International Journal of Scientific Research in Computer Science, Engineering and Information Technology

ISSN : 2456-3307 OPEN ACCESS

Available Online at : www.ijsrcseit.com

doi : https://doi.org/10.32628/IJSRCSEIT

Integrating Solar Heaters with Building Energy Systems : A Simulation Study

Dr. Vipul M Goti

Assistant Professor, Mechanical Engineering Department, Shree Swami Atmanand Saraswati Institute of Technology, Surat, Gujarat, India

ARTICLEINFO

Article History:

Accepted: 05 Oct 2023

Published: 28 Oct 2023

Publication Issue

Volume 9, Issue 5

September-October-2023

Page Number

312-327

ABSTRACT

This paper looks at the topic of high-tech solar water heating systems being incorporated into existing building energy infrastructure. Hybrid systems that use solar water heating in conjunction with other renewable energy sources are also discussed, as are technical developments in collector designs, the use of cutting-edge control and monitoring systems, and the like. Reduced carbon emissions and optimized resource utilization are only two of the environmental advantages highlighted in the report. It also emphasizes the need of precise system sizing and regional life cycle assessments (LCAs) in achieving maximum energy efficiency. The paper highlights knowledge gaps in the areas of performance analysis, localized environmental impact studies, integration difficulties, and economic assessments. By filling up these spaces, it hopes to promote more eco-friendly and economical construction methods. Sustainable construction, energy savings, less of an influence on the environment, and new innovations in solar water heating are some of the terms that come to mind.

Keywords: Solar Water Heating, Advanced Technology, Collector Design, Control Systems, Environmental Impact, and Sustainability.

I. INTRODUCTION

1.1 Background

The incorporation of solar heaters into building energy systems is a critical step toward developing a sustainable and energy-efficient infrastructure. A painstakingly created SolidWorks model of a solar water heater has been created to achieve this objective [1]. Extensive simulation research uses this complex model as a fundamental element [2]. Given the growing worries about climate change and energy sustainability, the background for this endeavor is the urgent need to minimize carbon emissions and dependence on fossil fuels for heating [3]. The SolidWorks model captures the complex structure and operation of a solar water heater, making it possible to analyze its performance in the context of a building's energy system in great detail. This simulation research intends to shed light on the potential advantages and difficulties of the seamless integration of solar heaters, highlighting energy savings, less environmental impact, and improved overall building efficiency [4]. This study aims to shed light on the revolutionary potential

of solar energy utilization for building heating applications by using state-of-the-art technology and engineering concepts.

1.2 Problem Statement

The issue at stake is that while having significant potential for sustainability and energy savings, solar water heaters are not widely used in building energy systems. This reluctance to use solar heating systems is brought on by doubts about their practical effectiveness and financial sustainability. The best integration techniques, system efficacy, and cost-effectiveness are crucial issues. Furthermore, it has been noticed that there isn't enough thorough simulation-based research to provide decisive findings. Promoting the broad use of solar heaters in building energy systems requires addressing these issues since doing so may considerably help to reduce carbon emissions and improve energy efficiency while assuring economic viability and practicality.

1.3 Aims and Objectives

Aim

The main aim of this analysis is to investigate the feasibility, performance, and economic viability of incorporating solar water heaters into building energy systems using thorough simulation-based evaluations.

Objectives

- To formally assess the improvements in energy efficiency brought about by the incorporation of solar water heaters into building energy systems
- To assess the initial investment, ongoing expenditures, and long-term benefits associated with the use of solar heaters
- To determine and suggest the best methods for integrating solar water heaters into the current building infrastructure
- To evaluate the environmental advantages and decrease in carbon emissions brought about by the use of solar heating technology

1.4 Research Question

Q1: What effect do solar water heaters have on the total energy efficiency and heating capacity of a building?

Q2: How does the long-term economic viability of integrating solar water heaters compare to that of conventional heating systems?

Q3: What are the best strategies for solar water heater design and integration with building energy systems to maximize their advantages?

Q4: What level of environmental impact reduction has been achieved by using solar heating technology, especially in terms of carbon emissions?

Q5: What suggestions may be made to make solar water heaters more widely used in building energy systems, and what regulations might encourage their usage more broadly?

1.5 Rationale

What is the issue?

The main problem is that solar water heaters have not been widely used and understood in building energy systems. Their broad usage is hampered by uncertainties about their efficacy, affordability, and best integration, which impedes the development of sustainable construction methods and minimized environmental impact.

Why is the issue?

The problem continues because there isn't enough in-depth analysis and useful advice on how to incorporate solar water heaters into building energy systems. Stakeholders are discouraged from adopting this sustainable solution due to a lack of information, doubts about performance, and worries about up-front expenditures. For the advancement of ecologically friendly and energy-efficient construction techniques, these obstacles must be removed.

Why is the issue now?

The relevance of the problem has been attributed to an increasing worldwide emphasis on environmental sustainability and the optimization of energy use. The growing apprehension over climate change and escalating energy expenses has heightened the need for

integrating renewable energy solutions inside building systems. Furthermore, the current advancements in technology and evolving energy legislation have rendered the incorporation of solar water heaters increasingly pertinent and urgent.

II. LITERATURE REVIEW

2.1 Introduction

The report has provided a thorough study of the body of knowledge regarding the incorporation of renewable energy in building environments. It examines the crucial facets of solar heater integration, such as system design, performance assessment, and energy efficiency optimization [5]. There have been various research has looked into the advantages and difficulties of integrating solar heating technologies into building energy systems [6]. The review's goal has been considered an important aspect to provide a solid foundation for the upcoming simulation study by synthesizing these results [7]. It also seeks to throw light on the existing state of knowledge and point out any research gaps that need to be filled.

2.2 Technological Advances in the Integration of Solar Water Heating

The report has analyzed the conceptual factors based on the advanced technology in solar water heating integration the purpose of this essential criterion is to explain the important technological breakthroughs that have been made about the incorporation of solar water heating systems into the energy infrastructures of buildings. This expanding landscape of solar water heating technologies has played a crucial role in improving the practicality and performance of these systems, which is aligned with the larger purpose of the dissertation [8]. Significant advancements have been achieved over the last several decades in the conception and development of solar water heating systems [9]. Recent advances on the other hand have ushered in a new era of collector designs that are more efficient and adaptable, such as concentrating solar collectors and evacuated tube collectors [10]. Because of these improvements, the capacity of solar water heaters to absorb solar radiation and convert it into thermal energy has improved, which has led to an increase in the overall efficiency of these systems.

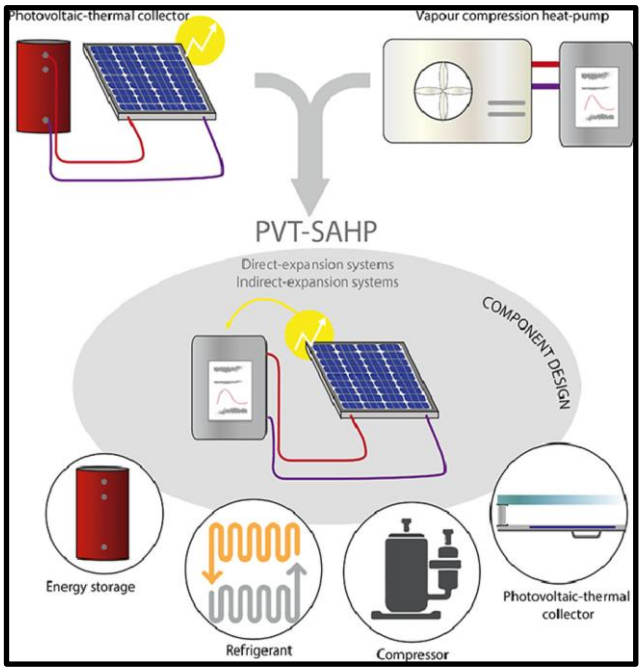

Fig. 1: Photovoltaic thermal solar-assisted heat pump systems

The above image represents the new technology adopted in the section of the water heater as a Photovoltaic thermal solar-assisted system in the heat pump. In addition, the incorporation of cutting-edge control and monitoring systems has proven to be an essential component in the process of optimizing the performance of solar water heaters within the context of building energy systems [11]. In order to intelligently regulate the distribution of hot water and guarantee that it is following the demand profile of the building, these systems make use of sensors, data analytics, and predictive algorithms [12]. This real-time control makes it possible to precisely regulate the temperature and reduces the amount of energy that is wasted, which is an important factor that is directly tied to the goal of increasing energy efficiency [13]. The creation of hybrid systems that combine solar water heating with other forms of renewable energy sources, such as photovoltaic panels or heat pumps, is yet another significant step forward in technical advancement [14]. These systems can keep a consistent

performance even when exposed to a wide range of weather conditions since the energy sources have been diversified.

2.3 Environmental Impact and Sustainability

The present study provides a comprehensive analysis of the existing literature about the environmental implications and sustainability considerations associated with the integration of solar water heaters into building energy systems. This review offers valuable insights into the subject matter. Multiple studies highlight the crucial significance of renewable energy technologies in the reduction of greenhouse gas emissions and the mitigation of the environmental consequences associated with building operations [15]. Solar water heaters have gained considerable attention as a feasible method to help achieve these objectives. Numerous studies have been made and various research materials have been gathered from journals like Google Scholar [16]. The research consistently shows a significant reduction in carbon emissions associated with the use of solar heaters as a substitute for conventional heating systems [17]. Thus, it is important to note that sustainability concerns have a broader scope than only focusing on the reduction of emissions [18]. Solar water heaters are often praised for their reduced resource usage in both the production and operational phases, in comparison to conventional systems. This benefit is in line with the overarching principles of sustainable construction practices, which prioritize the efficient use of resources and the reduction of environmental impact.

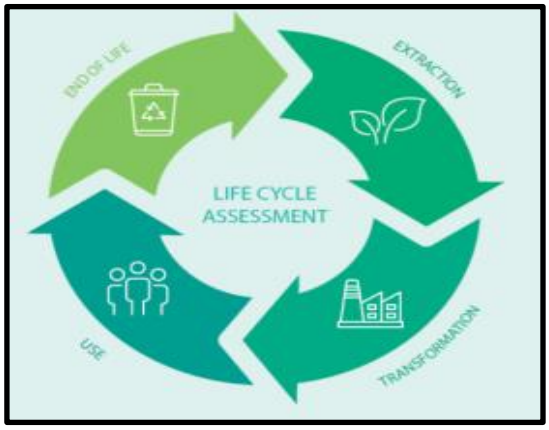

Fig.2: Life cycle Assessment

The picture that has been enumerated above describes the life cycle assessment that has been taken into account to deal with the analysis. Nevertheless, scholarly literature also emphasizes the significance of system design and optimization to fully exploit the environmental advantages [19]. The research emphasizes the need for accurate sizing and orienting systems to maximize energy collection and utilization efficiency [20]. Furthermore, the life cycle assessment (LCA) methodology has developed as a viable instrument for assessing the comprehensive environmental implications of solar water heater systems [21]. The aforementioned studies indicate that solar heaters often have positive environmental characteristics [22]. However, it is important to note that the sustainability advantages of solar heaters may be impacted by local circumstances and individual system attributes.

2.4 Literature Gap

The examination of the literature aspect in the previous sections provides valuable insights into solar water heater integration in building energy systems, specific gaps in the knowledge base require additional examination and research attention. The literature recognizes advances in collector technology such as concentrating solar collectors and evacuated tube collectors, however, there are few performance analyses and comparison studies [23]. Future studies should evaluate these unique collector designs' efficiency benefits, economic ramifications, and practical practicality in varied building contexts. It would help explain technical advances and their practical applications.

Solar water heaters minimize carbon emissions and use resources efficiently. However, geographic location, climate, and system designs may greatly affect sustainability outcomes. Localized life cycle assessments (LCAs) and environmental impact studies should address area energy sources, material availability, and disposal practices [24]. This would help evaluate the ecological impact and sustainability potential of solar water heating systems in perspective.

The literature recognizes the importance of accurate system sizing and orientation for energy efficiency, but it does not address the practicalities of integrating solar water heaters into existing building infrastructure. Retrofitting, compatibility, and optimization solutions should be studied in the future system design study [25]. Investigating building architecture and solar water heater integration may reveal best practices and design restrictions.

2.5 Summary

The report has analyzed an extensive investigation of solar water heater integration into building energy systems, with a special focus on technological improvements, environmental effects, and financial viability. By combining previously known information and highlighting significant gaps in the state of the art, the literature evaluation lays a strong basis for this research project. First of all, it has been highlighted the profound influence of technological advancements in solar water heating, notably the transition from conventional flat-plate collectors to more effective models like concentrating solar collectors and evacuated tube collectors. The evaluation also emphasizes the critical role that sophisticated control and monitoring systems play in maximizing energy utilization and stresses their significance in raising energy efficiency.

In addition, the integration of solar water heating is considered from an environmental standpoint, with a focus on lowering carbon emissions and maximizing resource effectiveness. The analysis has been considered the economic aspect of sustainability, where solar water heaters frequently exhibit favourable payback times and returns on investment. The literature analysis concludes by emphasizing the need for more study into sophisticated collector designs, localized environmental analyses, real-world integration issues, and nuanced economic evaluations. The dissertation's goal is to fill up these gaps and make a significant contribution to the conversation about green construction methods and the successful integration of solar water heating systems.

III. METHODOLOGY

3.1 Research Philosophy

The positivist research philosophy has been used for this study in terms of the research technique. The positivist method upholds the conviction that empirical proof and impartial observations are necessary for comprehending the study issue in greater depth. In this viewpoint, the researcher takes an impartial posture to identify patterns and correlations in the data that can be quantified and generalized [26]. The empirical character of the research, which entails running simulations and data analysis to look at the integration of solar heaters with building energy systems, is in line with the positivist ideology [27]. The researcher hopes to reduce subjective bias and assure the accuracy and dependability of the results by using this concept [28]. The positivist method also makes it easier to apply well-known theories and models to direct the simulation process, improving the study's validity and adding to the body of knowledge on sustainable building techniques and using renewable energy.

3.2 Research Design

The report has been categorized in the research design which is fundamentally grounded on quantitative analysis, creating intricate 3D models, and running simulations with SolidWorks software. With different architectural settings in mind, these models seek to statistically evaluate the thermal performance of solar water heating systems [29]. This method enables the thorough assessment of system efficiency, the influence of various parameters, and the overall practicality and economic viability of integrating solar water heaters into building energy systems by methodically monitoring and analyzing numerical data [30]. The quantitative aspect of the design guarantees that the study findings are anchored in empirical evidence, enabling rigorous statistical analysis and data-driven conclusions to successfully meet the research objectives.

Optimization of the design of solar heaters for efficient integration into building energy systems in the current study was carried out by looking at literature studies of solar collector devices such as [51-61] Patel Anand et al. for Solar Heater; [62, 63, 64] Anand Patel et al. for a hybrid combination of solar heater and heat exchanger; [65, 66, 67, 68] Patel Anand et al for heat exchanger and [69, 70] Anand Patel et al. for solar cooker in which geometrical components and materials variation in the collector devices to enhance the heat transfer efficacy by performing thermal analysis.

3.3 Research Approach

The research study that has been analyzed so far fully addresses its objectives and research problems via the use of a quantitative approach. This strategy requires the meticulous gathering and analysis of numerical data. It is simpler to analyze and quantify a range of elements and their interactions using this technology, which is particularly designed for the integration of solar heaters with building energy systems [31]. The researcher plans to apply statistical tools and approaches, perform simulations, gather empirical data, and do a complete analysis [32]. It has been known that the adaptation of this method allows the researcher to get precise and unbiased data on the applicability, value, and environmental impacts of solar heater integration [33]. Thus, it can be said that the study aims to further our understanding of green building practices and the use of renewable energy sources. By using a quantitative technique and creating findings that can be applied to a larger population of building energy systems, the research seeks to increase understanding in the field.

3.4 Research Strategy

The research strategy entails a diverse approach that combines a thorough literature study with quantitative analysis that is based on simulations. There have been contrasts to create a strong theoretical foundation, the first stage entails a thorough analysis of the body of literature. SolidWorks software is then used to create 3D models, run simulations, and produce quantitative data for evaluating the thermal performance of integrated solar water heating systems [34]. The effectiveness of the system, the consequences of the parameter settings, and the economic feasibility can all be empirically evaluated using this data-driven methodology [35]. The integration of solar water heaters into building energy systems is seen from a comprehensive viewpoint which is the combination of quantitative data from simulations and qualitative insights from the literature review.

Fig. 3: Quantitative Data

3.5 Data Collection

The study uses a reliable secondary data-gathering approach to support its conclusions. First, a thorough evaluation of the existing literature is undertaken using credible reports, conference proceedings, and peer-reviewed journal publications. This thorough review provides information on the effectiveness, viability, and environmental effects of solar water heaters [36]. Second, publically available databases and archives are used as the source for historical building energy use data. There have been learned about renewable energy regulations and incentives, and sources from the government and businesses are contacted [37]. These sources help in the evaluation of possible policy implications deriving from the study results by providing crucial background for the existing policy environment. The aims of the research are thoroughly and meticulously addressed using this wide range of data sources.

3.6 Data Analysis

The SolidWorks simulation's quantitative data has been characterized as systematically processed and evaluated throughout the data analysis step. The gathered data, which includes measurements of system efficiency, thermal performance, and economic indicators, is analyzed using statistical techniques and software tools. In order to get meaningful conclusions from the data, patterns, trends, and correlations are found and evaluated using statistical analysis [38]. This procedure not only makes it easier to assess the performance, economics, and practicality of integrating solar water heaters, but it also makes it possible to compare various scenarios and factors. Between gathering data and reaching conclusions based on evidence, the research methodology's data analysis step is a crucial link.

3.7 Tools and Technology

The categorization conducts a thorough examination of how solar water heaters integrate with building energy systems, cutting-edge methods and technologies must be used. SolidWorks software is an advanced technical tool that enables the construction of complex 3D models and simulations that closely resemble real-world circumstances [39]. With the help of this program, research has been statistically evaluated on system effectiveness, economic aspects, and thermal performance, giving their analyses a solid database [40]. Statistical software also helps with the quantitative examination of collected data, providing trends and insights that are essential for drawing accurate conclusions [41]. A thorough and data-driven study of the research objectives is made possible by these techniques and technologies when used together.

3.8 Software Feasibility

The aspect of this study, the phrase refers to the evaluation of SolidWorks software's appropriateness and capabilities for the stated study objectives. It entails determining if SolidWorks has the features required to create precise 3D models and run simulations that accurately reflect real-world situations [42]. It also takes into account whether the program can manage the quantitative parts of the investigation, including data creation and processing [43]. The categorization of the purpose of assessing the integration of solar water heaters into building energy systems is critical to ensure software viability to ensure that the technology is suitable for the study objectives and can produce accurate and trustworthy findings.

IV. RESULT AND DISCUSSION

4.1 Result

This report showcases the creative design of a helical pipe for a solar water heater, along with a detailed 3D model made in SolidWorks. SolidWorks, the industry standard in CAD modeling software, was used to accurately reproduce the helical pipe's complex form and function in a simulated three-dimensional environment. This CAD model is an essential part of evaluating solar water heaters as part of a building's energy system.

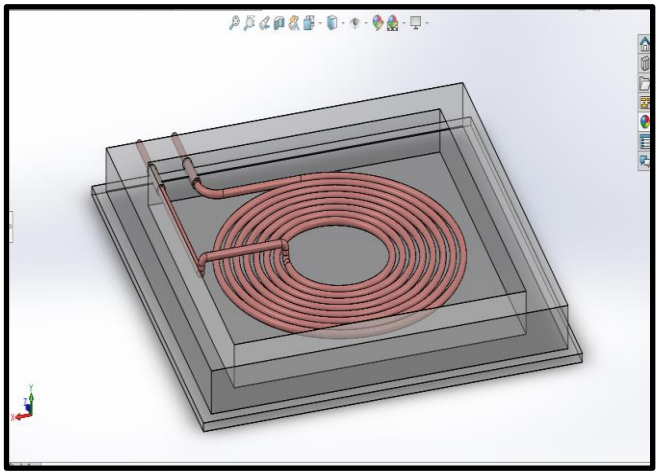

Fig. 4: Solar Water heater (Source: SolidWorks)

The helical pipe is modelled like its real-world analog, which allows for a thorough evaluation of its functionality and future incorporation into larger building energy systems. Since SolidWorks is so good at modelling complicated structures, you can rest certain that the CAD model accurately captures all of the helical pipe's finer details and workings.

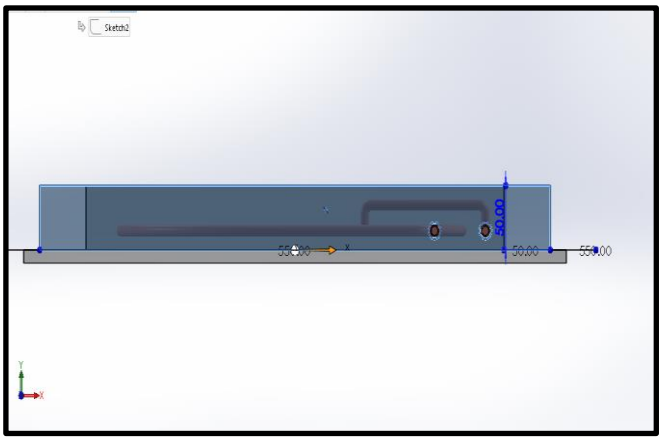

Fig. 5: Side view of the designed model with dimension
(Source: SolidWorks)

The attached snip shows the side view of the model where it can be noticed that the length of the model is 550 mm and the height of 50 mm. A glass panel of 10 mm is also attached which can enhance the solar radiation or absorption to increase the performance of the solar water heater. This CAD model not only improves comprehension of the helical pipe's operation, but also provides a way for comprehensive simulation studies to assess the pipe's influence on efficiency, economy, and sustainability. This further demonstrates the dedication to using innovative technologies in the search for eco-friendly and energy-saving improvements to the built environment.

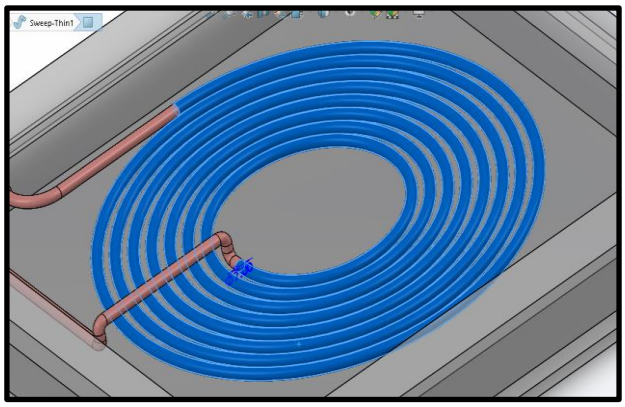

Figure 4.3: Spiral Pipe (Source: SolidWorks)

The attached figure shows the designed helical pipe for the solar water heater where the radius of the pipe is 7 mm. There is an inlet where the normal water will come and touch with the solar panel. Through this system, the water can gain heat and exit through the outlet.

4.2 Dicussion

Advanced technology in solar water heating systems in building energy systems is thoroughly examined in the paper. According to the study, technical advances improve the feasibility and efficacy of these systems, supporting sustainable and energy-efficient buildings. The paper highlights collector design progress, notably the switch from flat-plate collectors to more efficient concentrating solar collectors and evacuated tube collectors. These advances have greatly increased solar water heaters' ability to collect solar radiation and generate thermal energy. This has greatly improved these systems' efficiency. Modern management and monitoring systems are vital for optimizing solar water heater performance in building energy systems, according to the paper. These systems autonomously manage hot water distribution to match the building's demand profile using sensors, data analytics, and prediction algorithms. Real-time control guarantees exact temperature adjustment and eliminates energy waste, improving energy efficiency. Hybrid systems that combine solar water heating with photovoltaic panels or heat pumps are another report innovation. Due to diverse energy sources, these systems work well in every weather. The research also discusses solar water heater integration's environmental effect and sustainability. Solar water heaters reduce carbon emissions significantly, according to many studies. These technologies also use resources efficiently throughout manufacture and operation, supporting sustainable building.

V. FUTURE WORK

Future research into the integration of solar heaters with building energy systems has a lot of potential and offers prospects for future investigation. Numerous directions for future study and development might be explored by building on the research and conclusions that have already been made. First and foremost, there is a need for further developments in solar heater technology, with an emphasis on improving system

effectiveness, robustness, and adaptation to diverse building types and climates [44]. In order to maximize energy collection and utilization, research may focus on new materials, enhanced heat transfer processes, and creative system designs [45. Secondly, it is crucial to conduct long-term research that monitors the effectiveness and upkeep needs of solar water heaters in practical settings [46]. These studies would assist in improving maintenance procedures and provide insightful information about how long these systems would last [47]. Third, a new field ripe for research is the incorporation of solar heaters into smart building systems and grid-connected micro grids [48]. Future research might investigate how these technologies can function in concert to reduce energy use and improve grid interactions [49].

A thorough cost-benefit analysis would also provide a more nuanced picture of the economic sustainability of the adoption of solar heaters by taking into account a wider variety of economic considerations, such as government incentives, subsidies, and market dynamics [50].

VI. CONCLUSION

It can be concluded from the overall discussion that the enormous potential of renewable energy solutions in boosting sustainability and energy efficiency is shown by this thorough research on the integration of solar water heaters with building energy systems. The study has clarified the practicality, performance, and cost of adopting solar heaters by using cutting-edge technology and empirical data. It draws attention to how crucial system design, optimization, and policy backing are for effective implementation. The study highlights the need for ongoing research and practical application to solve the world's energy and environmental concerns by providing insightful information on lowering carbon emissions, decreasing resource consumption, and promoting sustainable construction practices. This research covered the integration of sophisticated technology in solar water heating systems inside building energy systems, highlighting important advances and environmental impacts. The results show that technical advances may improve these systems' efficiency and sustainability. Solar water heaters have improved due to collector design innovations. Concentrating solar collectors and evacuated tube collectors are more efficient than flat-plate collectors because they can capture sun energy. This works towards sustainable and energy-efficient building. Advanced control and monitoring systems optimize solar water heater performance. Sensors and predictive algorithms provide exact hot water delivery, decreasing energy waste and improving efficiency. Their role in real-time control reduces energy expenditures and environmental effects, according to the paper.

VII. REFERENCES

[1] K. Kaci et al, "Design, optimization and economic viability of an industrial low-temperature hot water production system in Algeria: A case study," International Journal of Renewable Energy Development, vol. 12, (3), pp. 448-458, 2023. Available: https://www.proquest.com/scholarly-journals/design-optimization-economic-viability-industrial/docview/2830121476/se-2. DOI: https://doi.org/10.14710/ijred.2023.49759.

[2] M. Samykano, "Hybrid Photovoltaic Thermal Systems: Present and Future Feasibilities for Industrial and Building Applications," Buildings, vol. 13, (8), pp. 1950, 2023. Available: https://www.proquest.com/scholarly-journals/hybrid-photovoltaic-thermal-systems-present/docview/2856971387/se-2. DOI: https://doi.org/10.3390/buildings13081950.

[3] L. Migla, R. Bogdanovics, and K. Lebedeva, "Performance Improvement of a Solar-Assisted Absorption Cooling System Integrated with Latent Heat Thermal Energy Storage," Energies, vol. 16, (14), pp. 5307, 2023. Available: https://www.proquest.com/scholarly-

journals/performance-improvement-solar-assisted-absorption/docview/2843056198/se-2. DOI: https://doi.org/10.3390/en16145307.

[4] C. Maraveas et al, "Agricultural Greenhouses: Resource Management Technologies and Perspectives for Zero Greenhouse Gas Emissions," Agriculture, vol. 13, (7), pp. 1464, 2023. Available: https://www.proquest.com/scholarly-journals/agricultural-greenhouses-resource-management/docview/2842902460/se-2. DOI: https://doi.org/10.3390/agriculture13071464.

[5] K. Rabea et al, "A Comprehensive Technoeconomic and Environmental Evaluation of a Hybrid Renewable Energy System for a Smart Farm in South Korea," Int. J. Energy Res., vol. 2023, 2023. Available: https://www.proquest.com/scholarly-journals/comprehensive-technoeconomic-environmental/docview/2840853025/se-2. DOI: https://doi.org/10.1155/2023/4951589.

[6] A. Villarruel-Jaramillo et al, "Modeling and Performance Evaluation of Hybrid Solar Cooling Systems Driven by Photovoltaic and Solar Thermal Collectors—Case Study: Greenhouses of Andalusia," Energies, vol. 16, (13), pp. 4888, 2023. Available: https://www.proquest.com/scholarly-journals/modeling-performance-evaluation-hybrid-solar/docview/2836392795/se-2. DOI: https://doi.org/10.3390/en16134888.

[7] O. K. Ahmed et al, "The Various Designs of Storage Solar Collectors: A Review," International Journal of Renewable Energy Development, vol. 12, (1), pp. 166-185, 2023. Available: https://www.proquest.com/scholarly-journals/various-designs-storage-solar-collectors-review/docview/2830126515/se-2. DOI: https://doi.org/10.14710/ijred.2023.45969.

[8] V. Bocullo et al, "A Digital Twin Approach to City Block Renovation Using RES Technologies," Sustainability, vol. 15, (12), pp. 9307, 2023. Available: https://www.proquest.com/scholarly-journals/digital-twin-approach-city-block-renovation-using/docview/2829882087/se-2. DOI: https://doi.org/10.3390/su15129307.

[9] F. L. Rashid et al, "Recent Advances, Development, and Impact of Using Phase Change Materials as Thermal Energy Storage in Different Solar Energy Systems: A Review," Designs, vol. 7, (3), pp. 66, 2023. Available: https://www.proquest.com/scholarly-journals/recent-advances-development-impact-using-phase/docview/2829795519/se-2. DOI: https://doi.org/10.3390/designs7030066.

[10] L. Pompei et al, "The Environmental and Energy Renovation of a District as a Step towards the Smart Community: A Case Study of Tehran," Buildings, vol. 13, (6), pp. 1402, 2023. Available: https://www.proquest.com/scholarly-journals/environmental-energy-renovation-district-as-step/docview/2829774593/se-2. DOI: https://doi.org/10.3390/buildings13061402.

[11] A. Elkhatat and S. Al-Muhtaseb, "Combined “Renewable Energy–Thermal Energy Storage (RE–TES)” Systems: A Review," Energies, vol. 16, (11), pp. 4471, 2023. Available: https://www.proquest.com/scholarly-journals/combined-renewable-energy-thermal-storage-re-tes/docview/2823995133/se-2. DOI: https://doi.org/10.3390/en16114471.

[12] K. Chopra et al, "Impact of Stearic Acid as Heat Storage Material on Energy Efficiency and Economic Feasibility of a Vacuum Tube Solar Water Heater," Energies, vol. 16, (11), pp. 4291, 2023. Available: https://www.proquest.com/scholarly-journals/impact-stearic-acid-as-heat-storage-material-on/docview/2823995106/se-2. DOI: https://doi.org/10.3390/en16114291.

[13] L. Cheng et al, "Thermal Performance Optimization Simulation Study of a Passive Solar House with a Light Steel Structure and Phase Change Walls," Energies, vol. 16, (9), pp. 3725, 2023. Available: https://www.proquest.com/scholarly-

journals/thermal-performance-optimization-simulation-study/docview/2812430299/se-2. DOI: https://doi.org/10.3390/en16093725.

[14] T. B. Michael and C. Atakara, "Residential Building Energy Conservation in Mediterranean Climate Zone by Integrating Passive Solar and Energy Efficiency Design Strategies," Buildings, vol. 13, (4), pp. 1073, 2023. Available: https://www.proquest.com/scholarly-journals/residential-building-energy-conservation/docview/2806504528/se-2. DOI: https://doi.org/10.3390/buildings13041073.

[15] O. Vonžudaitė et al, "Optimization of Heat Pump Systems in Buildings by Minimizing Costs and CO2 Emissions," Applied Sciences, vol. 13, (8), pp. 4864, 2023. Available: https://www.proquest.com/scholarly-journals/optimization-heat-pump-systems-buildings/docview/2806480840/se-2. DOI: https://doi.org/10.3390/app13084864.

[16] M. Jalali et al, "Reducing Energy Consumption in a Poultry Farm by Designing and Optimizing the Solar Heating/Photovoltaic System," Sustainability, vol. 15, (7), pp. 6059, 2023. Available: https://www.proquest.com/scholarly-journals/reducing-energy-consumption-poultry-farm/docview/2799809629/se-2. DOI: https://doi.org/10.3390/su15076059.

[17] K. Sornek et al, "A Review of Experimental and Numerical Analyses of Solar Thermal Walls," Energies, vol. 16, (7), pp. 3102, 2023. Available: https://www.proquest.com/scholarly-journals/review-experimental-numerical-analyses-solar/docview/2799616422/se-2. DOI: https://doi.org/10.3390/en16073102.

[18] Y. Han et al, "Study on the Performance of Photovoltaic/Thermal Collector–Heat Pump–Absorption Chiller Tri-Generation Supply System," Energies, vol. 16, (7), pp. 3034, 2023. Available: https://www.proquest.com/scholarly-journals/study-on-performance-photovoltaic-thermal/docview/2799608125/se-2. DOI: https://doi.org/10.3390/en16073034.

[19] J. F. Hinojosa, S. F. Moreno, and V. M. Maytorena, "Low-Temperature Applications of Phase Change Materials for Energy Storage: A Descriptive Review," Energies, vol. 16, (7), pp. 3078, 2023. Available: https://www.proquest.com/scholarly-journals/low-temperature-applications-phase-change/docview/2799597784/se-2. DOI: https://doi.org/10.3390/en16073078.

[20] J. Wu, M. Shen, and J. Feng, "The Application of a Solar–Air-Source Heat Pump Dual-Supply Heating System in a High-Cold Area in China," Processes, vol. 11, (3), pp. 737, 2023. Available: https://www.proquest.com/scholarly-journals/application-solar-air-source-heat-pump-dual/docview/2791698133/se-2. DOI: https://doi.org/10.3390/pr11030737.

[21] E. M. H. Ismaeil and E. S. Abu Elnasr, "Heuristic Approach for Net-Zero Energy Residential Buildings in Arid Region Using Dual Renewable Energy Sources," Buildings, vol. 13, (3), pp. 796, 2023. Available: https://www.proquest.com/scholarly-journals/heuristic-approach-net-zero-energy-residential/docview/2791600704/se-2. DOI: https://doi.org/10.3390/buildings13030796.

[22] R. Rotas et al, "Adaptive Dynamic Building Envelopes with Solar Power Components: Annual Performance Assessment for Two Pilot Sites," Energies, vol. 16, (5), pp. 2148, 2023. Available: https://www.proquest.com/scholarly-journals/adaptive-dynamic-building-envelopes-with-solar/docview/2785193893/se-2. DOI: https://doi.org/10.3390/en16052148.

[23] J. Kasperski, A. Bać and O. Oladipo, "A Simulation of a Sustainable Plus-Energy House in Poland Equipped with a Photovoltaic Powered Seasonal Thermal Storage System," Sustainability, vol. 15, (4), pp. 3810, 2023. Available: https://www.proquest.com/scholarly-journals/simulation-sustainable-plus-energy-

house-poland/docview/2779661940/se-2. DOI: https://doi.org/10.3390/su15043810.

[24] J. Hossain et al, "A Review on Optimal Energy Management in Commercial Buildings," Energies, vol. 16, (4), pp. 1609, 2023. Available: https://www.proquest.com/scholarly-journals/review-on-optimal-energy-management-commercial/docview/2779545624/se-2. DOI: https://doi.org/10.3390/en16041609.

[25] S. Ferrari et al, "Mapping Seasonal Variability of Buildings Electricity Demand profiles in Mediterranean Small Islands," Energies, vol. 16, (4), pp. 1568, 2023. Available: https://www.proquest.com/scholarly-journals/mapping-seasonal-variability-buildings/docview/2779529177/se-2. DOI: https://doi.org/10.3390/en16041568.

[26] N. Modi, X. Wang and M. Negnevitsky, "Solar Hot Water Systems Using Latent Heat Thermal Energy Storage: Perspectives and Challenges," Energies, vol. 16, (4), pp. 1969, 2023. Available: https://www.proquest.com/scholarly-journals/solar-hot-water-systems-using-latent-heat-thermal/docview/2779489082/se-2. DOI: https://doi.org/10.3390/en16041969.

[27] S. D. Mangan, "A Performance-Based Decision Support Workflow for Retrofitting Residential Buildings," Sustainability, vol. 15, (3), pp. 2567, 2023. Available: https://www.proquest.com/scholarly-journals/performance-based-decision-support-workflow/docview/2775019646/se-2. DOI: https://doi.org/10.3390/su15032567.

[28] H. T. Ebuy et al, "Occupant Behavior Impact on Building Sustainability Performance: A Literature Review," Sustainability, vol. 15, (3), pp. 2440, 2023. Available: https://www.proquest.com/scholarly-journals/occupant-behavior-impact-on-building/docview/2775019608/se-2. DOI: https://doi.org/10.3390/su15032440.

[29] L. G. Gesteira et al, "Thermoeconomic Optimization of a Polygeneration System Based on a Solar-Assisted Desiccant Cooling," Sustainability, vol. 15, (2), pp. 1516, 2023. Available: https://www.proquest.com/scholarly-journals/thermoeconomic-optimization-polygeneration-system/docview/2767293607/se-2. DOI: https://doi.org/10.3390/su15021516.

[30] W. Zakri, S. Mellouli and Y. Fageehi, "Performance Assessment of Three Latent Heat Storage Designs for a Solar Hot Water Tank," Sustainability, vol. 15, (1), pp. 640, 2023. Available: https://www.proquest.com/scholarly-journals/performance-assessment-three-latent-heat-storage/docview/2761219692/se-2. DOI: https://doi.org/10.3390/su15010640.

[31] S. Nijmeh et al, "Numerical Investigation of a Solar PV/T Air Collector Under the Climatic Conditions of Zarqa, Jordan," International Journal of Renewable Energy Development, vol. 11, (4), pp. 963-972, 2022. Available: https://www.proquest.com/scholarly-journals/numerical-investigation-solar-pv-t-air-collector/docview/2830126500/se-2. DOI: https://doi.org/10.14710/ijred.2022.45306.

[32] M. Khademy, A. Saraei and M. H. J. Abyaneh, "Application of trigeneration system power by concentrating photovoltaic-thermal solar collectors for energy demands of an industrial complex," International Journal of Energy and Environmental Engineering, vol. 13, (3), pp. 1101-1128, 2022. Available: https://www.proquest.com/scholarly-journals/application-trigeneration-system-power/docview/2704501030/se-2. DOI: https://doi.org/10.1007/s40095-022-00512-6.

[33] S. S. Baghbani, F. Farivar and Ahmadi-Danesh-Ashtiani Hossein, "Numerical simulation effect of PCM storage on flat storage on flat plate solar heater in different kinds of weather conditions," International Journal of Energy and Environmental Engineering, vol. 13, (1), pp. 135-

152, 2022. Available: https://www.proquest.com/scholarly-journals/numerical-simulation-effect-pcm-storage-on-flat/docview/2642109880/se-2. DOI: https://doi.org/10.1007/s40095-021-00436-7.

[34] S. Chen et al, "Study on Thermal Storage Wall Heating System of Traditional Houses in Cold Climate Zone of China: A Case Study in Southern Shaanxi," Atmosphere, vol. 13, (12), pp. 2049, 2022. Available: https://www.proquest.com/scholarly-journals/study-on-thermal-storage-wall-heating-system/docview/2756663588/se-2. DOI: https://doi.org/10.3390/atmos13122049.

[35] N. Ghazouani et al, "Solar Desalination by Humidification–Dehumidification: A Review," Water, vol. 14, (21), pp. 3424, 2022. Available: https://www.proquest.com/scholarly-journals/solar-desalination-humidification/docview/2734752768/se-2. DOI: https://doi.org/10.3390/w14213424.

[36] K. Sornek and K. Papis-Frączek, "Development and Tests of the Solar Air Heater with Thermal Energy Storage," Energies, vol. 15, (18), pp. 6583, 2022. Available: https://www.proquest.com/scholarly-journals/development-tests-solar-air-heater-with-thermal/docview/2716529065/se-2. DOI: https://doi.org/10.3390/en15186583.

[37] Olinto Evaristo da Silva Júnior et al, "Solar Heating with Flat-Plate Collectors in Residential Buildings: A Review," Energies, vol. 15, (17), pp. 6130, 2022. Available: https://www.proquest.com/scholarly-journals/solar-heating-with-flat-plate-collectors/docview/2711355420/se-2. DOI: https://doi.org/10.3390/en15176130.

[38] A. F. Wan et al, "Global Challenges of Current Building-Integrated Solar Water Heating Technologies and Its Prospects: A Comprehensive Review," Energies, vol. 15, (14), pp. 5125, 2022. Available: https://www.proquest.com/scholarly-journals/global-challenges-current-building-integrated/docview/2694003867/se-2. DOI: https://doi.org/10.3390/en15145125.

[39] R. S. Ghanem, L. Nousch and M. Richter, "Modeling of a Grid-Independent Set-Up of a PV/SOFC Micro-CHP System Combined with a Seasonal Energy Storage for Residential Applications," Energies, vol. 15, (4), pp. 1388, 2022. Available: https://www.proquest.com/scholarly-journals/modeling-grid-independent-set-up-pv-sofc-micro/docview/2632726340/se-2. DOI: https://doi.org/10.3390/en15041388.

[40] M. E. Kashan, A. S. Fung and J. Swift, "Integrating Novel Microchannel-Based Solar Collectors with a Water-to-Water Heat Pump for Cold-Climate Domestic Hot Water Supply, Including Related Solar Systems Comparisons," Energies, vol. 14, (13), pp. 4057, 2021. Available: https://www.proquest.com/scholarly-journals/integrating-novel-microchannel-based-solar/docview/2549333599/se-2. DOI: https://doi.org/10.3390/en14134057.

[41] L. G. Gesteira et al, "Thermoeconomic Optimization of a Polygeneration System Based on a Solar-Assisted Desiccant Cooling," Sustainability, vol. 15, (2), pp. 1516, 2023. Available: https://www.proquest.com/scholarly-journals/thermoeconomic-optimization-polygeneration-system/docview/2767293607/se-2. DOI: https://doi.org/10.3390/su15021516.

[42] W. Zakri, S. Mellouli and Y. Fageehi, "Performance Assessment of Three Latent Heat Storage Designs for a Solar Hot Water Tank," Sustainability, vol. 15, (1), pp. 640, 2023. Available: https://www.proquest.com/scholarly-journals/performance-assessment-three-latent-heat-storage/docview/2761219692/se-2. DOI: https://doi.org/10.3390/su15010640.

[43] L. Fiorini and M. Aiello, "Automatic optimal multi-energy management of smart homes," Energy Informatics, vol. 5, (1), pp. 68, 2022.

Available: https://www.proquest.com/scholarly-journals/automatic-optimal-multi-energy-management-smart/docview/2756516781/se-2. DOI: https://doi.org/10.1186/s42162-022-00253-0.

[44] S. Nijmeh et al, "Numerical Investigation of a Solar PV/T Air Collector Under the Climatic Conditions of Zarqa, Jordan," International Journal of Renewable Energy Development, vol. 11, (4), pp. 963-972, 2022. Available: https://www.proquest.com/scholarly-journals/numerical-investigation-solar-pv-t-air-collector/docview/2830126500/se-2. DOI: https://doi.org/10.14710/ijred.2022.45306.

[45] V-C Ifrim, L-D Milici and C. Bejenar, "Review on solar air heater hybrid systems thermal performances," IOP Conference Series.Materials Science and Engineering, vol. 1254, (1), pp. 012013, 2022. Available: https://www.proquest.com/scholarly-journals/review-on-solar-air-heater-hybrid-systems-thermal/docview/2722375580/se-2. DOI: https://doi.org/10.1088/1757-899X/1254/1/012013.

[46] S. Noman, H. Tirumalachetty and M. M. Athikesavan, "A comprehensive review on experimental, numerical and optimization analysis of EAHE and GSHP systems," Environmental Science and Pollution Research, vol. 29, (45), pp. 67559-67603, 2022. Available: https://www.proquest.com/scholarly-journals/comprehensive-review-on-experimental-numerical/docview/2717202676/se-2. DOI: https://doi.org/10.1007/s11356-022-22228-0.

[47] M. Khademy, A. Saraei and M. H. J. Abyaneh, "Application of trigeneration system power by concentrating photovoltaic-thermal solar collectors for energy demands of an industrial complex," International Journal of Energy and Environmental Engineering, vol. 13, (3), pp. 1101-1128, 2022. Available: https://www.proquest.com/scholarly-journals/application-trigeneration-system-power/docview/2704501030/se-2. DOI: https://doi.org/10.1007/s40095-022-00512-6.

[48] S. S. Baghbani, F. Farivar and Ahmadi-Danesh-Ashtiani Hossein, "Numerical simulation effect of PCM storage on flat storage on flat plate solar heater in different kinds of weather conditions," International Journal of Energy and Environmental Engineering, vol. 13, (1), pp. 135-152, 2022. Available: https://www.proquest.com/scholarly-journals/numerical-simulation-effect-pcm-storage-on-flat/docview/2642109880/se-2. DOI: https://doi.org/10.1007/s40095-021-00436-7.

[49] S. Chen et al, "Study on Thermal Storage Wall Heating System of Traditional Houses in Cold Climate Zone of China: A Case Study in Southern Shaanxi," Atmosphere, vol. 13, (12), pp. 2049, 2022. Available: https://www.proquest.com/scholarly-journals/study-on-thermal-storage-wall-heating-system/docview/2756663588/se-2. DOI: https://doi.org/10.3390/atmos13122049.

[50] A. I. Elshamy et al, "Challenges and Opportunities for Integrating RE Systems in Egyptian Building Stocks," Energies, vol. 15, (23), pp. 8988, 2022. Available: https://www.proquest.com/scholarly-journals/challenges-opportunities-integrating-re-systems/docview/2748533019/se-2. DOI: https://doi.org/10.3390/en15238988.

[51] Patel, A. (2023). Thermal Performance of Combine Solar Air Water Heater with Parabolic Absorber Plate. International Journal of All Research Education and Scientific Methods (IJARESM), 11(7), PP: 2385–2391. http://www.ijaresm.com/uploaded_files/document_file/Anand_Patel3pFZ.pdf

[52] Patel, Anand. “Effect of W Rib Absorber Plate on Thermal Performance Solar Air Heater.” International Journal of Research in Engineering and Science (IJRES), vol. 11, no. 7, July 2023, pp.

407–412. Available: https://www.ijres.org/papers/Volume-11/Issue-7/1107407412.pdf

[53] Patel, Anand. "Performance Evaluation of Square Emboss Absorber Solar Water Heaters." International Journal For Multidisciplinary Research (IJFMR), Volume 5, Issue 4, July-August 2023, PP 01-09. https://doi.org/10.36948/ijfmr.2023.v05i04.4917

[54] Anand Patel. (2023). Thermal Performance Analysis of Wire Mesh Solar Air Heater. Eduzone: International Peer Reviewed/Refereed Multidisciplinary Journal, 12(2), 91–96. Retrieved from https://www.eduzonejournal.com/index.php/eiprmj/article/view/389

[55] Patel, A (2023). "Thermal performance analysis conical solar water heater". World Journal of Advanced Engineering Technology and Sciences (WJAETS), 9(2), 276–283. https://doi.org/10.30574/wjaets.2023.9.2.02286

[56] Patel, A. (2023). INTEGRATING SOLAR HEATERS INTO RENEWABLE ENERGY SYSTEMS: A CASE STUDY. China Petroleum Processing and Petrochemical Technology, 23(2), 1050–1065. http://zgsyjgysyhgjs.cn/index.php/reric/article/view/2-1050.html

[57] Patel, A (2023). "Efficiency enhancement of solar water heaters through innovative design". International Journal of Science and Research Archive (IJSRA),10(01), 289–303. https://doi.org/10.30574/ijsra.2023.10.1.0724.

[58] Anand Kishorbhai Patel, 2023. Technological Innovations in Solar Heater Materials and Manufacturing. United International Journal for Research & Technology (UIJRT), 4(11), pp13-24.

[59] Patel, Anand. “OPTIMIZING SOLAR HEATER EFFICIENCY FOR SUSTAINABLE RENEWABLE ENERGY.” CORROSION AND PROTECTION, ISSN: 1005-748X, vol. 51, no. 2, 2023, pp. 244–258, www.fsyfh.cn/view/article/2023/02-244.php.

[60] Patel, Anand. “HEAT STORAGE STRATEGIES IN SOLAR HEATER SYSTEMS FOR NIGHTTIME USE.” NANOBIOTECHNOLOGY REPORTS (ISSN: 2635-1676) (E-ISSN: 2635-1684), vol. 18, no. 1, Oct. 2023, pp. 49–66. nanobiotechnologyreports.org/index.html.

[61] Patel, Anand. “A COMPARATIVE ANALYSIS OF SOLAR HEATER TECHNOLOGIES FOR RESIDENTIAL APPLICATIONS.” JOURNAL OF AERONAUTICAL MATERIALS (ISSN: 1005-5053), vol. 43, no. 02, Oct. 2023, pp. 633–47. www.hkclxb.cn/article/view/2023/2-633.html.

[62] Patel, A (2023). ""Comparative analysis of solar heaters and heat exchangers in residential water heating"". International Journal of Science and Research Archive (IJSRA),09(02), 830–843. https://doi.org/10.30574/ijsra.2023.9.2.0689."

[63] Patel, A. (2023). Enhancing Heat Transfer Efficiency in Solar Thermal Systems Using Advanced Heat Exchangers. Multidisciplinary International Journal of Research and Development (MIJRD), 02(06), 31–51. https://www.mijrd.com/papers/v2/i6/MIJRDV2I60003.pdf.

[64] Patel, Anand "Optimizing the Efficiency of Solar Heater and Heat Exchanger Integration in Hybrid System", TIJER - International Research Journal (www.tijer.org), ISSN:2349-9249, Vol.10, Issue 8, page no.b270-b281, August-2023, Available :http://www.tijer.org/papers/TIJER2308157.pdf.

[65] Patel, Anand. “Heat Exchanger Materials and Coatings: Innovations for Improved Heat Transfer and Durability.” International Journal of Engineering Research and Applications (IJERA), vol. 13, no. 9, Sept. 2023, pp. 131–42, doi:10.9790/9622-1309131142.

[66] Anand Patel, 2023, Heat Exchangers in Industrial Applications: Efficiency and Optimization Strategies, INTERNATIONAL JOURNAL OF ENGINEERING RESEARCH & TECHNOLOGY (IJERT) Volume 12, Issue 09 (September 2023), DOI : 10.17577/IJERTV12IS090003

(https://www.ijert.org/research/heat-exchangers-in-industrial-applications-efficiency-and-optimization-strategies-IJERTV12IS090003.pdf).

[67] Patel, Anand "Performance Analysis of Helical Tube Heat Exchanger", TIJER - International Research Journal (www.tijer.org), ISSN:2349-9249, Vol.10, Issue 7, page no.946-950, July-2023, Available :http://www.tijer.org/papers/TIJER2307213.pdf.

[68] Patel, Anand. “Advancements in Heat Exchanger Design for Waste Heat Recovery in Industrial Processes.” World Journal of Advanced Research and Reviews (WJARR), vol. 19, no. 03, Sept. 2023, pp. 137–52, doi:10.30574/wjarr.2023.19.3.1763.

[69] Anand Patel, "Comparative Thermal Performance Analysis of Circular and Triangular Embossed Trapezium Solar Cooker with and without Heat Storage Medium", International Journal of Science and Research (IJSR), Volume 12 Issue 7, July 2023, pp. 376-380, https://www.ijsr.net/getabstract.php?paperid=SR23612004356

[70] Patel, Anand.""Comparative Thermal Performance Analysis of Box Type and Hexagonal Solar Cooker"", International Journal of Science & Engineering Development Research (www.ijsdr.org), ISSN:2455-2631, Vol.8, Issue 7, page no.610 - 615, July-2023, Available :http://www.ijsdr.org/papers/IJSDR2307089.pdf".

Cite this article as :

Dr. Vipul M Goti, "Integrating Solar Heaters with Building Energy Systems : A Simulation Study", International Journal of Scientific Research in Computer Science, Engineering and Information Technology (IJSRCSEIT), ISSN : 2456-3307, Volume 9, Issue 5, pp.312-327, September-October-2023. Available at doi : https://doi.org/10.32628/CSEIT2390564
Journal URL : https://ijsrcseit.com/CSEIT2390564