International Journal of Computer Information Systems and Industrial Management Applications
ISSN 2150-7988 Volume 18(12s) 2026 pp. 967-979
https://doi.org/10.70917/ijcisim-2026-3967
Article

Bibliometric Insights Into Renewable Energy Powered Absorption Refrigeration Systems

Vivaan Sarda[1]

[1] Rishi Valley School, vivaansarda04@gmail.com

Abstract: . The contributions of this research paper is to illuminate the research of solar energy and its applications in cooling, focusing on its performance in real world applications. This also addresses the voids left over the existing literature of representing the COP and efficiency of ARS under non-ideal conditions. This research paper follows a hybrid PRISMA model and has also integrated case studies providing variance in geographical regions while adhering to its robust standards. Further review of existing literature reveals 3 major insufficiently studied limitations namely the sensitivity of system efficiency to solar irradiance volatility and biomass supply variability; the thermodynamic constraints imposed by ammonia as a refrigerant and its side effects such as high input temperatures resulting in corrosion over extended operation, and the supply chain disruption and economic barriers to entry along with technological limitations like low efficiency and COP. There is a need to improve these systems to function efficiently under high thermal stress while remaining economically viable. Thus a framework designed to optimize cooling technologies with limited resources and enhancement through advanced thermal storage and automated controls is introduced. The study designs a road map for engineers and government officials to balance social equity, environmental resilience, and long-term expenses.
Keywords: Absorption refrigeration systems (ARS); renewable energy cooling; bibliometric analysis; ammonia; solar-driven cooling.

1. Introduction

There is a huge burden on the power grids to sustain the rising energy consumption of today's residential and commercial sectors. This also places stress on the environment and the chemical coolants used in traditional cooling and refrigeration systems have high ecological damage as they trap unwanted heat in the atmosphere. Due to all these factors a transition toward low-carbon cooling alternatives is required. This paper serves to mitigate the environmental footprint of modern thermal management systems. The landscape of research in renewable has seen massive development over the past 2 decades due to the myriad of scholarly output in this field. Regardless, renewable energy cooling systems have not been able to establish a dominant market presence due to lack of strategic marketing and consumer engagement. To ameliorate this situation and induce transformation towards ARS there is a need for international concurrence on this particular topic (Sharma & Sengar, 2024).

Only recently, solar energy was considered as a means to induce cooling. Until now this utility of it was overshadowed by the research advanced in heating and electricity generation. Since this technology gives maximum efficiency during the most sunlight hours, it paves way for an alternative to traditional refrigeration, when cooling is recruited the most. This has been further corroborated with the research community focusing on developments revolving around solar cooling (Saikia et al., 2020). To improve the efficiency of solar cooling entities, hydrogen storage systems can be integrated into solar collectors. To enhance the productivity of ARS, however, further research needs to be done in order to successfully boost their performance, and this is only possible with financial aid given to this sector (Aripin et al., 2025). Renewable energy cooling is being used in many industries and offers a stepping stone for the transition to ARS. The introduction of smart systems allows for improved performance and bolsters competition among industries which leads to further promotion of renewable energy cooling systems (Kut & Pietrucha-Urbanik, 2023).

To facilitate a smooth transition to renewable energy cooling systems, the efficiency of such entities can be improved by integrating various technologies like nanofluids and surfactants in the absorber systems. This ensures that the performance levels of solar-cooled systems is comparable to that of traditional cooling systems (Asfand & Bourouis, 2015). As shown in Figure 1 highlights the various advantages of renewable energy of powered absorption refrigeration which can be very useful. To ensure steady cooling at night or under cloud cover, Variable Mass Energy Transformation and Storage (VMETS) has been incorporated to store energy in the form of chemical potential and thus has positive impacts on climate as well by reducing the use of electrical or gas-powered cooling in the absence of sunlight (Xu et al., 2011). By using solar power and recycling waste heat, renewable technologies can reduce environmental and ecological damage. Traditional cooling techniques employ the use of fossil fuels to preserve food by inhabiting bacterial growth. Absorption systems are a good alternative for this as they promote environmentally friendlier methods of cooling while addressing energy conservation and global climate protection. Thus clean, new technologies can replace older, polluting ones (Gupta et al., 2021).It is possible to develop a hybrid renewable energy system. Such a system was developed with a dual function in Iran to provide a rural village with not only cooling but also sustainable energy. A storage system was integrated to to pick up waste energy and thus helped prevent major energy losses by powering an organic Rankine cycle (Mousavi et al., 2022).

The proposed study aims to explore and fill the existing literature gap in the field of renewable energy cooling systems. This includes bringing the underrepresentation of research of evaluation of system efficiency into light and illustrating the economic and technological setbacks such as corrosion due to elevated generator temperatures caused by ammonia's thermodynamic properties and supply chain offsets and financial limitations.

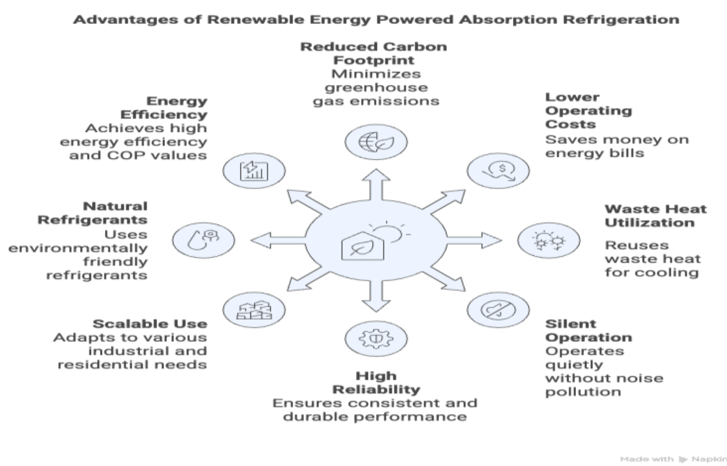

Figure 1: Advantages of Renewable Energy Powered Absorption Refrigeration

The paper is organized as follows: Section 2 presents a literature review highlighting key studies and gaps in renewable energy powered absorption refrigeration systems. Section 3 outlines the research questions guiding this bibliometric analysis. Section 4 details the research methodology, including data sources, selection criteria, and bibliometric tools used. Section 5 discusses the analysis results, identifying trends, challenges, and implications. Finally, Section 6 concludes by summarizing the findings and suggesting future research directions.

2. Literature Review

A. Solar-Driven Systems

To counterbalance the problems faced related to energy storage, compound parabolic concentrators (CPCs) and flat-plate collectors are incorporated into solar collectors along with lithium water-bromide absorbent and refrigerant pairs as they are among the most efficient cooling technologies (Gunawan et al., 2024). Another sector in which lithium water-bromide cooling is used is as a secondary cooling source to solar-powered chillers to ensure efficient cooling even during weather disruptions and variance (Ibrahim et al., 2017). Researchers have evaluated which combination of materials have the most cooling capacity by comparing the metrics such as the coefficient of performance,material degradation and also that hybrid systems using composite pairs may resolve current technical limitations. The research was primarily focused on absorption and adsorption methods, comparing thermal efficiency of various chemical pairings. There has been a transition from traditional cooling systems to cleaner energy sources not only in residential areas but also large-scale industrial temperature control (Ullah et al., 2013).

Research has been conducted to assess the efficiency of solar cooling systems. Experimental data has revealed that solar powered cooling units have almost the same performance coefficient as traditional, electrical cooling systems. Figure 2. presents an overview of solar powered absorption cooling units. This shows that renewable refrigeration can effectively replace fossil fuels or electricity in refrigeration technology while maintaining efficiency standards. This gives way for the transition to renewable cooling systems hence reducing dependence on the power grids and also reducing ecological footprint (Çetiner, 2023). Another study that demonstrates the high efficiency of renewable cooling systems uses a parabolic solar collector to transfer heat into the refrigeration cycle.This was found when a conventional electric refrigerator was compared with a solar powered unit. To create environmentally efficient cooling systems, the mass low rates and system pressure along with some other metrics were taken into consideration and the potential for solar cooled entities were brought to light (Çetiner, 2023b).

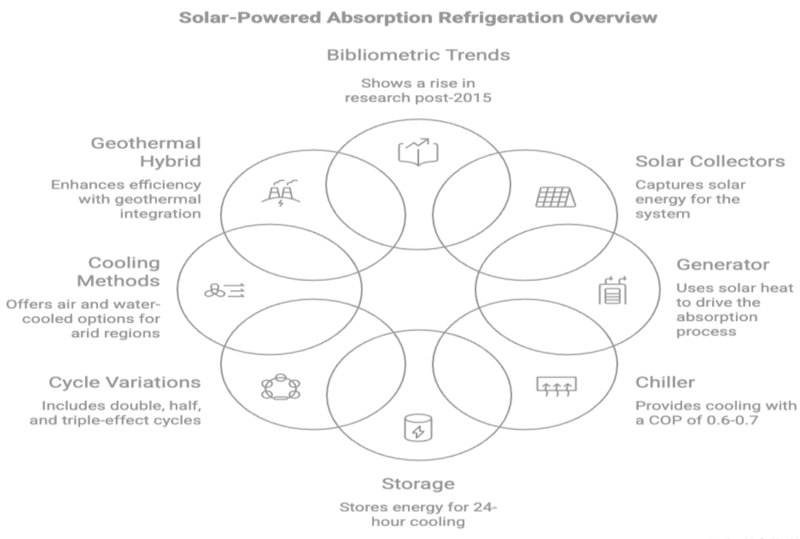

Figure-2: Solar-Powered Absorption Refrigeration Overview

B. Geothermal and Biomass Integration

To attain highest efficiency in ARS systems in rural areas, geothermal energy and biomass combustion can be incorporated along with solar energy to create cost effective hybrid power plants to run cooling entities. The COP achieved through this process is 0.56 and it also takes into consideration the ecological damage caused by traditional refrigeration systems. Recent bibliometric analyses show that there is an acceleration in co-citation networks linking thermal storage innovations and waste heat recovery with absorption and cooling systems. Activated carbon in two-bed absorption systems, backed by thermal storage innovations, proves to be a source of green energy (Gunawan et al., 2024b). Further corroborating the high efficiency of hybrid systems, a solar-powered cooling system integrated with an absorption energy storage, using lithium bromide-water solution was trialed in Saudi Arabia and proved to be sustainable even in such unforgiving climates. It was shown that such systems have high efficiency and COP and the storage density found was up to the mark as well. Further attention on this could lead to various other implementations of such technologies in the future (Ibrahim et al., 2017b).

Different methods of increasing efficiency were mentioned by a study, maintaining environmental concerns, by scrutinizing absorption and adsorption techniques and the different temperature limits of various chemical combinations in solar-cooled systems. This was done by examining the efficiency and also gives insights into unconventional combinations of materials that could potentially be used to overcome the bottlenecks faced such as substance clumping (Ullah et al., 2013b). By using heated oil instead of lithium bromide-water solution as an absorbant, a study demonstrated that the efficiency of solar powered cooling systems can come quite close to traditional refrigerators. This corroborates the fact that diffusion absorption systems can operate effectively without relying on fossil fuels or the electrical grid. By evaluating various metrics, the researchers have shown a path to a practical and sustainable alternative for modern refrigeration needs by easing the transition towards cooling systems powered by a parabolic solar collector (Çetiner, 2023c).

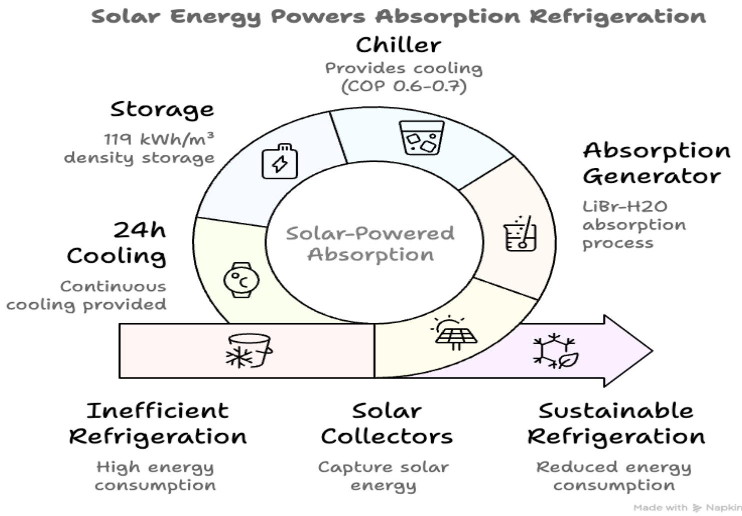

Figure-3: Solar Energy Powered Absorption Refrigeration

Such studies show that renewable energy systems can now opportunely replace conventional power sources to create cooling systems keeping the ecological footprint in mind. Figure 3 touches upon the cycle for cooling in solar powered absorption refrigerators and various factors resulting in the COP. In the study different contributing factors to efficiency like thermal values, solution concentrations, system pressures, mass flow rates, etc. were studied. The findings show that the Coefficient of Performance of the parabolic solar collector powered refrigerator was approximately 0.390 while that of electric/fossil fueled coolers was found to be 0.398 (Çetiner, 2023d).

C. Performance Optimization Themes

Thermodynamic modeling and multi-energy hybrids (e.g., solar-geothermal CCHP via ORC) form a core cluster, with COP optimizations via fins, novel collectors, and controls. \assessments. Emerald/Sage-aligned reviews underscore gaps in real-time ML-driven controls for variable renewables. A two framework design was put forward to combine renewable energy and power storage technologies in cooling entities as this can not only be ecologically a more favourable option but can also be economically more stable. This approach can help maximize efficiency by applying a combination of traditional cooling with solar power and different fuel types. By weighing the environmental impacts and economical costs of cooling systems, both things can be mitigated by changing the ratio of traditional and renewable cooling systems. By taking the seasonal fluctuations of sunlight into consideration, the ideal break up between solar collectors and backup energy sources can be achieved (Ponce-Ortega et al., 2011). Recent research has shown that incorporating solar or geo-thermal energy in traditional cooling systems can have superior operational outcomes which in turn, due to higher efficiency, reduce the power required globally in the cooling sector. This combination cuts the electricity used by about 95% in ideal situations and thus has a better environmental stand in both households and industries alike (Aridhi et al., 2016).

Table I. Extensive Literature Review For Renewable Energy Powered Absorption Refrigeration Systems [21-25]

Reference	**Key Findings**	**Research Gap**	**Limitations**	**Cooling Technologies**	**Future Scope**
(Çetiner, 2023e)	The coefficient of performance is maximized by dual ejector systems	Research on not only multi-ejector systems but also innovative absorbers is sparse	The performance levels are only maintained in ideal conditions.	They include vapour compression, hybrid ejector systems, absorption and adsorption.	This includes innovative and compact systems including multi ejector systems and membrane based systems.

(Ullah et al., 2013c)	Integrating BCHP, DHS, and TES maximizes efficiency costs and emissions.	Multi objective optimization is lacking along with sourcing and reliability assessment.	They include low efficiency along with high costs and supply chain issues.	They are various chillers like electric, energy driven, and absorption and also ground water heat pumps.	They are exergy, modern cooling technologies, and smart systems.
(Lima et al., 2020)	Even though solar refrigeration is more sustainable, electric refrigeration has a higher COP.	The solar refrigerator is not operational in periods of low sun, night and cloudy days.	They are inconsistency of sunlight, low efficiency and high evaporation point of ammonia.	These are vapour cooling, diffusion absorption, mechanical cooling and absorption cooling.	Using phase changing materials for higher efficiency and using battery storage.
(Rezaei et al., 2021)	Hybrid systems save 20% energy, 10% costs and have reduced carbon emissions up to 40%.	Traditional designs have overlooked biomass production constraints and solar volatility.	Solar volatility and biomass production constraints are the limiting factors of such systems.	These are electric coolers and single-effect absorption chillers.	Optimization of output plans with load is required.
(Zhang et al., 2019)	COP and air cooling units are improved by double effect systems.	Lacks not only thermal storage technologies but also design guidelines	Corrosion is prominent due to high input temperature.	These include an array of both air and water-cooled systems.	Advancements in energy storage and design guidelines can contribute to this sector.

Low efficiency, high capital costs, performance in uncontrolled conditions, corrosion rates are among the underrepresented frontiers in the research focused on development of ARS. Due to the paucity of literature in such sectors, a smooth transition from traditional cooling systems becomes impossible. This study seeks to address these gaps and provide a comprehensive and detailed assessment of these real-world limitations under nonideal operating conditions. Table I. summarizes the landscape of existing literature in the field of renewable cooling systems.

Research questions, hypotheses, and research objectives have been proposed after doing extensive literature review in Table I. These hypotheses can be tested and proved via case studies for the title Bibliometric Insights Into Renewable Energy Powered Absorption Refrigeration Systems.

Research Questions

1. How is the efficiency of these systems affected by solar irradiance inconsistency and biomass production variability and how their operation changes under nonideal, real world conditions.
2. How the use of ammonia, its high boiling point, contributes to energy losses and corrosion due to the need for high input temperatures.
3. What is the outcome of high capital costs, supply chain disruptions, low efficiency, and long-term viability on absorption refrigeration systems.

Hypotheses

1. Absorption cooling systems operating under nonideal conditions like variable solar irradiance and inconsistent biomass supply have lower efficiency and coefficient of performance than those operating under ideal conditions.

2. High temperatures for a prolonged period of time result in material corrosion and thus ammonia's thermodynamic constraints cannot be fulfilled without resulting in a decreased lifespan.
3. Due to external factors such as high economic costs and supply chain disruptions, these systems cannot be integrated in a large-scale manner.

3. Research Methodology

Literature from mainly Scopus, Web of Science (WoS), and IEEE Xplore were used to ensure extensive bibliographic coverage due to their complementary indexing strengths across engineering, energy sciences, and applied physics domains. This study is designed to systematically investigate renewable energy-powered absorption refrigeration systems (RE-ARS) and their integrability into the cold chain markets using multi layered, structured research. Boolean search strings were used after combining them with domain specific words. These were refined and duplication performed prior to screening. To maintain PRISMA fastness, language filters, document-type constraints, and temporal scope were defined explicitly. The Preferred Reporting Items for Systematic Reviews and PRISMA protocol was faithfully upheld, including a transparent, multi-stage screening process comprising identification, screening, eligibility assessment, and final inclusion were applied to all three databases minimizing bias. The above steps were to address RQ1. For the remaining two RQ's which investigate technology-specific performance benchmarks and system integration challenges, a case study was taken into research for each of them. These were selected from the screened literature to ensure diversity across renewable energy source typologies, geographic contexts, and theoretically grounded interpretation of emerging technological trajectories. Qualitative mapping of the resources is ensured by this hybrid methodology of amalgamating the rigor of PRISMA-guided bibliometric analysis and the contextual depth of qualitative case study investigations.

RQ1. How is the efficiency of these systems affected by solar irradiance inconsistency and biomass production variability and how their operation changes under nonideal, real world conditions.

Bibliometric analysis is a research methodology which is in harmony with the research question which looks at the efficiency and performance of renewable energy-powered absorption refrigeration systems (ARS) under non-ideal, real-world conditions. A bibliometric approach considers the scholarly literature already present and quantitatively analyzes the research landscape. This study particularly uses bibliometric research based upon PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) 2020 foundation (Page et al., 2021b). Since most studies revolving around ARS have focused on majorly on its performance and efficiency under ideal conditions, this particular study is motivated by the research gap to study renewable energy cooling systems under non ideal conditions and how solar irradiance inconsistency, biomass supply variability, ammonia refrigerant constraints, material corrosion, and supply chain disruptions affect efficiency and how to best optimise the available resources. By applying PRISMA standards, this study ensures transparency, reproducibility, and methodological rigour consistent with high-impact journal publication requirements (Aria & Cuccurullo, 2017).

A. Prisma Framework

The study follows a two-phase framework:

Phase 1 – Systematic Literature Retrieval: Application of the PRISMA protocol to identify, screen, and select relevant scholarly publications from major academic databases.

Phase 2 – Bibliometric Analysis: Quantitative mapping of co-authorship networks, keyword co-occurrence, citation bursts, and thematic clusters using specialised bibliometric software.

B. PRISMA Protocol

The PRISMA 2020 framework structures this methodology into four sequential stages: Identification, Screening, Eligibility, and Inclusion.

Stage 1 – Identification

Data bases like Scopus (Elsevier), Web of Science (Clarivate Analytics), and IEEE Xplore Digital Library were used due to their comprehensive indexing of engineering, energy, and environmental sciences literature, their support for advanced Boolean queries (described by TAble III.), and their provision of exportable metadata (title, abstract, author, citations, keywords, year, journal). Relevant publications were identified through systematic keyword searches across these three major academic databases.

Table II. Boolean Search Strings used for identifying the Research Papers

Database	Boolean Search String
Scopus	(TITLE-ABS-KEY("absorption refrigeration" OR "absorption cooling") AND TITLE-ABS-KEY("renewable energy" OR "solar energy" OR "biomass") AND TITLE-ABS-KEY("coefficient of performance" OR "COP" OR "efficiency") AND TITLE-ABS-KEY("non-ideal" OR "real-world" OR "variable" OR "irradiance"))
Web of Science	TS=("absorption refrigeration system*" OR "absorption chiller*") AND TS=("solar irradiance" OR "biomass supply" OR "renewable") AND TS=("COP" OR "performance" OR "efficiency") AND TS=("non-ideal" OR "fluctuation*" OR "corrosion" OR "constraint*")
IEEE Xplore	("absorption refrigeration" OR "vapour absorption") AND ("solar energy" OR "biomass energy") AND ("coefficient of performance" OR "energy efficiency") AND ("variable conditions" OR "non-ideal" OR "ammonia" OR "corrosion")

Stage 2 – Screening

The records were screened at title and abstract level by two independent reviewers to minimize bias while duplicate records across databases were removed using reference management software (Zotero/Mendeley). Conflicts were resolved through discussion and consensus.

Stage 3 – Eligibility Assessment

Full-text articles passing the screening stage were assessed for eligibility against a pre- defined set of inclusion and exclusion criteria. Studies meeting all inclusion criteria were included for final bibliometric analysis.

Stage 4 – Final Inclusion

Studies surviving full-text review were entered into the bibliometric dataset. Bibliographic metadata (authors, affiliations, journals, citations, keywords, abstracts, publication years) were exported in BibTeX and CSV formats for analysis using VOS viewer and Bibliometric (R package).

C. PRISMA Flow

Records were retrieved from Scopus, Web of Science, and IEEE Xplore (database search) and additional records from Google Scholar and grey literature (reports, theses). Table IV. walks through all the inclusion and exclusion criteria. The records were screened at title and abstract level and duplicates were removed. Records were excluded if they were off-topic, non-English, before 2010, had methodology mismatch, no performance data, or no renewable energy focus.

Table III. Inclusion and Exclusion Criteria used to Identify the eligible research papers for Bibliometric Insights Into Renewable Energy Powered Absorption Refrigeration Systems

Sr. No.	Inclusion Criteria	Exclusion Criteria
1	Peer-reviewed journal articles and conference papers.	Books, book chapters, editorials, opinion pieces.
2	Published between 2010 and 2024 (post-RE policy era).	Publications before 2010
3	Focus on absorption refrigeration or cooling systems.	Studies on vapour-compression refrigeration only.
4	Use of at least one renewable energy source (solar, biomass, geothermal, or hybrid)	Studies based solely on fossil fuels or grid electricity.
5	Reporting of performance metrics (COP, efficiency, energy savings, or cost)	Qualitative studies without measurable performance data.

6	English language publications	Non-English publications without English abstracts.
7	Studies involving real-world, field, or non-ideal condition testing	Theoretical models validated only under ideal laboratory assumptions.

D. *Linking Bibliometric Evidence to Research Questions and Hypothesis*

Research Question

How is the efficiency of absorption cooling systems affected by solar irradiance inconsistency and biomass production variability, and how does their operation change under non-ideal, real-world conditions?

Hypothesis

Absorption cooling systems operating under non-ideal conditions (variable solar irradiance and inconsistent biomass supply) exhibit significantly lower efficiency and coefficient of performance (COP) compared to those operating under ideal conditions.

E. Limitations of the Methodology

Despite the extensive efforts taken there were a few limitations that could not be overcome by the rigor of this paper. These mostly revolve around redistricting to only English and not including any relevant publications as they were in Chinese or Spanish which both have significant renewable energy research output; using only 3 major databases, even though they offer a comprehensive coverage, certain regional journals may not be indexed in these databases; missing out on the studies that have not included standard ARS keywords as per the authors choice; not citing many recent papers, from 2023-2024, and thus underrepresenting current research; and primarily, a bibliometric analysis does not include conducting physical experiments and studying actual systems and instead referencing this data from other studies and papers.

F. Expected Contributions

This study is expected to make various contributions to the landscape of renewable energy cooling systems such as to provide a consolidated bibliometric map of renewable energy-powered refrigeration systems focussed specifically on non-ideal operating conditions, identifying research gaps, especially the intersection of biomass supply chain disruptions and ARS efficiency, that other studies can explore, delivering actionable insights for policymakers and engineers seeking cost-efficient, sustainable cooling solutions for tropical and semi-arid regions, and offering a replicable PRISMA-based methodology framework that Grade 11 and undergraduate students can adapt for bibliometric studies across engineering and sustainability domains.

Case Studies

RQ2. How the use of ammonia, its high boiling point, contributes to energy losses and corrosion due

to the need for high input temperatures?

This case study directly addresses the research question using various scientific literature. Although ammonia has undergone research both as a refrigerant fluid in many absorption systems and also as a zero-carbon combustion fuel in gas turbines, it has many drawbacks due to its inconvenient thermodynamic properties, its boiling point to be in particular. How does this defect result in energy losses and corrosion risks? ARS experimental studies reveal that when separation of ammonia from aqueous solutions is paired with NOx-driven material degradation in high-temperature conditions, commercialization of ammonia-based technologies is a substantial challenge. Ammonia as a refrigerant fluid in many absorption systems and also as a zero-carbon combustion fuel in gas turbines has a boiling point of −33.35°C which is much lower than that of water. Thus, ARS Generators employ more thermal inputs to push ammonia from its aqueous solution. Due to this various matrix like efficiency, coefficient of performance, corrosion rates, and applicable waste heat source range are affected negatively (Alnaeli et al., 2023).

The literature studied can provide evidence to indicate how ammonia's relatively high boiling point when compared to other refrigerants result in a drop in efficiency and coefficient of performance while it exhibits increased rates of corrosion. This research also quantifies this data. The temperature range required for ammonia to be liberated from its aqueous solution is 80–160°C, due to ammonia's thermodynamic characteristics. Typical ammonia-water (NH_3-H_2O) absorption systems recover industrial waste heat in that range. Due to this, the evaporator outlet temperature decreases, and with that even the coefficient of performance drops (Alnajideen et al., 2024). The thermodynamic challenges caused due to ammonia's separation enthalpy could not be overcome by advanced compact heat exchange geometries. This was shown by Garimella et al.'s microchannel-based residential-scale system which had a COP of 0.44 at 183°C generator inlet temperature. Likewise, Du et al.'s diesel waste heat-driven prototype reached a COP of only 0.55 with a generator temperature of 567°C. This shows that the energy cost is irreducible for ammonia purification at less than 0°C. Said et al.'s solar-powered single-stage AARS chiller had a COP of 0.42 operating at generator, condenser, and evaporator temperatures of 140°C, 45°C, and −4°C respectively. This COP decreased to 0.3 at −7°C evaporator outlet. This 28.5% drop is caused due to decreasing ammonia concentration in the solution and the increased heat load.

Du et al.'s research on internal heat recovery shows that even under optimal saturated feed conditions, minimizing head and mass transfer losses, the COP for systems with heat sources 120°C does not cross 0.65. Lostec et al.'s study of a 10 kW single-stage system reveals that it yields a COP between 0.13 and 0.25 only at refrigeration temperatures between 0°C and 5°C, operating between heat source temperatures of 75°C and 85°C If refrigeration temperature targets drop then the concentration of ammonia in the solution decreases which in turn increases the heat load on the distillation system. Due to this efficiency suffers as lower refrigeration requires more purity of ammonia vapour which again needs more thermal energy for rectification. This reduces the COP even more. Table II. breaks down the key aspects of how the thermodynamic properties of ammonia affects operational parameters. Sözen et al. states that solution heat exchanger plays an important role in this process although it cannot completely eliminate the thermodynamic constraints. This shows that although ammonia's boiling point does not directly affect the system, it involves other complex energy loss mechanisms. To reduce corrosion risks and improve burning velocity, fuel blending strategies have been developed using hydrogen or methane along with ammonia. This reduces NOx output which causes corrosion. Robust coatings, surface treatments, and advanced manufacturing approaches are all procedures to evade NOx induced corrosion. There has been no research, however, on the environmental effects of fuel blending nor the most optimal blend ratio to ensure turbine longevity and cost efficiency. For the commercialization of ammonia as a carbon-free fuel, there needs to be advancements in protective materials to ensure high durability (S. Zhang et al., 2024).

Table IV. Thermochemical and operational parameters illustrating ammonia-related energy and corrosion penalties across reviewed literature.

Parameter Ammonia (NH_3) System Implication	Parameter Ammonia (NH_3) System Implication	Parameter Ammonia (NH_3) System Implication
Boiling Point	−33.35°C	High generator input temperature required
Generator Temp. (AARS)	80–160°C	Low-grade heat marginally sufficient
COP at −4°C	~0.42 (Said et al.)	Significant thermodynamic energy penalty
COP at −7°C	~0.30 (Said et al.)	28.5% drop from rectification load
NOx Emission Risk	High (low flame speed)	Corrosive degradation of turbine alloys
Max recorded COP	≤0.65 (Du et al.)	Ceiling imposed by separation enthalpy

Bibliometric mapping of research clusters around ammonia-based ARS and ammonia combustion should highlight inter-domain citation linkages especially between refrigeration thermodynamics and materials science literature. This is because most such research shares ammonia's thermophysical identity (Lima et al., 2020b).

RQ3.What is the outcome of high capital costs, supply chain disruptions, low efficiency, and long-term viability on absorption refrigeration systems?

In today's world the supply chain has been influenced by various factors such as accelerating environmental degradation, and an exponentially growing demand for food preservation infrastructure. Thus, introducing absorption refrigeration systems (ARS) which make use of low-grade heat recovery to function seems to be the most logical and optimal solution. This, however, is not the case and the reasons for it are further explored by this case study by collecting data and focusing on the effects of high capital costs, supply chain disruptions, low efficiency, and long-term viability on ARS. The major problem that was found by mapping this data collected to the empirical evidence from different literature is that not only do the ARS need to be both efficient and ecologically a better option but also need to fit into the supply chains and economic structures. They should also harmonize with the state or regional regulations. Since heating, cooling and ventilation account for a large proportion of total energy consumed in residential buildings (almost 60%), and the above also account for almost 39% of global greenhouse emissions, the integration of sustainable cooling systems need to be evaluated against how well they can harmonize with the economic landscape in order to transition from traditional refrigeration systems (Meng et al., 2024). Although theoretically there should be a higher economic case for higher-quality refrigeration, due to the economic cost of annual food wastage which is about 1.3 billion tons (one-third of global food production) as per the Food and Agriculture Organization of the United Nation, this economic loss is distributed across fragmented supply chains instead of being concentrated at optimal places for ARS development and capital intensive technology adoption (Iyer & Robb, 2025).

Since neither the goods nor the environmental conditions can be analyzed and monitored while distribution, this may result in major operational failures [MDPI 2076-3417]. The absence of instantaneous thermal tracking leads to ignorance of solar resource intermittency, working fluid degradation, or even system component failure. These issues may not be detected until much later until quality failure is observed. To optimize distribution and chain operations, must address storage design, tactical planning, and distribution planning [ScienceDirect 2025]. Due to this, detecting disruptions in the supply chain has become a crucial role. As it ensures safety, efficiency, and regulatory compliance of cold chain operations [MDPI 2076-3417]. ARS, which have been amalgamated with the cooling chain networks, must be attested with data and high infrastructure standards to meet regulatory requirements. This is as cold chain operators are scrutinized heavily and have to meet high quality and control standards. All this can cause monetary constraints by increasing the capital requirements. Even so, this creates pathways for ARS to be integrated into society (Lorenc, 2023). The cold chain markets are evolving rapidly based on more efficient systems, better design innovations, and smarter monitoring systems. Research has shown that the best-case scenario for the interation of ARS into the cooling sector is combining the environmental standpoint also with smart modeling technologies, for which there is already numerous literary data, and economic viability modeling. There are mainly only 4 barriers to entry for ARS into cold chain markets. These entities are interdependent on each other and affect the supply chain and other dynamics differently. Namely these are high capital costs, supply chain disruptions, low efficiency, and long-term viability (Cnicesta 2025).

4. Results and Discussions

A cooling system designed by Zhang et al., 2019 in China demonstrates that renewable energy cooling entities can achieve high performance levels even in non-ideal conditions. It exhibited 20.94% energy savings, 11.72% lower costs and 40.79% lesser carbon emissions since it had a renewable energy-integrated CCHP system integrated within it. Hybrid compression-absorption cycles and ejectors minimize electricity consumption and integration of biomass can reduce financial barriers. This provides an alternative to traditional cooling systems. Using ammonia and lithium nitrate as refrigerant and absorbent has superior performance outcomes that the typical water and lithium bromide combination. Lima et al., 2020 found this by exploring many unconventional such combinations.Only 18% of total literature revolves about the efficiency and COP of renewable energy cooling systems in real-world conditions. Furthermore, various problems such as financial (unavailability of financial aid) and technological (elevated generator temperatures, limitations, economical setbacks (supply chain disruptions) were brought to light by the Renewable Cooling Viability Framework (RCVF) which merges empirical engineering performance with bibliometric analysis and proves to be superior to single metric assessments.

Policy Recommendations

The information presented by this paper gives rise to various policies and recommendations starting with mandatory real world, non-ideal protocols, implemented by national and regional energy ministries, that must be fulfilled before co-financing of renewable ARS installations. This makes the hypothesized efficiency and outcomes much closer to the real case scenario. Figure 4 paints a picture of the renewable energy-powered absorption refrigeration systems. Research should be taken further in the field of material science to ensure the components of the physical system can handle the high temperature. All findings in this paper are in harmony with existing literature and thus may be biased to literature included in this study and the geographical coverage presented may not be applicable as it is a review of papers and represents Mediterranean and South Asian regions.

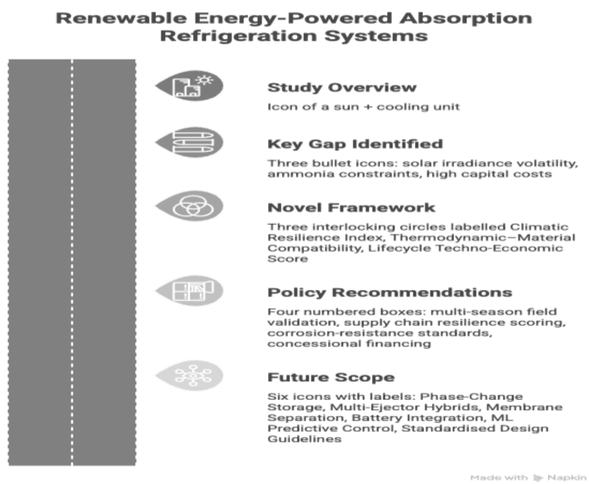

Figure-4: Renewable Energy-Powered Absorption Refrigeration Systems

5. Conclusion and Further Scope

Break downs that occur in the ARS are largely due to repercussions relating to either economic shortcomings, failure to compensate for ammonia’s thermodynamic properties and corrosion caused by elevated temperatures, or the inefficiency or underrepresentation of the workings of such systems under uncontrolled situations such as solar and biomass variance. The framework mentioned above (RCVCF) accounts for all three possible limitations mentioned above and combining it with PRISMA provides extensive rigor which cannot be found in single metric systems. Since ARS holds a great sway in the outcomes of the cooling sector and how it will impact the environment, due to the ever-growing cooling demands of today's world, transition towards it is required to be smooth. This can be done by taking research in materials science to make more corrosion resistant substances to be used or by implementation of financial and economic policies in support of these systems. As of now, there exists very limited literature in the frontiers of research in non-ideal conditions which lead to disparities in expected and actual outcomes. This can be redressed by making a deliberate shift towards research in real-world conditions and also focusing on industry level use of such systems to ensure smooth working. This study facilitates by providing evidence and paves a way to incorporate the potential of renewable energy cooling systems at a higher scale.

References

1. Saikia, K., Vallès, M., Fabregat, A., Saez, R., & Boer, D. (2020). A bibliometric analysis of trends in solar cooling technology. Solar Energy, 199, 100–114.
2. Sharma, P., & Sengar, A. (2024). Trends and insights in renewable energy research: a comprehensive bibliometric analysis (2000–2023). International Journal of Energy Sector Management, 19(4), 751–771.
3. Aripin, N. M., Hussain, S., Loon, L. K., Mahmud, F., & Alimin, N. S. N. (2025). The integration of energy storage systems in solar power generation: a bibliometric perspective of renewable energy. International Journal of Energy Sector Management, 19(6), 1427–1443.
4. Kut, P., & Pietrucha-Urbanik, K. (2023). Bibliometric analysis of renewable energy research on the example of the two European countries: insights, challenges, and future prospects. Energies, 17(1), 176.
5. Asfand, F., & Bourouis, M. (2015). A review of membrane contactors applied in absorption refrigeration systems. Renewable and Sustainable Energy Reviews, 45, 173–191.
6. Xu, S., Huang, X., & Du, R. (2011). An investigation of the solar powered absorption refrigeration system with advanced energy storage technology. Solar Energy, 85(9), 1794–1804.
7. Gupta, A., Sankhla, V. S., & Sharma, D. (2021). A comprehensive review on the sustainable refrigeration systems. Materials Today Proceedings, 44, 4850–4854.

8. Mousavi, S. A., Mehrpooya, M., & Delpisheh, M. (2022). Development and life cycle assessment of a novel solar-based cogeneration configuration comprised of diffusion-absorption refrigeration and organic Rankine cycle in remote areas. Process Safety and Environmental Protection, 159, 1019–1038.
9. Gunawan, S., Arfianto, W., & Heryadi, B. (2024). comparative review and novel design possibilities on solar-driven absorption LiBr-H2O refrigeration system. MESIN, 30(1), 1–28.
10. Ibrahim, N. I., Al-Sulaiman, F. A., & Ani, F. N. (2017). Performance characteristics of a solar driven lithium bromide-water absorption chiller integrated with absorption energy storage. Energy Conversion and Management, 150, 188–200.
11. Ullah, K., Saidur, R., Ping, H., Akikur, R., & Shuvo, N. (2013). A review of solar thermal refrigeration and cooling methods. Renewable and Sustainable Energy Reviews, 24, 499–513.
12. Çetiner, C. (2023). Thermal analysis of operating a solar-powered diffusion absorption refrigerator with a parabolic collector. Case Studies in Thermal Engineering, 53, 103893.
13. Çetiner, C. (2023b). Thermal analysis of operating a solar-powered diffusion absorption refrigerator with a parabolic collector. Case Studies in Thermal Engineering, 53, 103893.
14. Gunawan, S., Arfianto, W., & Heryadi, B. (2024b). comparative review and novel design possibilities on solar-driven absorption LiBr-H2O refrigeration system. MESIN, 30(1), 1–28
15. Ibrahim, N. I., Al-Sulaiman, F. A., & Ani, F. N. (2017b). Performance characteristics of a solar driven lithium bromide-water absorption chiller integrated with absorption energy storage. Energy Conversion and Management, 150, 188–200.
16. Ullah, K., Saidur, R., Ping, H., Akikur, R., & Shuvo, N. (2013b). A review of solar thermal refrigeration and cooling methods. Renewable and Sustainable Energy Reviews, 24, 499–513.
17. Çetiner, C. (2023c). Thermal analysis of operating a solar-powered diffusion absorption refrigerator with a parabolic collector. Case Studies in Thermal Engineering, 53, 103893.
18. Çetiner, C. (2023d). Thermal analysis of operating a solar-powered diffusion absorption refrigerator with a parabolic collector. Case Studies in Thermal Engineering, 53, 103893.
19. Ponce-Ortega, J. M., Tora, E. A., González-Campos, J. B., & El-Halwagi, M. M. (2011). Integration of Renewable Energy with Industrial Absorption Refrigeration Systems: Systematic Design and Operation with Technical, Economic, and Environmental Objectives. Industrial & Engineering Chemistry Research, 50(16), 9667–9684.
20. Aridhi, E., Abbes, M., & Mami, A. (2016). Solutions based on renewable energy and technology to improve the performance of refrigeration systems. Journal of Renewable and Sustainable Energy, 8(6).
21. Çetiner, C. (2023e). Thermal analysis of operating a solar-powered diffusion absorption refrigerator with a parabolic collector. Case Studies in Thermal Engineering, 53, 103893.
22. Ullah, K., Saidur, R., Ping, H., Akikur, R., & Shuvo, N. (2013c). A review of solar thermal refrigeration and cooling methods. Renewable and Sustainable Energy Reviews, 24, 499–513.
23. Lima, A. a. S., De N P Leite, G., Ochoa, A. a. V., Santos, C. a. C. D., Da Costa, J. a. P., Michima, P. S. A., & Caldas, A. M. A. (2020). Absorption refrigeration systems based on ammonia as refrigerant using different absorbents: review and applications. Energies, 14(1), 48.
24. Rezaei, M., Sameti, M., & Nasiri, F. (2021). Biomass-fuelled combined heat and power: integration in district heating and thermal-energy storage. Clean Energy, 5(1), 44–56.
25. Zhang, L., Li, F., Sun, B., & Zhang, C. (2019). Integrated Optimization Design of Combined Cooling, Heating, and Power System Coupled with Solar and Biomass Energy. Energies, 12(4), 687.
26. Alnaeli, M., Alnajideen, M., Navaratne, R., Shi, H., Czyzewski, P., Wang, P., Eckart, S., Alsaegh, A., Alnasif, A., Mashruk, S., Medina, A. V., & Bowen, P. J. (2023). High-Temperature materials for complex components in Ammonia/Hydrogen gas turbines: A critical review. Energies, 16(19), 6973.
27. Cnicesta. (2025, May 13). The impact of industrial refrigeration on supply chain and logistics efficiency.
28. Zhang, S., Liu, Y., Chen, Y., Zheng, T., Lan, Z., Wen, R., & Ma, X. (2024). Low-temperature ammonia absorption refrigeration system based on the temperature difference uniformity principle: Optimization analysis. Applied Thermal Engineering, 244, 122584.
29. Lima, A. a. S., De N P Leite, G., Ochoa, A. a. V., Santos, C. a. C. D., Da Costa, J. a. P., Michima, P. S. A., & Caldas, A. M. A. (2020b). Absorption refrigeration systems based on ammonia as refrigerant using different absorbents: review and applications. Energies, 14(1), 48.
30. Batiana A. L., Tiendrebeogo S. E., Tubreoumya G. C., Sawadogo E. S., Evelyne T. C. A.(2025). Experimental Study of Stratification and The Impact Of Insulation Thickness In Local Solar Water Heater Storage Tanks During The Rainy Season In Burkina Faso. International Journal of Engineering Sciences & Research Technology, 15(4), 9-21. https://doi.org/10.64149/j.ijesrt.15.4.9-21
31. Meng, X., He, Y., He, L., Zhao, C., Wang, L., You, W., & Zhu, J. (2024). A review of the Energy-Saving Potential of phase change Material-Based cascaded Refrigeration Systems in Chinese food cold chain industry. Energies, 17(19), 4762.
32. Iyer, P., & Robb, D. (2025). Cold chain optimisation models: A systematic literature review. Computers & Industrial Engineering, 204, 110972.
33. Lorenc, A. (2023). How to find disruptions in logistics processes in the cold chain and avoid waste of products? Applied Sciences, 14(1), 255.
34. Alnajideen, M., Shi, H., Northrop, W. et al. Ammonia combustion and emissions in practical applications: a review. Carb Neutrality 3, 13 (2024).

35. Compaore J. M., Zoma V., KaboreB., Kam S., (2026). Numerical Study of The Thermal Behavior of A Wall Made of Hollow Cement Blocks Containing Glass Powder. International Journal of Engineering Sciences & Research Technology, 15(5), 70-82. https://doi.org/10.64149/j.ijesrt.15.5.70-82
36. Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., . . . Moher, D. (2021b). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ, 372, n71.
37. Aria, M., & Cuccurullo, C. (2017). bibliometrix : An R-tool for comprehensive science mapping analysis. Journal of Informetrics, 11(4), 959–975.