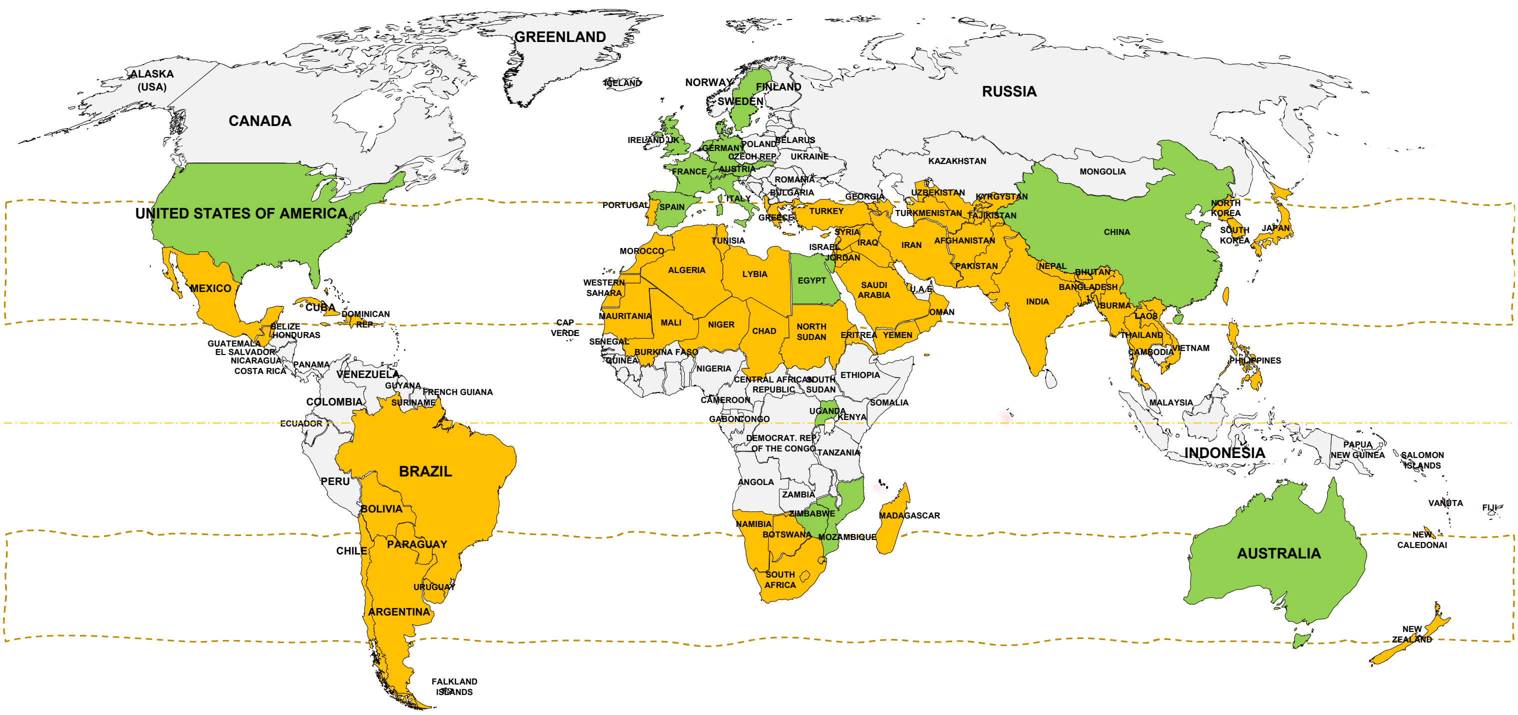
SOLAR HEATING & COOLING PROGRAMME
INTERNATIONAL ENERGY AGENCY

Standardization Activities



IEA SHC TASK 65 | SOLAR COOLING FOR THE SUNBELT REGIONS

Technology Collaboration Programme
by iea

Standardization Activities

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

Our members

Australia	European Commission	SACREEE
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CCREEE	Italy	Spain
China	Netherlands	Sweden
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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 A5 "Standardization activities". Activity A5 is dedicated to provide a comprehensive understanding of the significance of standardized actions and key performance indicators (KPIs) in driving advancements in the field of solar heating and cooling systems. Therefore, the importance of standardization in promoting interoperability, ensuring quality and fostering confidence among stakeholders was examined. In addition, the critical role of KPIs in assessing system performance, economic profitability and environmental impact were investigated.

As a final result of Activity A5, this report provides a comprehensive roadmap outlining actionable strategies, recommendations, and initiatives aimed at catalysing the widespread adoption of solar heating and cooling solutions. The Australian Standard AS 5389 emerged as a cornerstone for implementing these measures, providing a solid foundation for addressing the specific challenges and opportunities inherent to Sunbelt climates. The proposed list of actions aims to enhance the applicability of AS 5389 to Sunbelt climates by addressing specific challenges and opportunities. These actions encompass various initiatives aimed at streamlining the integration of solar thermal heating and cooling systems, enhancing industry expertise, and promoting financial mechanisms to support sustainable energy solutions.

2 Scope of Activity A5

The activity A5 focuses on both KPI identification and definition, on a survey on existing standards and introducing new ones for solar cooling across various technologies and Sunbelt countries. The standardization efforts were already addressed by the IEA SHC Task 48, resulting in the establishment of the Australian Standard AS5389 for solar heating and cooling systems. Additionally, a recent standard, VDI 3988, addressing solar process heat, has emerged, incorporating elements pertinent to solar cooling, such as considerations for chiller and heat rejection costs.

3 Introduction

The present document reports about the technical aspects related to Key Performance Indicator (KPI) definitions and global standards for solar cooling systems. With air-conditioning demand steadily rising, particularly in Sunbelt regions, there's a pressing need to refine solar cooling technologies to meet this escalating need efficiently with a unique language and receiving the necessary supports from policies and technical rules.

The focus lies on KPI definitions and standardization that can be considered essential for the advancement of solar cooling systems since, currently, cost reduction, simplification of systems, and policy-driven market stimulation represent crucial aspects.

By providing a technical KPI definitions and a global standards screening, this report seeks to provide stakeholders, researchers, and policymakers with actionable insights for the effective deployment of solar cooling solutions.

4 Standardization of Definitions and KPIs Identification

To assess the performance of specific systems and facilitate comparisons among various evaluated systems, a set of key performance indicators (KPIs) has been formulated. These KPIs are tailored to each operational strategy, with their significance varying based on the objectives of the strategy in question. For example, when assessing the Base Load operational strategy, KPIs related to economic factors are considered, albeit to a lesser extent compared to the evaluation of the Optimal Economics strategy.

KPIs serve as indispensable tools for assessing and comparing various solutions and technologies within specific domains. However, within the field of solar cooling, there remains a notable absence of precision and a comprehensive vision in their definition. This challenge is compounded by the diverse range of applications and the relatively low penetration of solar cooling technologies compared to electric cooling.

The complexity of solar cooling technology, coupled with its varied applications, necessitates a new approach to defining KPIs. Three primary categories of performance indicators emerge: technological, environmental, and economic. These categories encompass parameters ranging from system efficiency and environmental impact to cost-effectiveness and market viability. Yet, the multitude of parameters often confuses and impedes effective technology assessment.

Furthermore, the existing literature presents a wide number of KPIs for solar cooling, underscoring the need for a systematic screening and integration process. Such an approach is vital for identifying the most pertinent parameters while ensuring clarity, relevance, and applicability across diverse stakeholders.

Within activity A5, a structured decision-making process was proposed to guide the identification of key parameters. This process emphasizes simplicity, clarity, and meaningfulness, ensuring that the selected KPIs are easily understood and universally applicable (see the workflow depicted in Figure 1).

For instance, the useful temperature range emerges as a critical yet often overlooked parameter in the initial screening of solar cooling technologies. By considering factors such as regulatory directives and system interdependencies, the proposed methodology aims to provide a comprehensive framework for defining economic and environmental KPIs.

Given the multifaceted nature of solar cooling technology and its integration into energy systems, a revised methodology is essential for the definition and application of KPIs. This methodology seeks to bridge existing gaps in KPI definitions and facilitate a holistic evaluation of solar cooling technologies across diverse contexts. Through rigorous screening, integration, and application of KPIs, stakeholders can make informed decisions and drive advancements in the field of solar cooling.

In the field of solar cooling, the definition of KPIs for diverse system configurations is gaining interest because of the rising need for a common language among stakeholders. However, a systematic process for their formulation remains a challenge, prompting researchers to explore various methodologies aimed at ensuring comprehensive and stakeholder-inclusive KPI definitions.

Traditionally, the definition of KPIs has primarily been the purview of technical experts, who rely on literature reviews and analysis to identify pertinent parameters. While this approach offers a solid foundation, it often overlooks the perspectives of stakeholders, leading to potential gaps in understanding and evaluation. Conversely, involving stakeholders in the KPI definition process presents its own set of challenges, including divergent priorities among participants.

To address these challenges, in A5 a methodology that balances technical rigour with stakeholder engagement was carried out. The approach involved a simplified process that integrates literature analysis with stakeholder input, aiming to synthesize a set of energy/cost-related KPIs. This method acknowledges the importance of aligning KPIs with stakeholder needs while also ensuring clarity and applicability across diverse contexts.

The process involved steps such as stakeholder prioritization, KPI selection, data collection, performance issue analysis, and target setting. By systematically integrating stakeholder perspectives into the KPI definition process, it has been possible to ensure relevance, applicability, and stakeholder buy-in.

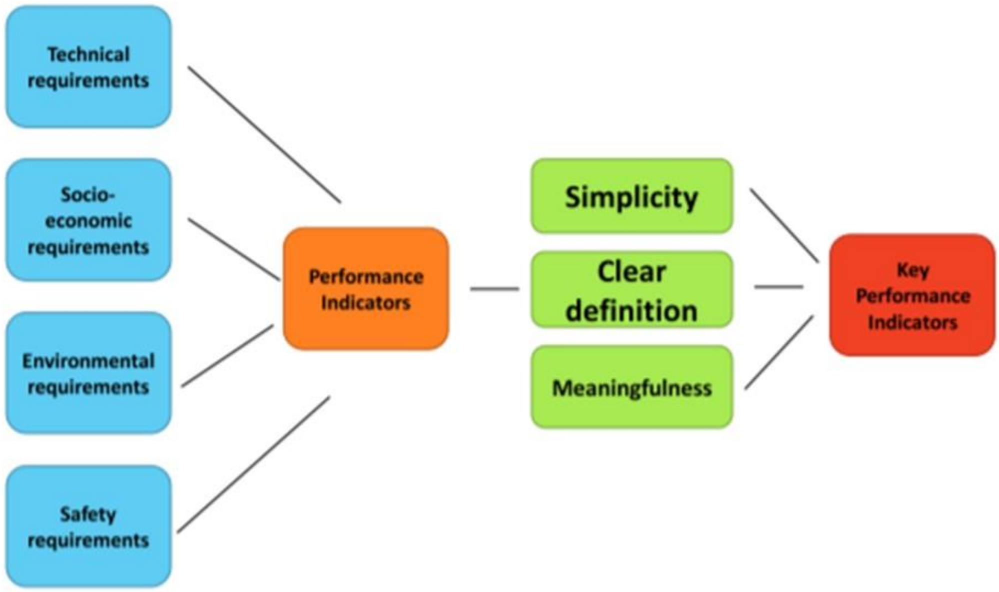

Figure 1: A5 activity's workflow

During the A5 activities, the methodology has been tailored to address the challenges of integrating energy storage into systems as well and it drew on standardized procedures and stakeholder viewpoints to define KPIs that accurately reflect the performance and impact of solar cooling technologies.

The methodology proposed for solar cooling KPI assessment encompasses tasks such as literature analysis, technical roadmap analysis, and objective translation into performance indicators. This approach aims to derive a comprehensive set of KPIs tailored to the specific needs and objectives of solar cooling systems. The recursive strategy followed is shown in Figure 2.

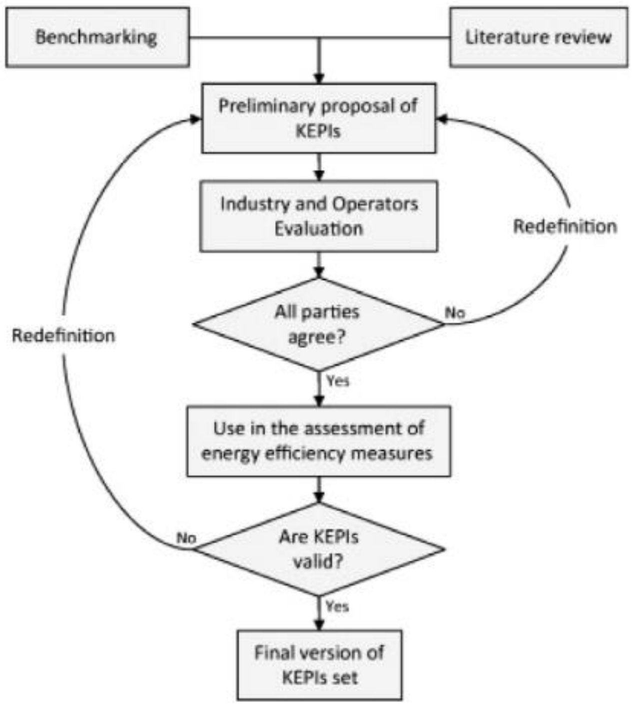

Figure 2: Description of the procedure followed in A5

As the field of solar cooling continues to evolve, the refinement and application of robust KPI definition methodologies will be crucial in driving innovation, facilitating informed decision-making, and ultimately advancing the adoption and effectiveness of solar cooling technologies.

However, the scarcity of literature data and heterogeneity in presentation pose challenges in directly paralleling literature analysis with the evaluation of technical roadmaps.

To overcome this issue, a preliminary possibility to define KPIs at different levels was initially investigated (Figure 3). The proposed level for KPIs definition were the followings:

- Materials
- Components
- Systems

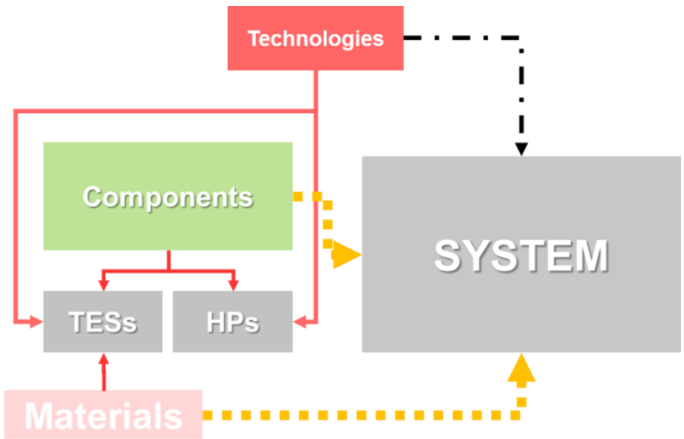

Figure 3: Preliminary scheme for KPI level identification.

Concerning the system level, the final shared list on KPIs on which both scientific and industrial stakeholder agreed is the following:

1. **Coefficient of Performance (COP):** This metric quantifies the efficiency of the solar cooling system by comparing the amount of cooling produced to the energy input required to achieve it. A higher COP indicates greater efficiency, as more cooling is generated per unit of energy consumed. COP values typically range from 2 to 8 for solar cooling systems, with higher values indicating better performance.

2. **Solar Fraction:** The solar fraction represents the proportion of the total cooling load provided by solar energy. It is calculated by dividing the cooling load provided by the solar system by the total cooling load required. A higher solar fraction indicates a greater reliance on solar energy for cooling, which is desirable for maximizing the system's renewable energy utilization and reducing reliance on conventional energy sources.

3. **Energy Consumption:** This KPI quantifies the total energy consumed by the solar cooling system over a given period, including both electricity and any auxiliary fuel used. It serves as a comprehensive measure of system performance, reflecting both operational efficiency and cost-effectiveness. Lower energy consumption values indicate greater efficiency and reduced operational costs.

4. **System Efficiency:** System efficiency encompasses the overall performance of the solar cooling system, including the efficiency of individual components such as solar collectors, thermal energy storage, and cooling equipment. It reflects the system's ability to convert solar energy into usable cooling efficiently. Higher system efficiency values indicate greater effectiveness in utilizing solar energy for cooling purposes.

5. **Thermal Energy Storage Capacity:** This metric quantifies the capacity of the thermal energy storage (TES) system integrated into the solar cooling system. It represents the amount of thermal energy that can be stored and used for cooling during periods of low solar irradiance or high cooling demand. Higher storage capacities allow for greater flexibility in meeting cooling requirements and optimizing system performance.

6. **System Reliability:** System reliability measures the frequency and severity of system downtime or failures, reflecting the system's overall reliability and robustness. It encompasses factors such as component durability, maintenance requirements, and the likelihood of system malfunctions. A reliable solar cooling system minimizes interruptions in operation, ensuring continuous cooling provision.

7. **Environmental Impact:** This KPI assesses the environmental footprint of the solar cooling system, including its carbon emissions and other environmental impacts. It considers factors such as the use of renewable energy sources, energy efficiency, and emissions reductions compared to conventional cooling technologies. A lower environmental impact indicates a more sustainable and environmentally friendly system.

8. **Installation Cost:** The installation cost represents the initial investment required to purchase and install the solar cooling system, including components such as solar collectors, thermal storage tanks, and associated infrastructure. It includes expenses related to equipment procurement, labor, permitting, and site preparation. Lower installation costs contribute to the overall affordability and attractiveness of the solar cooling system.

9. **Operating and Maintenance Cost:** Operating and maintenance costs encompass the ongoing expenses associated with operating and maintaining the solar cooling system over its lifetime. This includes costs for routine maintenance, periodic inspections, repairs, and replacements of components. Lower operating and maintenance costs contribute to the system's long-term affordability and economic viability.

10. **Payback Period:** The payback period represents the time required for the solar cooling system to generate savings or recoup its initial investment cost through reduced electricity or cooling expenses. It serves as a measure of the system's financial viability and attractiveness to investors. A shorter payback period indicates a faster return on investment and greater financial benefits.

11. **Levelized Cost of Cooling:** The levelized cost of cooling calculates the average cost of cooling provided by the solar cooling system over its lifetime, factoring in all relevant costs such as installation, maintenance, and operating expenses. It helps assess the long-term economic viability and competitiveness of the system compared to conventional cooling technologies. Lower levelized costs indicate greater cost-effectiveness and economic efficiency.

12. **Return on Investment (ROI):** ROI measures the financial return generated from the investment in the solar cooling system, taking into account both costs and savings generated by the system over its lifetime. It quantifies the profitability of the investment and serves as a key metric for evaluating its financial performance. A higher ROI indicates a more financially beneficial investment, while a negative ROI indicates a loss.

13. **Cost per Cooling Unit:** This metric calculates the cost per unit of cooling provided by the solar cooling system, allowing for comparison with conventional cooling methods. It considers the total cost of ownership, including installation, maintenance, and operating expenses, and divides it by the total cooling capacity generated. Lower costs per cooling unit indicate greater cost competitiveness and affordability of the solar cooling system.

14. **Incentive and Rebate Utilization:** This KPI evaluates the extent to which the solar cooling system takes advantage of available financial incentives, such as government rebates, tax credits, or subsidies. Maximizing incentive and rebate utilization can significantly reduce the overall cost of the system and improve its financial attractiveness.
15. **Lifetime Cost:** The lifetime cost represents the total cost of owning and operating the solar cooling system over its expected lifetime, including all expenses related to installation, operation, maintenance, and eventual decommissioning. It provides a comprehensive assessment of the total cost of ownership and helps stakeholders make informed decisions about the system's economic viability and long-term sustainability.

The provided list of KPIs offers a comprehensive framework for evaluating the performance, economic viability, and environmental impact of solar cooling systems. However, several considerations can enhance the effectiveness and applicability of these metrics.

Firstly, stakeholders should carefully select and prioritize KPIs based on their specific goals and project requirements to avoid resource-intensive monitoring of all metrics. Quantifiability is crucial for objective evaluation, and efforts should be made to standardize measurement methodologies, especially for metrics like "System Reliability" and "Environmental Impact."

Integrating multiple KPIs into composite indicators or indices could provide a more holistic assessment of system performance. Data availability and accessibility, particularly for economic metrics such as "Payback Period" and "Levelized Cost of Cooling," need attention to ensure consistency and transparency across evaluations.

Given the dynamic nature of solar cooling systems due to technological advancements and policy changes, KPI frameworks should be adaptable and periodically updated to remain relevant. Involving stakeholders in framework development and refinement can enhance usability and acceptance within the industry.

Incorporating case studies and best practices showcasing the successful implementation of solar cooling systems, along with associated KPIs and performance metrics, can provide valuable insights and guidance for future projects.

By addressing these considerations, stakeholders can effectively utilize KPIs to optimize the performance, economics, and sustainability of solar cooling systems, facilitating their widespread adoption and contribution to renewable energy goals.

Moreover, in a future activity, some specific aspects of the KPI framework and its implications for the design, implementation, and evaluation of solar cooling systems should be taken into consideration:

1. **The granularity of Metrics:** Consider discussing the granularity of metrics within the framework. While a comprehensive set of KPIs provides a detailed understanding of system performance, it may also lead to complexity. Balancing the need for granularity with simplicity and ease of interpretation is essential.
2. **Dynamic Modelling:** Discuss the potential for dynamic modelling approaches to incorporate real-time data and predictive analytics into the evaluation of KPIs. This could enable proactive system management, optimization, and predictive maintenance, enhancing overall system performance and reliability.
3. **Emerging Technologies:** Explore how the KPI framework accommodates emerging technologies and innovations in solar cooling. As technology evolves, new metrics may be necessary to capture the unique features and benefits of these advancements.
4. **Cross-Sectoral Implications:** Consider the cross-sectoral implications of solar cooling systems beyond energy and environmental domains. For example, discuss how these systems may impact sectors such as agriculture, water conservation, and urban planning, and how corresponding KPIs could capture these broader impacts.
5. **Stakeholder Engagement and Communication:** Emphasize the importance of stakeholder engagement and effective communication regarding KPIs. Clear communication of KPIs and their implications can foster stakeholder buy-in, support decision-making processes, and drive continuous improvement efforts.
6. **Policy and Regulatory Alignment:** Discuss how the KPI framework aligns with existing policies, regulations, and standards governing solar cooling systems. Ensuring alignment with regulatory requirements and industry standards can facilitate compliance and promote market acceptance.
7. **Education and Capacity Building:** Highlight the role of education and capacity building in promoting understanding and adoption of KPIs within the solar cooling sector. Training programs, workshops, and

knowledge-sharing platforms can empower stakeholders to effectively utilize KPIs for system optimization and performance improvement.

8. **Long-Term Monitoring and Evaluation:** Stress the importance of long-term monitoring and evaluation of KPIs to track system performance over time. Longitudinal studies can provide insights into system behaviour, identify trends, and inform future decision-making and investment strategies.

By expanding on these themes, further comments can provide additional depth and context to the discussion of KPIs for solar cooling systems, ultimately enriching the understanding and application of these metrics within the industry.

5 Current Standards Analysis (Worldwide)

In recent years, the quest for sustainable and efficient cooling solutions has gained significant momentum, spurred by the pressing need to mitigate climate change and reduce dependence on fossil fuels. Among the myriad of renewable energy technologies, solar cooling systems have emerged as a promising avenue for meeting cooling demands while minimizing environmental impact.

As the demand for cooling continues to rise, driven by factors such as urbanization, population growth, and changing climate patterns, the need for standardized approaches to assess and implement solar cooling systems becomes increasingly imperative. Standards play a pivotal role in ensuring the safety, reliability, and interoperability of these systems, while also facilitating market acceptance and driving innovation.

Despite the growing interest in solar cooling technologies, the landscape of standards governing these systems remains fragmented and complex. Standards may encompass a wide range of aspects, including system design and installation, performance evaluation, durability testing, and safety requirements. Navigating this intricate web of standards poses challenges for stakeholders involved in the design, deployment, and regulation of solar cooling systems.

In response to these challenges, there is a pressing need for a comprehensive review and analysis of existing standards related to solar cooling and their adaptation to the specific needs of Sunbelt regions climate and, in general, for harsh summer weather conditions. Such an endeavour would not only provide clarity and guidance to industry practitioners and policymakers but also identify gaps and opportunities for further standardization efforts.

The activity carried out in Subtask A, aimed to address this need by undertaking a full screening of standards relevant to solar cooling systems worldwide (preliminary action) and providing shared solutions for future standard implementation (second step). Through a systematic review and analysis of international, regional, and national standards, activity A5 sought to:

1. **Catalogue and Categorize Standards:** Compile a comprehensive inventory of standards pertaining to various aspects of solar cooling systems, including design, installation, performance evaluation, and safety requirements.
2. **Evaluate Applicability and Compatibility:** Assess the applicability and compatibility of existing standards to different types of solar cooling technologies, geographical regions, and market contexts.
3. **Identify Gaps and Inconsistencies:** Identify gaps, inconsistencies, and redundancies within the current landscape of standards governing solar cooling systems, highlighting areas where further standardization efforts are needed.
4. **Inform Best Practices and Guidelines:** Extract insights and lessons learned from existing standards to inform the development of best practices, guidelines, and regulatory frameworks for the design, deployment, and operation of solar cooling systems.
5. **Facilitate Harmonization and Collaboration:** Foster collaboration and harmonization efforts among standardization bodies, industry stakeholders, and policymakers to streamline and improve the standardization process for solar cooling technologies.

The survey encompassed standards from various international, regional, and national bodies, including but not limited to:

- International Organization for Standardization (ISO)
- International Electrotechnical Commission (IEC)
- American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE)
- European Committee for Standardization (CEN)
- European Committee for Electrotechnical Standardization (CENELEC)
- National Institute of Standards and Technology (NIST)
- Bureau of Indian Standards (BIS)
- Standards Australia
- Standards Council of Canada
- China National Standards Institute (CNS)

The review process involved systematic identification, screening, and analysis of relevant standards, utilizing methodologies for literature review and standard screening. Key criteria for inclusion was relevance to solar cooling systems, currency, and availability in the public domain.

Furthermore, the review considered standards across the entire lifecycle of solar cooling systems, from design and installation to operation, maintenance, and decommissioning. This approach ensured a comprehensive understanding of the regulatory landscape governing solar cooling technologies.

In addition to cataloguing and evaluating existing standards, the study will also examine emerging trends and developments in the field of solar cooling, such as advancements in technology, changes in regulatory frameworks, and evolving market dynamics. Insights from this analysis will inform recommendations for future standardization efforts and policy interventions to support the growth and maturation of the solar cooling industry.

The goal of this work was to provide stakeholders with a valuable resource that facilitates informed decision-making, fosters collaboration, and drives continuous improvement in the design, implementation, and regulation of solar cooling systems.

1. **ISO 9806:2017** This standard provides specifications for solar collectors used in solar thermal systems, including solar cooling systems. It outlines test methods for determining the thermal performance of solar collectors, offering guidance on collector design and construction. By specifying rigorous testing procedures, ISO 9806:2017 ensures the reliability and accuracy of performance data for solar collectors, facilitating informed decision-making and quality assurance in the selection and deployment of solar cooling technologies[1].

2. **ISO 9459-1:2013** Solar Heating and Cooling Domestic Hot Water Systems Part 1: System Performance Characterization employing Dynamic Calculation Methods: This standard offers guidelines for characterizing the performance of solar heating and cooling systems, including those employed for domestic hot water and space cooling purposes. By employing dynamic calculation methods, ISO 9459-1:2013 provides a comprehensive framework for assessing system performance under varying operating conditions, aiding in the design, optimization, and evaluation of solar cooling installations[2].

3. **ASHRAE 93-2003** developed by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), offers test methods for determining the performance of solar collectors utilized in solar thermal systems, including those applied in solar cooling applications. The standard specifies detailed test procedures and provides guidance on the measurement and calculation of collector efficiency, ensuring accurate and consistent performance assessments[3].

4. **ASHRAE Standard 169-2020** Climatic Data for Building Design Standards: This standard published by ASHRAE provides essential climate data required for the design, simulation, and analysis of solar cooling systems in different geographical regions. It includes meteorological data such as temperature, humidity, solar radiation, wind speed, and precipitation, collected from weather stations worldwide. The climate data provided by ASHRAE Standard 169 enables engineers, architects, and building designers to accurately assess the

[1] https://www.iso.org/standard/67978.html, Last access April 2024.

[2] https://www.iso.org/standard/17186.html, Last access March 2024.

[3] https://webstore.ansi.org/preview-pages/ASHRAE/preview_ANSI+ASHRAE+93-2003.pdf, Last access March 2024.

feasibility and performance of solar cooling systems, considering local climatic conditions and seasonal variations. This data is instrumental in conducting energy simulations, sizing system components, and predicting system performance under various operating scenarios[4].

This standard serves as a comprehensive repository of climate data essential for professionals engaged in building design and it is referenced in several other standards such as Standards 90.1, 90.2, 90.4, 100, 127, and 189.1. It provides valuable data compiled from the 2021 ASHRAE Handbook—Fundamentals, Chapter 14, "Climatic Design Information," and other sources such as ASHRAE RP-1847.

In particular, Appendix A of the document contains climatic design data for over 8,000 locations in the U.S., Canada, and internationally. This data includes annual and monthly percentiles of temperature, humidity measures, and wind speed, crucial for designing building energy and ventilation systems. It also includes annual average values of heating degree days (HDD) and cooling degree days (CDD), along with heating and cooling design temperatures. Sample climatic data for an example city is provided in Figure 4.

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EXAMPLE CITY, GA, USA WMO: 777777

Lat: 33.640N Lon: 84.430W Elev: 1027 StdP: 14.16 Time Zone: -5.00 (NAE) Period: 90-14 WBAN: 99999

Annual Heating, Humidification, and Ventilation Design Conditions

	Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest Month WS/MCDB				MCWS/PCWD to 99.6% DB		WSF	
				99.6%			99%			0.4%		1%					
		99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD		
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(1)	1	21.9	26.5	4.9	7.3	29.3	9.3	9.2	32.8	24.8	39.7	23.3	39.2	11.8	320	0.435	(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

	Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB		
			0.4%		1%		2%		0.4%		1%		2%				
			DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(2)	7	16.7	94.0	74.2	91.6	73.8	89.5	73.3	77.3	88.3	76.3	86.5	75.4	84.8	8.7	300	(2)

	Dehumidification DP/MCDB and HR									Enthalpy/MCDB						Extreme Max WB	
	0.4%			1%			2%			0.4%		1%		2%			
	DP	HR	MCDB	DP	HR	MCDB	DP	HR	MCDB	Enth	MCDB	Enth	MCDB	Enth	MCDB		
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(3)	74.3	133.3	81.3	73.4	128.9	80.3	72.6	125.5	79.6	41.3	88.3	40.3	86.7	39.5	85.4	82.4	(3)

Extreme Annual Design Conditions

	Extreme Annual WS				Extreme Annual Temperature				n-Year Return Period Values of Extreme Temperature								
					Mean		Standard Deviation		n=5 years		n=10 years		n=20 years		n=50 years		
	1%	2.5%	5%		Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	
	(a)	(b)	(c)		(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(4)	21.3	18.9	17.0	DB	15.0	96.6	4.6	3.7	11.6	99.3	8.9	101.4	6.3	103.5	3.0	106.2	(4)
(5)				WB	12.6	79.0	4.4	1.5	9.5	80.1	6.9	81.0	4.4	81.8	1.2	82.9	(5)

Monthly Climatic Design Conditions

				Annual	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
				(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(6)	Temperatures, Degree-Days and Degree-Hours	DBAvg		63.0	44.5	48.0	54.9	62.6	70.5	77.3	80.1	79.5	73.9	63.6	53.5	46.4	(6)
(7)		DBStd		14.60	9.66	8.88	9.00	7.40	6.17	4.51	3.50	3.84	5.47	7.07	8.10	8.82	(7)
(8)		HDD50		653	224	132	55	6	0	0	0	0	0	4	56	176	(8)
(9)		HDD65		2640	635	477	329	127	25	1	0	0	7	111	352	576	(9)
(10)		CDD50		5391	54	76	205	385	636	819	933	914	717	425	161	66	(10)
(11)		CDD65		1901	0	1	14	56	195	370	468	449	273	67	7	1	(11)
(12)		CDH74		16445	0	3	103	435	1509	3337	4488	4173	2014	360	22	1	(12)
(13)		CDH80		6151	0	0	8	66	419	1333	1922	1726	637	40	0	0	(13)
(14)	Wind	WSAvg		8.2	9.2	9.4	9.5	8.8	7.9	7.3	7.0	6.7	7.5	7.8	8.2	8.9	(14)
(15)	Precipitation	PrecAvg		50.8	4.7	4.8	5.8	4.3	4.3	3.6	5.0	3.7	3.4	3.1	3.9	4.3	(15)
(16)		PrecMax		64.9	10.2	12.8	11.7	11.9	8.4	7.4	8.5	8.7	6.1	7.5	7.2	9.9	(16)
(17)		PrecMin		37.7	1.7	0.8	2.4	1.5	0.4	1.0	0.7	0.5	0.7	0.1	0.9	0.7	(17)
(18)		PrecStd		7.2	2.1	2.7	2.7	2.4	2.3	1.8	2.2	2.2	1.6	2.1	1.6	2.4	(18)
(19)	Monthly Design Dry Bulb and Mean Coincident Wet Bulb Temperatures	0.4%	DB		70.5	73.4	80.8	85.0	90.2	94.5	97.6	97.4	92.8	83.5	77.4	72.3	(19)
(20)			MCWB		60.8	61.3	62.6	66.5	71.3	72.9	74.8	74.3	72.0	68.3	64.1	63.1	(20)
(21)		2%	DB		66.3	69.1	76.9	82.0	87.0	92.0	94.1	93.7	89.0	80.9	73.3	68.6	(21)
(22)			MCWB		58.7	58.8	60.6	64.9	69.8	72.9	74.7	74.6	71.4	66.7	61.8	61.6	(22)
(23)		5%	DB		63.0	65.9	73.5	79.2	84.6	89.8	91.6	90.9	86.4	78.2	70.3	64.6	(23)
(24)			MCWB		57.2	56.9	59.1	63.4	68.8	72.5	74.3	74.2	70.7	64.7	60.6	59.0	(24)
(25)		10%	DB		59.5	62.7	69.8	76.1	82.1	87.4	89.1	88.3	83.8	75.3	67.1	60.9	(25)
(26)			MCWB		53.9	54.5	57.7	61.8	67.8	71.9	74.2	73.4	70.2	64.1	58.4	55.2	(26)
(27)	Monthly Design Wet Bulb and Mean Coincident Dry Bulb Temperatures	0.4%	WB		64.2	65.5	66.4	70.8	74.9	77.3	78.9	78.4	76.4	72.0	69.2	66.7	(27)
(28)			MCDB		67.5	67.9	72.8	79.2	83.3	88.4	89.6	89.9	86.1	78.8	71.8	69.8	(28)
(29)		2%	WB		61.6	62.4	64.1	68.3	72.7	75.9	77.5	77.2	74.6	70.2	66.1	63.5	(29)
(30)			MCDB		64.6	66.6	71.5	76.3	82.3	86.5	88.3	88.4	83.2	75.9	70.0	66.4	(30)
(31)		5%	WB		58.6	59.5	62.1	66.4	71.3	74.9	76.5	76.2	73.5	68.7	63.5	60.3	(31)
(32)			MCDB		61.9	64.0	70.0	74.4	80.6	85.0	86.7	86.1	80.9	73.8	67.7	64.1	(32)
(33)		10%	WB		55.2	56.3	60.0	64.5	69.9	73.8	75.4	75.2	72.6	66.9	60.5	56.3	(33)
(34)			MCDB		58.3	60.6	67.0	72.3	78.6	83.1	84.9	84.2	79.5	72.3	65.4	59.8	(34)
(35)	Mean Daily Temperature Range		MDBR		17.3	18.2	19.2	19.8	18.2	17.2	16.7	16.4	16.5	18.1	18.7	16.6	(35)
(36)		5% DB	MCDBR		19.5	20.9	22.5	22.0	20.1	20.1	20.2	19.5	19.1	20.4	20.9	19.5	(36)
(37)			MCWBR		13.6	13.3	11.0	9.5	7.5	6.6	6.1	6.0	6.8	8.9	11.7	13.2	(37)
(38)		5% WB	MCDBR		16.0	17.5	17.9	18.2	17.3	17.3	17.5	16.8	15.3	14.9	16.8	16.8	(38)
(39)			MCWBR		13.2	13.8	11.0	9.8	7.7	6.9	6.4	6.1	6.9	8.9	12.9	13.6	(39)
(40)	Clear-Sky Solar Irradiance	taub			0.310	0.315	0.347	0.386	0.440	0.473	0.515	0.515	0.417	0.363	0.333	0.311	(40)
(41)		taud			2.538	2.521	2.453	2.324	2.213	2.168	2.066	2.052	2.312	2.460	2.484	2.554	(41)
(42)		Ebn at Noon			288	298	295	286	270	260	249	246	268	277	276	281	(42)
(43)		Edh at Noon			26	29	34	40	46	48	53	52	39	31	27	24	(43)
(44)	All-Sky Solar Radiation	RadAvg			852	1054	1407	1751	1904	1954	1858	1726	1496	1275	963	738	(44)
(45)		RadStd			50	122	109	126	164	162	134	103	148	163	82	73	(45)

Historical Trends

		DBAvg	Heating		Cooling			Degree-Days				
			99% DB	99% DP	1% DB	1% WB	1% DP	HDD50	HDD65	CDD50	CDD65	
		(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	
(46)	Station Only	N/A	N/A	N/A	N/A	-0.36	-0.41	N/A	N/A	N/A	N/A	(46)
(47)	Regional (1 neighbor)	N/A	N/A	N/A	N/A	-0.43	-0.47	N/A	N/A	N/A	N/A	(47)

Figure 4: ASHRAE Standard 169-2020 Climatic Data for Building Design Standards, example of climatic data for a city

4 https://www.ashrae.org/file%20library/technical%20resources/standards%20and%20guidelines/standards%20addenda/169_2020_a_20211029.pdf, last access March 2024

Appendix B provides informative climate zone maps for major countries and continents. These maps offer visual representations of climate zones but do not replace the detailed climatic data found in Appendix A. The maps have a resolution of 0.25 x 0.25° and are intended to illustrate the general locations of climate zones (see Figure 5).

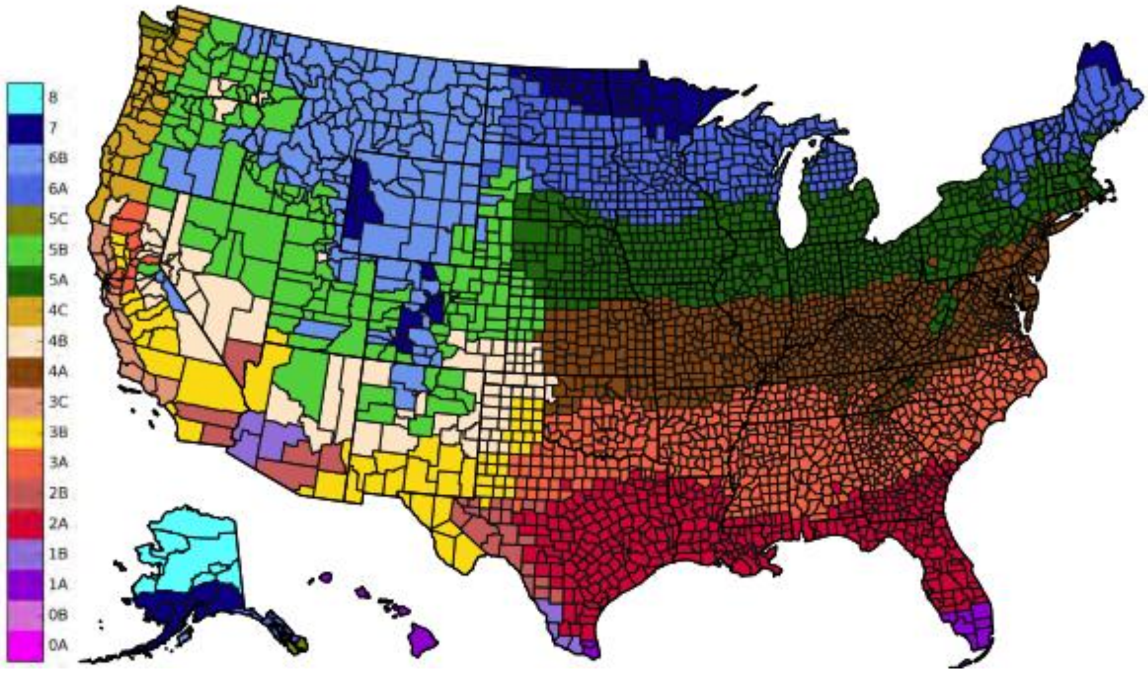

Figure 5: ASHRAE Standard 169-2020 Climatic Data for Building Design Standards Climate Zones for United States Counties

5. **AS/NZS 2712:2017** This Australian and New Zealand standard offers comprehensive guidelines for the design, installation, and maintenance of solar water heating systems. While primarily focused on solar water heating, the principles outlined in this standard may also be relevant to solar heating and cooling systems. It covers various aspects such as system components, sizing, installation requirements, safety considerations, and maintenance procedures. Compliance with AS/NZS 2712 ensures the quality, efficiency, and safety of solar water heating systems, assuring users and regulatory authorities alike[5]. It consists of the following sub-sections:

- AS/NZS 2712:2007 A1: This is an amendment to the AS/NZS 2712:2007 standard, which covers solar and heat pump water heaters' design and construction. Amendments typically address updates, corrections, or additions to the original standard. AS/NZS 2712:2007 A1 may include changes to specifications, testing procedures, safety requirements, or other relevant aspects of solar and heat pump water heater systems.

- AS/NZS 2712:2007 A2: Similar to A1, this is an amendment to the AS/NZS 2712:2007 standard, focusing on solar and heat pump water heaters' design and construction. Amendment 2 may introduce further updates, revisions, or clarifications to the original standard to ensure its relevance and effectiveness in regulating solar and heat pump water heater systems.

- AS/NZS 2712:2007 A3: This amendment to AS/NZS 2712:2007 was issued in 2014. Like the previous amendments, A3 likely addresses specific changes or enhancements to the standard's requirements, procedures, or guidelines for solar and heat pump water heaters' design and construction. It ensures that the standard reflects the latest industry practices, technological advancements, and safety considerations.

- AS/NZS 3823.1.2:2012: This standard pertains to the performance testing and rating of electrical appliances, specifically focusing on air conditioners and heat pumps. Part 1.2 of AS/NZS 3823.1.2 covers ducted air conditioners and air-to-air heat pumps, outlining procedures and criteria for testing these systems' performance. The standard provides guidelines for evaluating factors such as energy efficiency, cooling capacity, airflow, and noise levels, ensuring that ducted air conditioners and heat pumps meet specified performance standards and consumer expectations.

5 https://www.intertekinform.com/preview/825354646821.pdf?sku=117174_saig_as_as_245154, last access February 2024.

6. **EN 12975:2006** This European standard specifies requirements and test methods for solar thermal collectors used in solar heating systems. It provides detailed specifications for collector design, construction, and performance testing, including parameters such as thermal efficiency, optical efficiency, and pressure drop. EN 12975 aims to ensure the reliability, durability, and performance consistency of solar thermal collectors across Europe. Compliance with this standard facilitates product quality assurance, promotes interoperability among different collector models, and enhances consumer confidence in solar heating and cooling technologies. The standards directly connected to EN 12975, which this guide addresses, include:

   - EN 12975-1:2006: General Requirements for Thermal Solar Systems and Components – Solar Collectors. Defines the general requirements for solar collectors.
   - EN 12975-2:2006: Test Methods for Thermal Solar Systems and Components – Solar Collectors. Specifies test methods for assessing solar collector performance.
   - EN 12976-1:2000: General Requirements for Factory-Made Thermal Solar Systems and Components. Applies to factory-made systems, with some requirements overlapping with EN 12975.
   - EN 12976-2:2000: Test Methods for Factory-Made Thermal Solar Systems and Components. Covers testing procedures for factory-made systems, with some exclusions compared to EN 12975.
   - EN ISO 9488:1999: Vocabulary for Solar Energy. Defines essential terms, including collector area definitions.
   - ISO 9060: Specification and Classification of Instruments for Measuring Hemispherical and Direct Solar Radiation. Provides normative references to EN 12975-2 for radiation measurement principles.

   These standards are part of a broader landscape of solar thermal collector standards. Historically, ASHRAE standard 93-77 was widely used, followed by the development of the ISO 9806 series and subsequently the EN 12975. While many national standards outside Europe are based on ISO 9806, within Europe, EN 12975 has replaced them.

7. **IEC 60891:2021** Solar Thermal Electric Plants Collectors[6]: This International Electrotechnical Commission (IEC) standard specifies requirements and test methods for solar collectors utilized in solar thermal electric plants. It covers aspects such as collector design, construction, performance, and durability. While primarily intended for solar thermal electric plants, the requirements and test methods outlined in this standard may also be applicable to solar cooling systems, particularly in terms of collector performance and reliability. IEC 60891:2021 outlines procedures for correcting temperature and irradiance effects on the measured current-voltage (I-V) characteristics of photovoltaic devices. It also specifies methods for determining relevant correction factors. The standard builds upon requirements set forth in IEC 60904-1 for I-V measurement of photovoltaic devices. Key technical updates from the previous edition include:

   - Expansion of translation procedures to account for irradiance changes during I-V measurement.
   - Addition of two new translation procedures.
   - Revision of the procedure for determining temperature coefficients to encompass PV modules.
   - Introduction of a new procedure for determining internal series resistance.
   - Definition of a new procedure for calculating curve correction factors.

The previous standard 60891:2009 was withdrawn on 2021-10-27, however.

8. **EN 12977:2018** Thermal Solar Systems and Components Custom Built Systems: This European standard addresses custom-built solar heating and cooling systems, establishing requirements for their design, installation, and performance evaluation. It covers aspects such as system components, sizing, safety considerations, and testing procedures. Compliance with EN 12977 ensures the quality, efficiency, and safety of custom-built solar thermal systems, including those used for solar cooling applications[7].

9. **ASHRAE Standard 93 2010** Methods of Testing to Determine the Thermal Performance of Solar Collectors: Published by the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), this standard provides methods for testing and determining the thermal performance of solar collectors[8]. It covers

[6] https://webstore.iec.ch/publication/61766, last access January 2024.

[7] https://standards.iteh.ai/catalog/standards/cen/91f15c46-1caf-4212-9899-ac92288539e6/en-12977-1-2018, last access January 2024.

[8] https://webstore.ansi.org/preview-pages/ASHRAE/preview_ANSI%2BASHRAE%2BStandard%2B93-2010%2B(R2014).pdf, last access March 2024.

various parameters such as thermal efficiency, optical efficiency, and stagnation temperature, which are crucial for evaluating the effectiveness of solar collectors in solar cooling systems.

ASHRAE Standard 93 delineates a meticulous test procedure for assessing the thermal performance of solar energy collectors, both indoors and outdoors. It encompasses a broad spectrum of collector types, encompassing liquid-cooled non-concentrating, concentrating collectors, and those employing air as the heat transfer medium. Initially published in 1986 and reaffirmed subsequently, the standard has undergone revision to align with ISO Standard 9806-1. This revision introduces novel calculation methods for performance efficiency predicated on various parameters and modifies the approach to determining the heat capacity time constant. Editorial corrections and updated references are also integrated into this edition. The standard is crafted to furnish test methodologies for evaluating the thermal performance of solar energy collectors utilizing single-phase fluids, devoid of significant internal energy storage.

ASHRAE Standard 93 applies to non-concentrating and concentrating solar collectors configured with single inlet and outlet setups. It authorizes testing of collectors with multiple inlets/outlets if effectively connected to mimic single inlet/outlet conditions. The standard extends to collectors employing either liquid or gas heat transfer fluids, albeit not a mixture of both. It encompasses methods for conducting tests outdoors under natural solar irradiance and indoors under simulated solar irradiance. Additionally, it encompasses test methods for ascertaining steady-state and quasi-steady-state thermal performance, time, and angular response characteristics. However, it's not pertinent to collectors where the thermal storage unit is integral and inseparable from the collection process or collectors with phase-changing heat transfer fluids containing vapor. Nonetheless, an alternative test procedure is proffered for phase-change collectors with integral heat exchangers conforming to specified descriptions.

10. **ISO 9808:1999** Solar Energy Solar Thermal Collectors Test Methods: This International Organization for Standardization (ISO) standard outlines general test methods for solar thermal collectors. It covers procedures for evaluating collector performance, durability, and reliability under different operating conditions. ISO 9808 provides a standardized approach to testing solar thermal collectors, ensuring consistency and comparability of results across different systems and manufacturers[9].
11. **ISO 9488:2022** (replaced ISO 9488:1999)[10] Solar Energy Vocabulary: This ISO standard offers a comprehensive vocabulary for solar energy terminology. It defines terms and concepts relevant to various aspects of solar energy, including solar thermal technology. Understanding the terminology provided in ISO 9488 can facilitate communication and collaboration in the field of solar cooling systems, helping stakeholders effectively discuss and address related issues and challenges

6 Australian Standard AS5389 on Solar Heating and Cooling Systems

The introduction of Australian Standard AS 5389[11] marks a significant milestone in the realm of solar heating and cooling systems. Published on June 28 by Standards Australia's Committee CS-028 on Solar Water Heaters, this standard is the first of its kind dedicated specifically to solar air conditioning. Its emergence stems from a collaborative effort initiated in 2012, driven by the imperative to develop a robust methodology for estimating the cooling or heating loads of buildings under varying climatic conditions.

The impetus for the creation of AS 5389 was multifaceted. Foremost among these factors was the advocacy and research efforts spearheaded by the solar cooling research group, led by Dr. Stephen White, at the Australian Institute of Refrigeration, Air conditioning and Heating (AIRAH). Dr. White's involvement in the IEA SHC Task 48 (task48.iea-shc.org) further underscored the importance of establishing quality assurance measures for solar cooling systems.

Additionally, government initiatives, particularly those led by the government of New South Wales, played a pivotal role in galvanizing support for the development of AS 5389. The aim was to broaden the eligibility of energy-saving technologies, including solar cooling systems, for NSW Energy Savings Certificates, colloquially known as White Certificates. This regulatory push reflected a broader imperative to level the playing field for emerging technologies within the energy efficiency landscape.

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[9] https://www.iso.org/standard/17682.html, last access February 2024.

[10] https://www.iso.org/standard/74269.html, last access February 2024.

[11] https://store.standards.org.au/product/as-5389-2019, last access March 2024

The genesis of AS 5389 can be traced back to its predecessor, AS 5389(Int)—2013, which was published in 2013 and focused solely on one solar air-conditioning technology. In contrast, the latest iteration of the standard encompasses five distinct technologies, including solar desiccant cooling systems, solar air space heating systems, solar water space heating systems, building ventilating systems, and evaporative cooling systems. This expansion underscores the standard's commitment to inclusivity and comprehensiveness in addressing diverse technological solutions.

Australia's proactive stance in developing innovative standards in the renewable energy sector has long been recognized internationally. Notably, the country's support for solar water heating technologies is underpinned by AS/NZS 4234, a standard established in 1993 that served as the basis for ISO 9459-4: 2013, an international benchmark in solar heating standards. Collaboration between Australian and US standards writers further underscores Australia's leadership in shaping global standards frameworks.

Moreover, Australia's preference for certificate-based support schemes, as opposed to direct subsidies, has contributed to the impetus behind AS 5389. By providing a standardized framework for evaluating the energy performance and thermal comfort of solar heating and cooling systems, AS 5389 seeks to promote transparency, consistency, and accountability in the deployment of renewable energy technologies.

Looking ahead, AS 5389 is poised to serve as a foundational document for the development of international standards on solar cooling systems. Its comprehensive methodologies for calculating energy consumption, assessing thermal comfort, and determining system performance offer valuable insights and benchmarks for global stakeholders in the renewable energy sector. As Australia lies in the Sunbelt regions (Figure 6), the standard was used as the base text for the proposition of adaptation measures designed within Subtask A and better described in the next section.

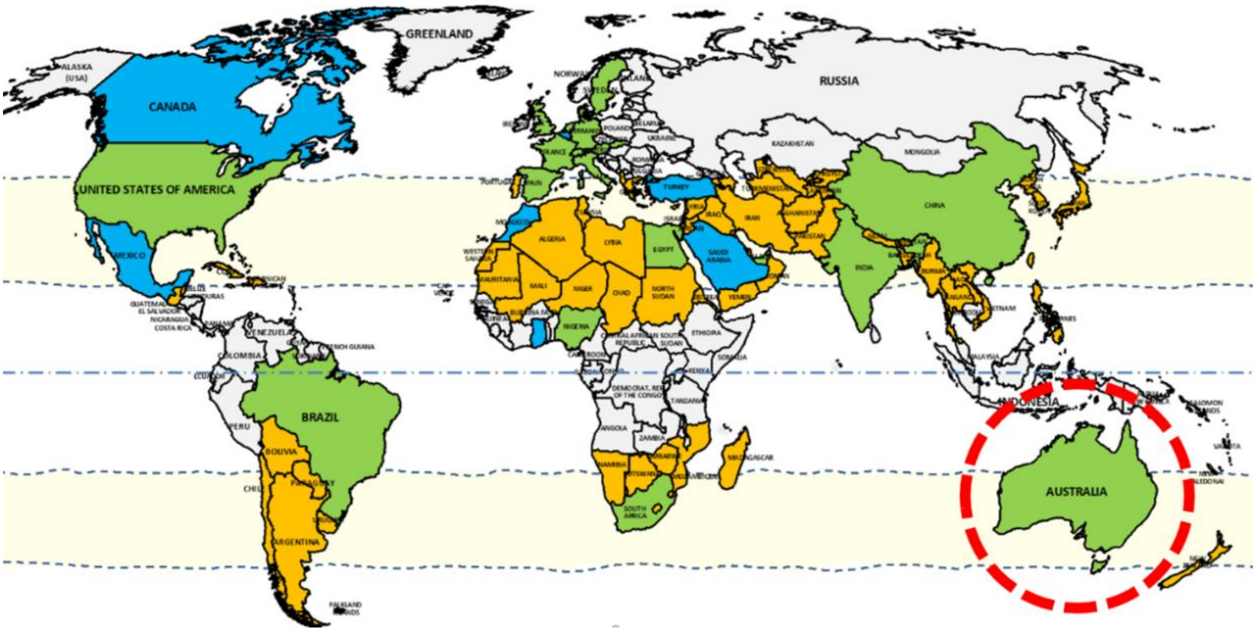

Figure 6: Geographical position of Australia as shown it lies in the Sunbelt region.

The introduction of AS 5389 represents a significant stride towards advancing the adoption of solar heating and cooling systems, not only within Australia but also on the global stage. With its robust methodologies and inclusive approach, AS 5389 stands as a testament to Australia's commitment to sustainable energy practices and its role as a leader in renewable energy standards development.

Concerning its technical content, Australian Standard AS 5389 serves as a comprehensive guideline for the design, installation, and maintenance of solar heating and cooling systems. Encompassing a wide array of considerations, this standard plays a pivotal role in ensuring the effective and efficient utilization of solar energy for heating and cooling applications in various settings, ranging from residential buildings to commercial complexes and industrial facilities.

With the growing emphasis on sustainability and renewable energy sources, solar heating and cooling systems have emerged as integral components of green building initiatives worldwide. These systems leverage the abundant and freely available solar energy to provide heating and cooling solutions, thereby reducing reliance on conventional energy sources and minimizing environmental impact.

AS 5389 sets forth stringent requirements and best practices aimed at optimizing the performance, reliability, and safety of solar heating and cooling systems. It provides detailed specifications for the selection, sizing, and installation of components such as solar collectors, thermal storage tanks, heat exchangers, and control systems. Additionally, the standard delineates guidelines for system integration, including interfaces with existing heating, ventilation, and air conditioning (HVAC) infrastructure.

One of the key objectives of AS 5389 is to ensure the thermal comfort of occupants while maximizing energy efficiency and minimizing operational costs. To achieve this, the standard incorporates provisions for the design and optimization of system configurations tailored to specific climatic conditions and building requirements. By considering factors such as solar irradiance, ambient temperature, building orientation, and thermal insulation, AS 5389 facilitates the development of solar heating and cooling solutions that are both effective and sustainable.

Moreover, AS 5389 underscores the importance of ongoing maintenance and monitoring to uphold system performance and longevity. It outlines procedures for routine inspections, performance evaluations, and troubleshooting, enabling system operators and maintenance personnel to identify and address issues promptly.

In alignment with global standards and best practices, AS 5389 reflects the latest advancements in solar heating and cooling technology and incorporates feedback from industry experts, researchers, and stakeholders. By adhering to the guidelines outlined in this standard, stakeholders can ensure the successful implementation and operation of solar heating and cooling systems, thereby contributing to the advancement of sustainable building practices and environmental stewardship across Australia.

7 Proposition of Current Standards Integration (With Respect to Sunbelt Regions)

The quest for sustainable and efficient heating and cooling solutions has become increasingly paramount, particularly in regions characterized by abundant solar resources. The Sunbelt regions, renowned for its ample sunlight and high temperatures, presents a unique opportunity for leveraging solar energy to meet heating and cooling demands in a more eco-friendly and cost-effective manner. Recognizing the potential of solar-based technologies in this context, withing the subtask A, a concerted effort has been undertaken to develop a comprehensive list of standardized actions aimed at facilitating the adoption of solar heating and cooling solutions within the Sunbelt market.

This collaborative endeavour stems from a collective recognition of the pressing need to transition towards cleaner and more sustainable energy sources, while also addressing the specific challenges and opportunities presented by the Sunbelt region. Industry experts and researchers collaborated in the subtask A to harness the full potential of solar energy to meet the heating and cooling needs of residential, commercial, and industrial sectors in the Sunbelt regions.

The development of standardized actions represents a pivotal step towards streamlining the adoption and deployment of solar heating and cooling technologies across the Sunbelt market. By establishing clear and consistent guidelines, protocols, and best practices, stakeholders within the region can navigate regulatory frameworks, overcome technical barriers, and capitalize on the immense potential of solar energy for thermal applications.

Activity A5 served as a precursor to a comprehensive roadmap that outlines actionable strategies, recommendations, and initiatives aimed at catalysing the widespread adoption of solar heating and cooling solutions using the Australian standard as a solid base text, as the AS 5389 emerges as a cornerstone for the implementation of the proposed measures aimed at facilitating the adoption of the technology in the Sunbelt regions.

Here's how AS 5389 served as an optimal foundation for the implementation of proposed measures:

- **Tailored Approach:** AS 5389 is specifically designed to address the challenges and opportunities associated with solar heating and cooling systems in Australia, a country that encompasses vast Sunbelt territories. Its methodologies and guidelines are calibrated to optimize performance and efficiency in high-sunlight environments, making it inherently well-suited for application in the Sunbelt regions.
- **Inclusive Scope:** The standard encompasses a wide array of solar heating and cooling technologies, including solar desiccant cooling systems, solar air space heating systems, solar water space heating systems, building ventilating systems, and evaporative cooling systems. By accommodating diverse technologies, AS 5389 provides a holistic framework that caters to the varied needs and preferences of stakeholders within the Sunbelt market.
- **Energy Performance Assessment:** AS 5389 offers robust methodologies for assessing the energy consumption and thermal comfort provided by solar heating and cooling devices. This enables stakeholders to accurately gauge the performance and efficacy of solar-based solutions in meeting heating and cooling demands, thereby instilling confidence in their adoption and deployment across the Sunbelt region.
- **Alignment with Global Standards:** While tailored to the Australian context, AS 5389 adheres to internationally recognized standards and practices, ensuring compatibility and interoperability with global initiatives in the solar heating and cooling domain. This alignment enhances the standard's credibility and facilitates knowledge exchange and collaboration on a global scale, fostering innovation and continuous improvement in solar thermal technologies.
- **Support for Policy Initiatives:** AS 5389 serves as a linchpin for policy initiatives aimed at promoting renewable energy adoption and sustainability objectives in the Sunbelt regions. By providing a clear framework for energy performance assessment and compliance, the standard facilitates the integration of solar heating and cooling systems into regulatory frameworks, incentive programs, and certification schemes, thereby incentivizing their uptake and proliferation.

AS 5389 Australian Standard on solar cooling stands as an exemplar of best practices and guidelines tailored to harnessing solar energy for heating and cooling applications in the Sunbelt regions. Its comprehensive scope, robust methodologies, global alignment, and support for policy initiatives make it an indispensable tool for realizing the proposed measures aimed at advancing sustainable heating and cooling solutions in Sunbelt regions.

The proposed list of actions aims to enhance the applicability of the AS 5389 Australian Standard on solar cooling to Sunbelt climates by addressing specific challenges and opportunities inherent to these regions. Here's a detailed breakdown of each action:

1. **Incorporate Solar Cooling:** The standard should explicitly include solar cooling systems within its scope to ensure comprehensive coverage of heating and cooling solutions relevant to Sunbelt climates.
2. **Climate-Specific Design Guidelines:** Develop region-specific design criteria tailored to the unique climatic conditions prevalent in Sunbelt regions, such as high solar irradiance and temperature variations.
3. **Collector Technologies:** Address various types of solar collectors and optimizations suitable for harnessing high solar irradiance characteristics of Sunbelt regions, ensuring optimal performance and efficiency.
4. **Chiller Technologies:** Include guidance on absorption and adsorption chillers, which are commonly utilized in solar cooling systems, to ensure their seamless integration and compatibility with the standard's requirements.
5. **Thermal Storage:** Provide guidelines for the design and implementation of thermal energy storage systems, considering the specific needs and challenges associated with Sunbelt climates, such as seasonal variations in solar availability.
6. **Integration with Existing Systems:** Offer recommendations for effectively integrating solar cooling systems with existing HVAC infrastructure, taking into account compatibility, efficiency, and performance optimization.
7. **Performance Monitoring and Verification:** Specify procedures for assessing the performance of solar cooling systems, including metrics, monitoring techniques, and verification protocols to ensure compliance with standards and regulations.
8. **Maintenance and Inspection:** Detail comprehensive maintenance and inspection procedures for solar cooling components to ensure long-term reliability, efficiency, and safety of installations in Sunbelt climates.

9. **Regulatory and Incentive Guidance:** Include information on relevant regional regulations, standards, and incentive programs applicable to solar cooling installations in Sunbelt regions to facilitate compliance and incentivize adoption.
10. **Training and Certification:** Promote specialized training programs and certification initiatives aimed at equipping professionals with the necessary skills and expertise to design, install, and maintain solar cooling systems in Sunbelt climates effectively.
11. **Case Studies and Examples:** Provide practical examples and case studies showcasing successful solar cooling installations in Sunbelt regions, demonstrating real-world applications, benefits, and best practices.
12. **Energy Modelling and Simulation:** Encourage the use of energy modelling and simulation tools for assessing the performance and feasibility of solar cooling systems in Sunbelt climates, facilitating informed decision-making and optimization.
13. **Collaboration and Research:** Promote industry collaboration and research participation to drive innovation, knowledge exchange, and continuous improvement in solar cooling technologies tailored to Sunbelt conditions.
14. **Public Awareness and Education:** Foster public understanding and awareness of the benefits and potential of solar cooling in Sunbelt climates through educational initiatives, outreach programs, and information dissemination campaigns, encouraging broader adoption and support.

By implementing these proposed actions, the AS 5389 Australian Standard on solar cooling can effectively address the unique challenges and opportunities posed by Sunbelt climates, fostering the widespread adoption and deployment of solar heating and cooling solutions tailored to the region's specific needs and requirements.

Furthermore, to facilitate heating and cooling in the Sunbelt regions market, the adoption of standardized actions is paramount. This approach encompasses various initiatives aimed at streamlining the integration of solar thermal heating and cooling systems, enhancing industry expertise, and promoting financial mechanisms to support sustainable energy solutions. Here's a comprehensive outline of the proposed actions:

1. **Standardization and Best Practice Design:** Develop standardized designs for solar thermal heating and cooling systems tailored to the unique climatic conditions of the Sunbelt region. These designs should accommodate diverse collector and chiller technologies while ensuring seamless integration into existing building systems. Standardization not only lowers initial system costs but also instills confidence among stakeholders and fosters the development of local components. Regulatory support, such as an extension of AS5389, is crucial for estimating energy savings and promoting the adoption of standardized designs.
2. **Environment Upgrade Agreements (EUA):** Encourage the establishment of agreements that incentivize environmental upgrades in buildings, including the integration of solar thermal systems. EUAs provide a framework for property owners to invest in sustainable technologies by offering financial incentives or regulatory concessions.
3. **Training and Knowledge Dissemination:** Promote training programs and knowledge sharing initiatives within the heating and cooling industry to enhance expertise and understanding of solar thermal technology. By equipping professionals with the necessary skills and knowledge, we can accelerate the adoption and implementation of solar thermal systems in the Sunbelt region.
4. **On-Bill Finance:** Explore financial mechanisms that allow customers to finance solar thermal systems through their utility bills. On-bill financing offers a convenient and accessible way for building owners to invest in renewable energy solutions without upfront capital costs, thereby accelerating the transition to sustainable heating and cooling technologies.
5. **Energy Performance Contracts (EPCs) and Pilot Projects:** Initiate pilot projects and energy performance contracts to demonstrate the viability and benefits of solar thermal systems in real-world applications. EPCs provide a framework for implementing energy efficiency measures, including solar thermal installations, with guaranteed energy savings. Pilot projects serve as tangible examples of successful deployments, showcasing the economic, environmental, and operational advantages of solar heating and cooling.
6. **Energy Services Companies (ESCOs):** Encourage the involvement of Energy Services Companies in the planning, implementation, and management of solar thermal projects. ESCOs play a crucial role in providing turnkey solutions for energy efficiency and renewable energy projects, offering services such as project financing, design and engineering, installation, and ongoing maintenance.

The proposed standardized actions for the Sunbelt region encompass a multi-faceted approach that addresses key aspects of system design, regulatory support, financial mechanisms, and industry expertise.

8 Conclusions

In conclusion, the activity A5 has provided a comprehensive understanding of the significance of standardized actions and key performance indicators (KPIs) in driving advancements in the field of solar heating and cooling systems. Therefore, the importance of standardization in promoting interoperability, ensuring quality and fostering confidence among stakeholders was examined. In addition, the critical role of KPIs in assessing system performance, economic profitability and environmental impact were investigated.

The formulation of KPIs tailored to specific operational strategies and system configurations has emerged as a fundamental aspect of evaluating solar cooling technologies. While existing literature offers a plethora of KPIs, the challenge lies in defining a comprehensive yet streamlined set of metrics that align with stakeholder priorities and project objectives. Through a structured decision-making process and stakeholder engagement, efforts have been made to synthesize a set of energy/cost-related KPIs, aiming to provide clarity, relevance, and applicability across diverse contexts.

Moreover, the iterative refinement of KPI frameworks, such as the proposed methodology within Activity A5, underscores the importance of adaptability and stakeholder inclusivity. By incorporating stakeholder perspectives, balancing technical rigor with simplicity, and addressing dynamic factors such as emerging technologies and policy changes, the KPI framework can evolve to remain relevant and effective in guiding decision-making and system optimization.

Looking ahead, several considerations can enhance the effectiveness and applicability of KPIs within the solar cooling sector. These include careful selection and prioritization of metrics, standardization of measurement methodologies, integration of multiple KPIs into composite indicators, and periodic updates to reflect technological advancements and policy shifts. Additionally, cross-sectoral implications, stakeholder engagement, policy alignment, and long-term monitoring are key areas that warrant further exploration and attention.

As the demand for cooling continues to escalate due to factors like urbanization, population growth, and changing climate patterns, this standardization of approaches to assess and implement solar cooling systems becomes increasingly imperative. In this scenario, not only KPIs, but also standards play a crucial role in ensuring safety, reliability, and interoperability while fostering market acceptance and driving innovation.

However, despite the growing interest in solar cooling technologies, the landscape of standards governing these systems remains fragmented and complex. Covering various aspects including design, installation, performance evaluation, and safety requirements, navigating this intricate web of standards poses challenges for stakeholders involved in system design, deployment, and regulation.

To address these challenges, a comprehensive review and analysis of existing standards related to solar cooling is essential. Such an endeavour would provide clarity, guidance, and identify gaps for further standardization efforts, particularly regarding adaptation to specific climatic conditions like those in the Sunbelt region.

The goals of the review encompassed cataloguing and categorizing existing standards, evaluating their applicability and compatibility, identifying gaps and inconsistencies, informing best practices and guidelines, and fostering harmonization and collaboration among stakeholders and standardization bodies.

The review, conducted across international, regional, and national standards bodies, employed systematic identification, screening, and analysis methodologies. It covered the entire lifecycle of solar cooling systems, ensuring a comprehensive understanding of regulatory landscapes.

Insights from the review, including emerging trends and developments, will inform recommendations for future standardization efforts and policy interventions to support the growth and maturation of the solar cooling industry.

Of particular significance is the Australian Standard AS 5389, which marks a milestone in the realm of solar heating and cooling systems. Its inclusive approach, robust methodologies, and technical content serve as a comprehensive guideline for the design, installation, and maintenance of solar heating and cooling systems, contributing to sustainable building practices and environmental stewardship.

Eventually, concerted efforts have been made within subtask A to develop a comprehensive list of standardized actions aimed at facilitating the adoption of solar heating and cooling solutions within the Sunbelt market. This collaborative endeavour reflects a collective acknowledgment of the urgent need to transition towards cleaner and more sustainable energy sources, while addressing the specific challenges and opportunities presented by the Sunbelt regions.

Industry experts and researchers collaborated within subtask A to harness the full potential of solar energy to meet the heating and cooling needs of residential, commercial, and industrial sectors in the Sunbelt regions. The development of standardized actions represents a pivotal step towards streamlining the adoption and deployment of solar heating and cooling technologies across the Sunbelt market.

Activity A5 served as a precursor to a comprehensive roadmap outlining actionable strategies, recommendations, and initiatives aimed at catalysing the widespread adoption of solar heating and cooling solutions. The Australian Standard AS 5389 emerged as a cornerstone for implementing these measures, providing a solid foundation for addressing the specific challenges and opportunities inherent to Sunbelt climates.

The proposed list of actions aims to enhance the applicability of AS 5389 to Sunbelt climates by addressing specific challenges and opportunities. These actions encompass various initiatives aimed at streamlining the integration of solar thermal heating and cooling systems, enhancing industry expertise, and promoting financial mechanisms to support sustainable energy solutions.

By implementing these proposed actions, stakeholders can effectively address the unique challenges posed by Sunbelt climates and foster the widespread adoption and deployment of solar heating and cooling solutions tailored to the region's specific needs and requirements. This multi-faceted approach encompasses key aspects of system design, regulatory support, financial mechanisms, and industry expertise, laying the groundwork for a sustainable and resilient energy future in the Sunbelt regions.