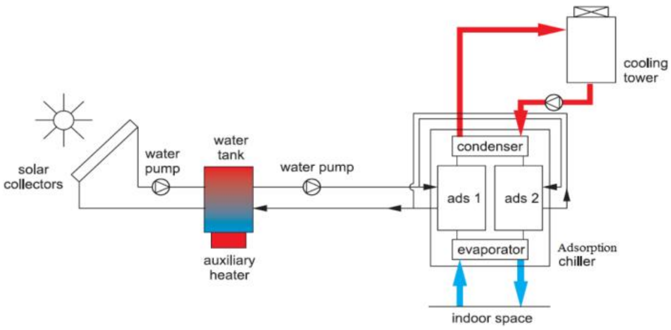

Fig. 5: Schematic of solar adsorption cooling (Dorota Chwieduk et al., 2014)

3.4 PV/T Solar Cooling

A PV/T solar cooling system is a hybrid system that combines photovoltaic and thermal technologies to provide both electricity generation and cooling capabilities. It integrates photovoltaic (PV) modules with solar thermal collectors, commonly known as Photovoltaic-Thermal (PV/T) collectors, to maximize solar energy utilisation and improve overall system efficiency.

In a PV/T solar cooling system, the PV modules convert sunlight directly into electricity, which can be used to power the cooling system components. Simultaneously, the PV/T collectors absorb solar radiation and extract thermal energy. This thermal energy is then used in the cooling process, typically through an absorption or adsorption chiller.

The PV/T collectors in a solar cooling system are designed with a dual-purpose structure. First, photovoltaic cells are embedded within the collector, allowing for simultaneous electricity generation and thermal energy collection. The advantage of this configuration is that it maximizes the system's overall energy output while utilizing the available solar energy resource more efficiently.

The thermal energy collected by the PV/T collectors can be used in several ways for cooling purposes. One common approach is to drive an absorption chiller, where thermal energy is utilized to generate a cooling effect through the absorption process. Another option is to employ an adsorption chiller, where the thermal energy is used to desorb adsorbent materials, creating a cooling effect through evaporation and condensation cycles.

The integration of PV/T technology into solar cooling systems offers several advantages. Firstly, it allows for the simultaneous generation of electricity and thermal energy, increasing the system's overall energy efficiency.

Secondly, it reduces the space requirements compared to separate PV and solar thermal installations, making it more suitable for constrained areas. Additionally, PV/T solar cooling systems contribute to reducing greenhouse gas emissions by utilizing renewable energy sources and reducing reliance on conventional cooling methods.

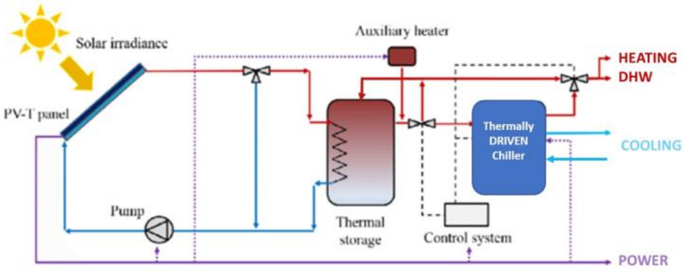

Fig. 6: Schematic of a PV/T solar sorption cooling system.

3.4 Solar Assisted Ejector Cooling

The overall system consists of a solar collector loop, a generator loop, and an ejector loop. The ejector cooling cycle (ECC) replaces the compressor in a vapour compression cycle by thermodynamic mixing of two working fluids in a convergent-divergent nozzle, as shown in Fig 6. Ejector cooling system has a more straightforward design and low equipment cost than absorption/adsorption cooling, although thermal efficiency is low (Saito et al., 2014). Alternate working fluids that can be used in this system make it an attractive option (Varga, S.. 2017). As shown in Fig. 7, solar ECC has two main streams, the solar conduit and ejector cooling cycle. A heat transfer fluid is generally used in the system to transfer heat from the solar collector to the working cooling refrigerant in the generator (Braimakis, 2021).

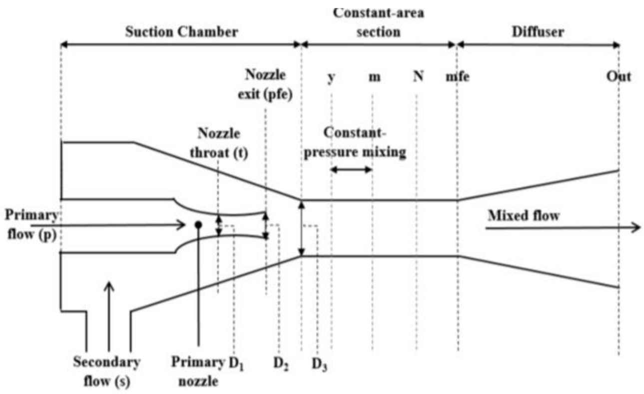

Fig. 7: Schematic of an ejector (Eveloy and Alkendi, 2021)

Eveloy and Alkendi, (2021) studied the use of a three-stage ejector cooling system powered by an evacuated tube collector for a small-scale building. The proposed system is shown to have reduced 42% of the annual energy consumption for a building in the United Arab Emirates, a country in the Sunbelt region.

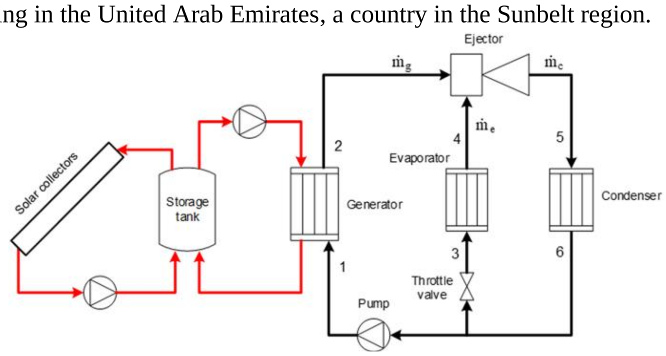

Fig. 8: Schematic diagram of a solar cooling ejector refrigeration system (Braimakis, 2021)

Owing to its low COP, ejector cooling devices are coupled with other effective cooling technologies such as solar ejector-vapour compression and ejector-absorption cycles, which are promising in achieving COP improvements

(Buyadgie, D,2012). Zarei et al., (2020) demonstrated the use of a novel combined solar cooling system using PVT panels and an ejector compression cooling system. The heater, compressor, and pumps were electrically powered by the PV panel and the output thermal energy from the PVT system was used to cool the condenser and the sub-cooler. The study shows that the PV panel efficiency and COP of the system can be improved by up to 11.1%

4. Results of the survey

Solar cooling has the potential to be an effective and efficient solution for decarbonization in countries across the Sunbelt region. With an expected increase in the cooling demands in these countries, it could be an excellent opportunity to identify the correct component choice and analyze existing projects to further catapult its reach and impact. The study summarizes 32 works from across 18 countries in the Sunbelt region. The distribution of projects is depicted below.

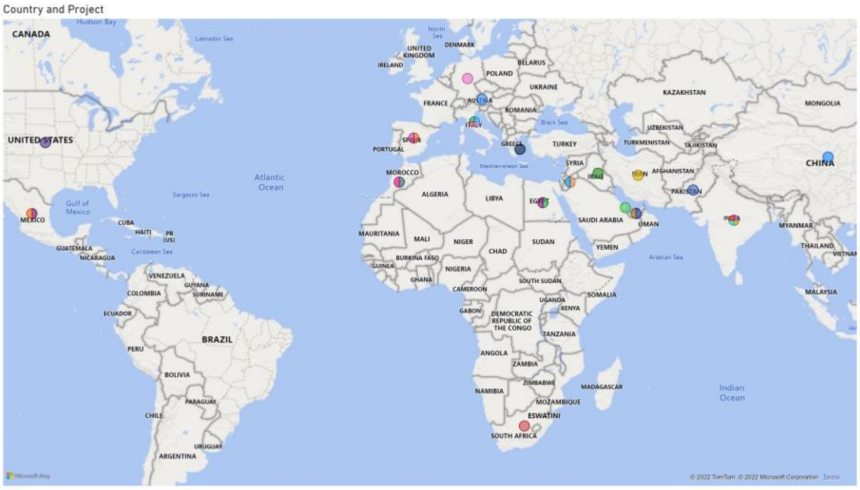

Fig. 9: Representation of projects from across different countries

4.1 Koppen-Geiger climate classification

Koppen-Geiger climate classification divides climate across the globe into five main categories, the equatorial zone(A), the arid zone (B), the warm temperate zone (C), the snow zone D, and the polar(E) and 31 sub-types adding in additional ranges for precipitation and air temperature. It is classified based on monthly air temperature precipitation and maximum and minimum values. Knowing each country's climate zone can be a critical criterion for choosing the right type of cooling system and solar energy collectors. Figure 10 shows the distribution of our projects studied across various climate classification zones.

Table1: ***Koppen-Geiger climate classification***

Main climates	Precipitation	Temperature
A: equatorial	W: desert	a: hot summer $T_{max} \geq +22$ °C
B: arid	S: steppe	b: warm summer not (a) and at least 4 $T_{mon} \geq +10$ °C
C: warm temperate	f: fully humid	c: cool summer not (b) and $T_{min} > -38$ °C
D: snow	s: summer dry	d: extremely continental like (c) but $T_{min} \leq -38$ °C
E: polar	w: winter dry	h: hot arid $T_{ann} \geq +18$ °C
	m: monsoonal	k: cold arid $T_{ann} < +18$ °C
		F: polar frost
		T: polar tundra

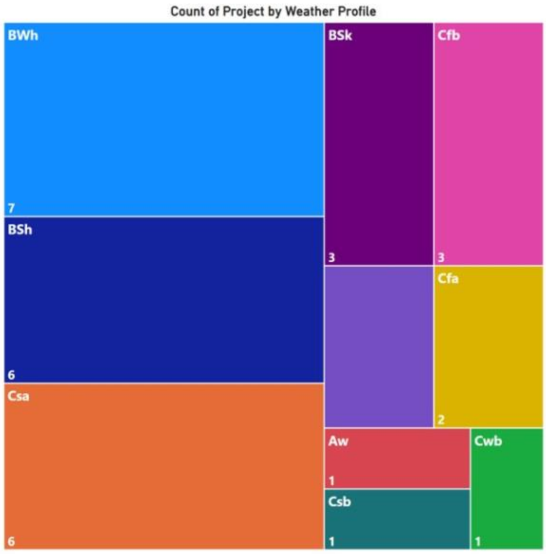

Fig. 10: Representation of projects studied and their climate classification

The temperature criterium estimates the intensity of solar insolation, the number of sunny days, and maximum and minimum temperatures in a zone. Countries in the Sunbelt region fall in the range between Group A (tropical climates), Group B (dry climates) and Group C (temperate climates). The solar cooling projects included in this study are located (actually or simulated) in 60% of the Sunbelt region throughout 9 sub-types. Most of the projects reported are from BWh (Hot desert) (23%), and BSh (Hot semi-arid) & Csa (Hot summer-Mediterranean) (both 20%) climate regions.

4.2 Projects Typologies

The studies were from a wide range of types as shown in Figure 11. 50% of the projects are in the implementation phase at various stages while 18% of the works are operational projects with established results. A quarter of these works are project concepts studied for implementation in nature.

Others have been simulated by using tools such as TRNSYS, Python, Matlab, and other mathematical modelling tools that can effectively estimate a system's performance before its implementation. Some published works of laboratory experiments and simulations validated by real-time building energy use have also been used in our survey for a broad range of analyses. Projects of different categories are studied to enhance the understanding of their performance and generate design rules that apply to different climate zone. The design rules encompass various components in a specific weather zone.

As shown in the following figure, almost 70% of the projects studied are either implemented or detailed projects, 25 % are concepts, and 6% are experimentations and validated using real-time buildings.

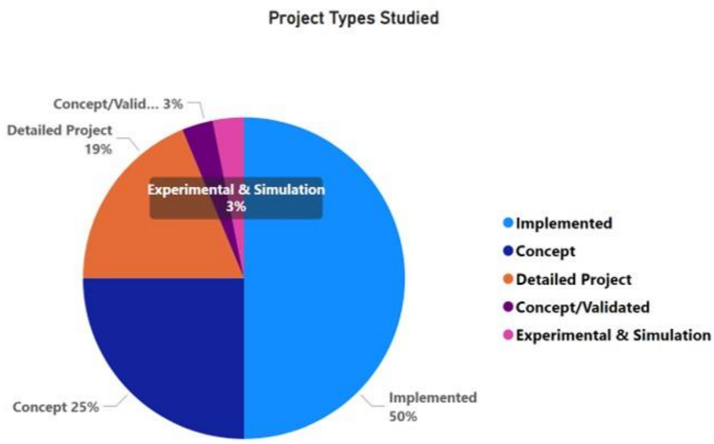

Fig. 11: Project typology distribution

4.3 Solar Collector types

Solar Cooling uses a range of solar energy harnessing devices. Evacuated tube collectors constitute 30% of the projects studied, and flat plate collectors and Fresnel collectors are equally next in usage. The studies also noted that Fresnel and flat plate collectors are the most popular options in implemented projects, with evacuated tubes the highest in simulation projects.

The distribution of different solar collectors over various temperature profiles gives a fair understanding of which is most suitable in different scenarios. As shown below (Figure 12.) Evacuated tube collectors have widespread application over three climate regions, BSk, BWh, and Csa and similarly with Flat plate collectors in Bsh, Cfb, Bwh, and Csa.

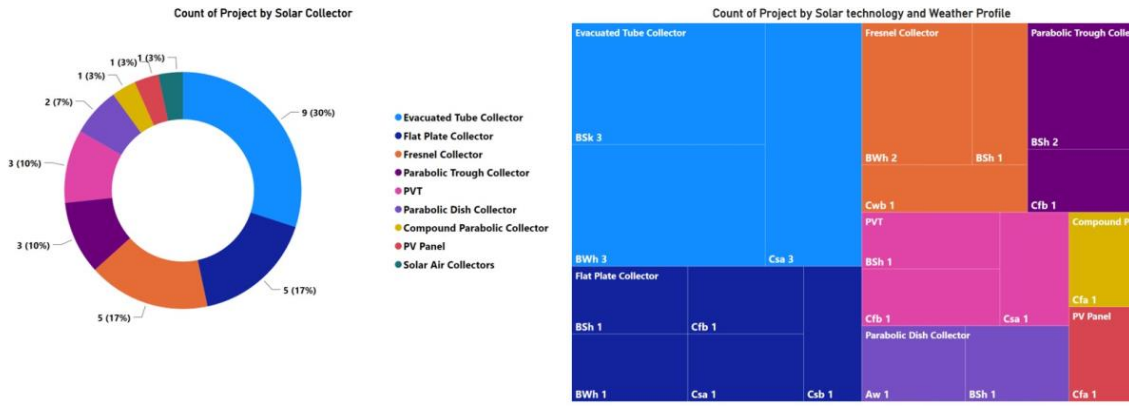

Fig. 12: Solar Collector types (left) and Representation of Solar collector type by weather profile (right)

ST cooling is the most applied solar cooling technology over solar electric cooling. Out of which, 30% of cases studied use evacuated tube collectors, Flat plate collectors (17%), Fresnel collectors (17%), Parabolic trough collectors (10%) and PV panels (10%). These are some of the most preferred options.

4.4 Solar cooling applications

In most cases studied, solar cooling systems are installed in public buildings such as offices, schools, and university buildings, making it suitable to use the sun during the daytime directly for utilization. Domestic buildings appear to be the next most studied because of their widespread need in the Sunbelt region for enhancing indoor comfort. They also have good potential for sectors like food preservation, process industries, etc.

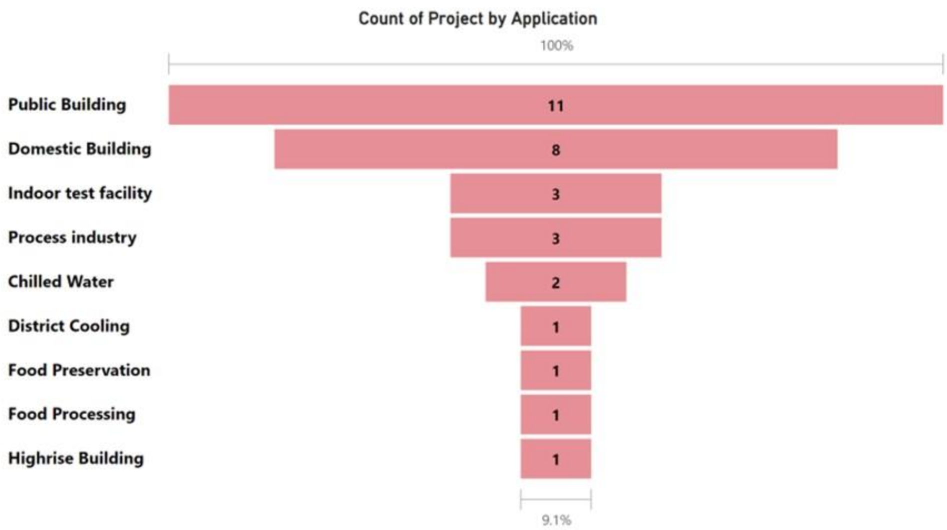

Fig. 13: Solar cooling applications

4.5 Adapted components

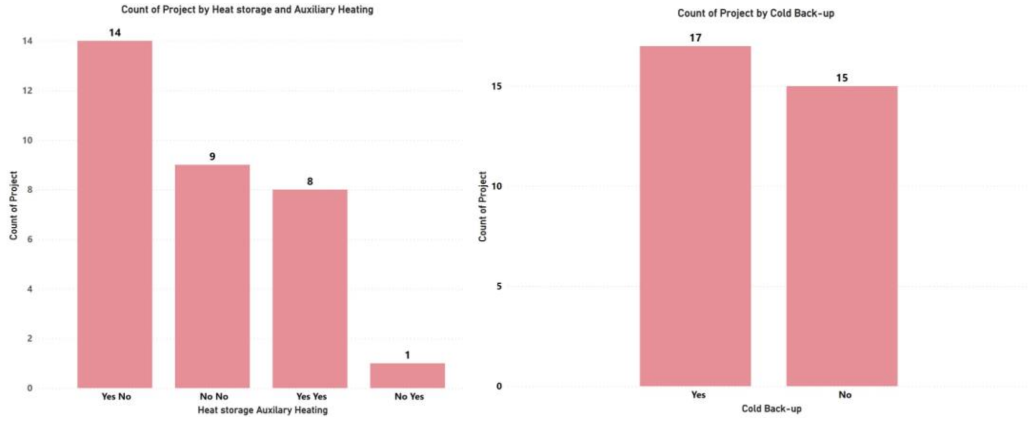

Fig. 14: Heat storage auxiliary heating in projects (left) and cold backup in projects (right)

As mentioned in section 3, heat storage tank and auxiliary heating are used to meet the cooling load when there is low or zero (es. during nighttime) solar radiation. In public buildings such as office spaces and educational institutions, the cooling load is mainly concentrated during the daytime, reducing the need and capacity of these components. However, cooling demand could be needed throughout the day for domestic applications such as villa houses, multi-family buildings, and process industries. Cold backup components include devices that can prolong the cooling effect even when the solar cooling device does not function such as a vapor compression system. In particular, cold backup was comparatively less in use with 53% when compared to heat-back up. To account for the intermittency of solar radiation, heat storage or auxiliary heating is observed to be the common practice. Indeed, hot water storage or heat backup by auxiliary heating was used in 72% of the projects with heat storage being more popular over heat backup.

4.6 Three-way Sankey diagram

The chart below depicts the interrelation between the climate classification each project has been based on, to the solar collector used, and the adopted solar cooling system. This gives an insight into commonalities in the appropriate component and system use about the climatic zone a project falls into. For example, when the maximum number of projects are from BWh (hot desert climate), Fresnel and evacuated tube collectors are mostly preferred over flat plate collectors and others to harness solar energy. Similarly, most studies show evacuated tube collectors are chosen in Csa (Hot summer Mediterranean) and BSk (Tropical and subtropical steppe climate). Of the available ST cooling techniques, 71% use solar absorption, whereas 19% use solar adsorption cooling and other technologies such as Ejector cooling, PV assisted cooling (3% each).

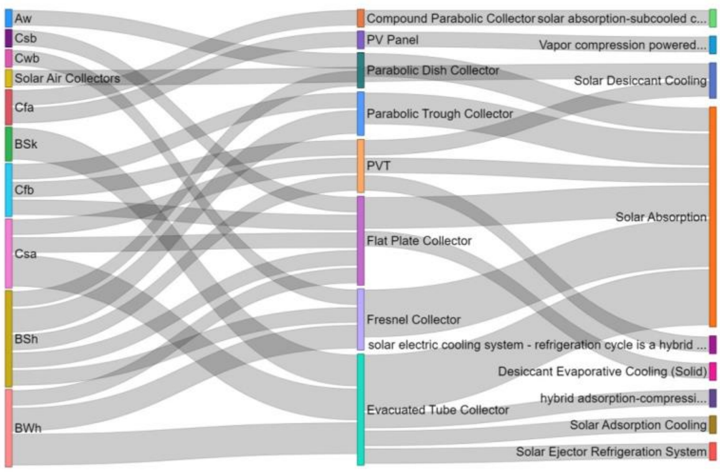

Fig. 15: Representation of weather profile with solar collector and solar cooling technology used

The survey results demonstrated a favourable environment to prove the maturity of solar cooling technology. Insights drawn from this study could benefit a range of stakeholders: private users, public entities, 'hard to abate industrial sectors', policymakers, etc. Moreover, the outcome of this study, and in general the expected results of Task 65, will facilitate tracing the pathway to decarbonization goals and contribute towards energy transition in the region. With the certainty of different case studies presented, energy professionals can take a more informed decision in choosing components and system adaptions suitable for varying climatic conditions. The first presented results are drawn from 32 projects across 18 countries representing a range of 10 weather profiles such as the tropical wet and dry (Aw), hot desert (BWh), hot semi-arid (BSh), hot summer-Mediterranean (Csa), Warm-summer Mediterranean (Csb), Humid subtropic (Cfa), Monsoon-influenced humid subtropical (Cwa), Hot summer humid continental climate zones.

5. Conclusion

This paper aimed to present the first survey results conducted within the activities of two IEA Task 65 subtasks: Adapted components (A2) and showcases on system and component level (B1). The first presented results are drawn from 32 projects across 18 countries representing a range of 10 weather profiles. The 32 projects studied are over 17.06 MW of thermal cooling projects, which are summarized as follows:

- Most of the projects reported are from BWh (Hot desert) (23%), and BSh (Hot semi-arid) & Csa (Hot summer-Mediterranean) (both 20%) climate regions.
- Almost 70% of the projects studied are implemented or detailed, with 25 % being concepts. In addition, 6% of the project is experimentation and validated using real-time buildings.
- ST cooling is by far the most applied solar cooling technology over solar electric cooling. Out of which 30% of cases studied use evacuated tube collectors, Flat plate collectors (17%), Fresnel collectors (17%), Parabolic trough collectors (10%) and PV panels (10%). These are some of the most preferred options.
- Of the available ST cooling techniques, 71% of them use solar absorption, whereas 19% use solar adsorption cooling and other technologies such as Ejector cooling, PV assisted cooling (3% each)
- Hot water storage or heat backup by auxiliary heating was used in 72% of the projects with heat storage being more popular over heat backup.
- Cold backup was comparatively less in use with 53% when compared to heat-back up. To account for the intermittency of solar radiation, heat storage or auxiliary heating is observed to be the common practice.

The primary application was on the public buildings (34%) with an average working span of 8hr/day. In comparison, some others were utilized in the domestic building (25%), process industry (9%), and food processing sector.

6. References

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