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Economic Analysis of Solar Water Heaters for Residential Applications

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ABSTRACT

This research examines the design and economic analysis of a flat plate solar water heater, revealing its promise as a sustainable and cost-effective hot water-producing system. Solar water heaters minimize greenhouse gas emissions and fossil fuel reliance, making them important in global energy transitions. To maximize efficiency, the flat plate solar water heater's material selection emphasizes absorptivity, emissivity, and heat loss processes. Its strong architecture shows that the model can optimize performance while being economically reasonable. Solar water heating systems' financial sustainability depends on cost-effectiveness and payback periods, which are examined in the economic analysis. This study shows that solar water heaters may save energy and minimize water heating use. These systems are financially advantageous because of government incentives and subsidies, which shorten the payback time and reduce consumer costs. The paper emphasizes the importance of government subsidies, grants, and tax incentives in designing domestic solar water heaters. These projects encourage renewable energy, reduce greenhouse gas emissions, and protect the environment. This study shows the economic and environmental benefits of solar water heaters, but it also finds a deficit in holistic research on cost-effectiveness, payback periods, and government subsidies. Future research should fill this gap and help customers and governments comprehend solar water heaters' economic advantages. This paper concludes that flat plate solar water heaters are a realistic and sustainable option for addressing hot water needs, giving economic, environmental, and energy-efficient benefits.

Keywords: - Solar Water Heater, Renewable Energy, Economic Analysis, Government Incentives, Sustainability, Cost-effectiveness.

I. INTRODUCTION

A. Background Analysis

Residential solar water heater economics is the study subject. As the globe moves towards green energy, this topic is worldwide. Renewable energy exploration has increased due to rising energy prices and environmental worries about climate change [1]. Residential solar water heaters have promise in reducing fossil fuel consumption and greenhouse gas emissions. Homes looking to save money and lessen their carbon impact should consider solar water heaters [2]. These systems, which include flat-plate and evacuated-tube collectors, have a long history. A thorough economic investigation of their cost-effectiveness and long-term advantages is needed to distribute them [3]. This study examines the economic viability of household solar water heaters. Several variables are examined in this study. First, it looks at the upfront expenditures of solar water heaters, including collectors, storage tanks, and installation [4]. Tax credits, subsidies, and government incentives help offset these initial costs and encourage adoption. Solar water heaters may save households electricity, according to the research. These systems offer long-term savings by removing the need for electricity or natural gas for water heating [5]. Payback periods the time it takes energy cost reductions to recoup the original investment are also analyzed.

The report also emphasizes solar water heaters' ability to minimize greenhouse gas emissions and fossil fuel consumption. The economic feasibility of home solar water heaters is assessed by considering maintenance and operating expenses, resale value, and financing alternatives [6]. Therefore, studying household solar water heater economics is crucial to sustainable energy uptake. This study helps enhance decision-making and promote renewable energy solutions in households globally by revealing the financial costs of incorporating these systems.

B. Problem Statement

The issue is household solar water heater economics. Sustainable alternatives are needed to address rising energy prices, environmental concerns, and the depletion of existing energy sources. Residential solar water heaters utilize the sun's plentiful energy to create hot water. Despite their advantages, household solar water heaters encounter several obstacles [7]. Buying and installing these systems requires a large upfront cost and material selection which may prevent households from using this renewable technology. A comprehensive economic study of household solar water heaters addresses these essential gaps. This research aims to help and design solar water heaters, and by considering their costs, savings, and environmental advantages [8]. This study intends to make domestic water heating more sustainable and affordable.

C. Aim and Objective

Aim

This report's goal is to use SolidWorks software to design, model, and simulate a highly efficient solar water heater system for residential applications, taking advantage of the software's capabilities to ensure accurate modeling and simulation and thereby easing the adoption of a long-term, cost-effective solution to the problem of domestic water heating.

Objectives

- To utilize SolidWorks to create a solar water heater system in 3D, including collector components, storage tanks, and pipes
- To model solar water heater heat transfer and fluid dynamics to analyze thermal efficiency, energy distribution, and system performance under different climatic situations
- To use SolidWorks simulation results to iteratively optimize the solar water heater design for heat absorption, energy efficiency, and structural integrity
- To develop SolidWorks-designed solar water heater system engineering drawings and documentation, including specifications, material needs, and assembly instructions
- To perform a thorough cost study of the SolidWorks-designed solar water heater system's initial expenditures, maintenance costs, and energy cost reductions will determine its home practicality

D. Research Question

Question 1: How can SolidWorks help with accurate 3D modelling of a domestic solar water heater system?

Question 2: What are the solar water heater system's thermal performance characteristics under various climatic conditions?

Question 3: How can SolidWorks be used to optimize the design of the solar water heater system to maximize heat absorption and minimize energy losses?

Question 4: What technical documents and drawings may be produced using SolidWorks to help the solar water heater concept be implemented practically?

Question 5: What is the financial viability of the solar water heater system created in SolidWorks, taking into account the startup expenditures, ongoing expenses, and possible energy savings for residential applications?

E. Rationale

The report's topics are timely because of the urgent need for long-term, budget-friendly options in home water heating. Residential energy usage, especially for water heating, continues to be a major factor in the rising cost of energy and the deterioration of the environment [9]. Conventional energy sources, such as electricity or natural gas, are costly for households and harmful to the environment because of the greenhouse gas emissions they cause when used for water heating.

Constant worries about energy costs, environmental sustainability, and global warming highlight the critical nature of finding solutions to these problems. The ongoing use of fossil fuels contributes to the global climate issue and puts a burden on family finances. In order to address these problems, this research proposes using SolidWorks for domestic solar water heater system design, modeling, and simulation [10]. In doing so, it hopes to provide an alternative to traditional means of heating water that is both affordable and ecologically friendly. Methods for optimizing system components, evaluating thermal performance, and generating thorough technical documentation are detailed in the paper using exact 3D modeling and simulation. In the end, the report equips homeowners, policymakers, and stakeholders with the information they need to make educated decisions about installing solar water heaters in their homes, thereby decreasing energy bills, decreasing emissions of greenhouse gases, and increasing sustainability. The report's focus on these concerns is consistent with the need to reduce greenhouse gas emissions and increase home energy efficiency, and it helps speed up the worldwide shift towards renewable energy options.

II. LITERATURE REVIEW

A. Introduction

An examination of the available research on the economic aspect of household solar water heaters has been outlined in the literature criteria. The study's backdrop is briefly outlined, with an emphasis on the growing interest in renewable energy sources throughout the world and the particular value of solar water heaters in decreasing reliance on fossil fuels and tackling climate change [11]. This perspective also foreshadows the review of pertinent literature that has been done to comprehend the technical, economic, and environmental aspects of solar water heaters [12].

B. Use of Literature

Cost-Effectiveness and Payback Periods

The economic study of household solar water heaters must take cost-effectiveness and payback times into account critically [13]. These indicators are essential for determining if installing solar water heating systems, which often require a sizable upfront investment, is financially viable.

Cost-effectiveness

The categorized aspect of residential solar water heaters, cost-effectiveness refers to the capacity of these systems to supply hot water at a reduced overall cost during their lifetime compared to traditional water heating techniques, such as electric or gas water heaters [14]. The goal of cost-effective systems is to strike a balance between these initial expenses

and future savings. The cost-effectiveness of solar water heaters has been also classified with the impact of potential maintenance requirements.

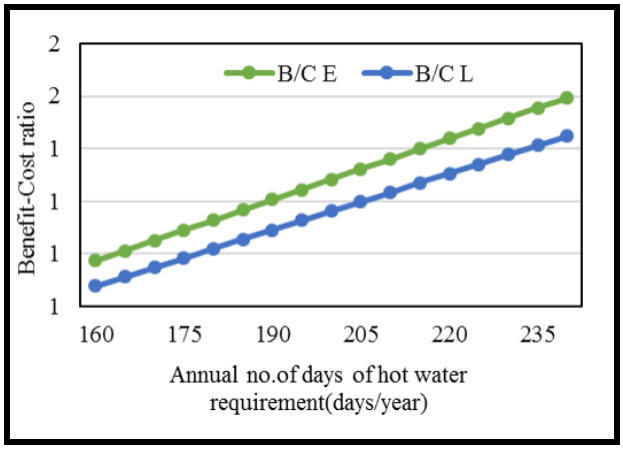

Figure 1: Cost Ratio of Requirement for Solar

In the aspect of measuring the impact of maintenance operations on overall economics, research evaluates the frequency and expenditures of these actions [15].

Payback Periods

A solar water heater's payback period is the length of time it is considered to take for the total amount of energy costs saved to match or surpass the initial expenditure [16]. For people and organizations thinking about using solar water heating systems, this statistic is an essential tool for decision-making. There have been analyzed one of the major factors in the calculation is the overall cost of buying and installing the solar water heater, including any available incentives or subsidies [17]. A shorter payback time denotes a more financially advantageous choice because the system pays for itself more quickly and continues to provide savings throughout its operating life.

Government Incentives and Subsidies

The environment for household solar water heaters has been assumed significantly shaped by government incentives and subsidies. These governmental tools are intended to lessen homeowners' financial burdens and promote the use of renewable energy sources [18].

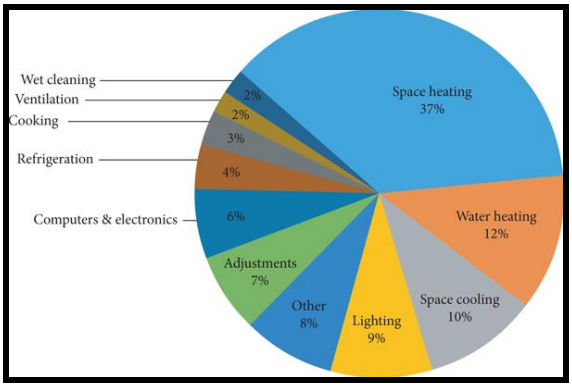

Figure 2: Modelling of Household-Scale Solar Water Heater

Government incentives and subsidies in the context of solar water heaters have a significant influence on the cost and all-around allure of these systems.

Supporting Financially

Governments support the adoption of solar water heaters financially as one of their main strategies for doing so. Direct subsidies, grants, or tax incentives can all be used to accomplish this [19]. There have been analyses in lowering the up-front expenses related to buying and installing a solar water heater, subsidies in particular provide homeowners with a clear financial benefit [20]. A wider spectrum of households may now afford solar water heaters thanks to these incentives, which essentially decrease the entrance barrier.

Tax credits include

Homeowners who purchase solar water heaters frequently qualify for tax incentives from the government. These tax credits let people exclude a percentage of the system's cost from their yearly tax obligation [21]. Along with easing the immediate financial load, this financial incentive offers continued advantages for the duration of the solar water heater. The aspect of reducing the payback time significantly increases the system's cost-effectiveness [22].

Effect on Economics

Government incentives and subsidies are frequently taken into account in studies on the economic analysis of solar water heaters. Several studies have examined the impact of these incentives on the systems' overall cost-effectiveness as well as their payback times [23].

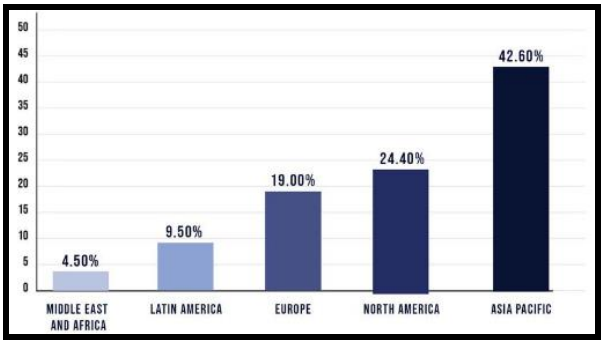

Figure 3: Solar Water Heaters Market Size

Research has provided a more realistic picture of the underlying economic advantages of using solar water heaters by taking these financial gains into account.

Promote sustainable practices

By promoting the use of clean and renewable energy sources, government incentives and subsidies support larger environmental goals [24]. These regulations help lower greenhouse gas emissions and encourage environmental preservation by minimizing the dependency on fossil fuels for water heating.

C. Literature Gap

The aspect gap in the research on home solar water heaters' cost-effectiveness, payback periods, and government subsidies is substantial [25]. It is rare to find complete studies that include all these factors to analyze solar water heater economics. Previous research has focused on cost analysis or incentive programs without a holistic view [26]. Synthesizing these aspects can help homeowners and policymakers make better solar water heater economic decisions by filling this gap.

D. Summary

The study of solar water heaters demonstrates their potential to cut down on the usage of fossil fuels and greenhouse gas emissions while delivering long-term energy savings [27]. The economic study looks at payback times, cost-effectiveness, and the influence of government incentives. The integration of these variables for a thorough assessment does, however, lack in the literature. By bridging this gap, solar water heater economics may be better understood on a more comprehensive level, assisting consumers and policymakers in making educated choices regarding adoption [28]. Compatibility to encourage the broad use of solar water heaters and improve sustainability in household water heating, a synthesis of cost analysis, incentives, and system performance is necessary.

III. METHODOLOGY

A. Research Philosophy

This study's research philosophy shapes its strategy and data-gathering techniques. Positivism and interpretivism are two main research ideologies in Saunders and colleagues' research onion model. The best research philosophy for this domestic solar water heater economic study is positivism. Positivism suits a thorough and impartial investigation of financial aspects, expenses, and quantitative facts connected to solar water heater adoption [29]. It relies on empirical facts, objectivity, and varied measurements to conclude. Positivism is ideal for economic analysis since it permits the collection of quantifiable data like cost figures, energy savings, and payback periods that can be statistically analyzed [30]. These methods guarantee that study conclusions are based on solid facts and may be applied broadly. Therefore, the positivist research philosophy is best for this study because it matches economic analysis's empirical and quantitative nature and provides a structured framework for collecting, analyzing, and interpreting data on residential solar water heater adoption.

B. Research Design

A descriptive research approach is suitable for this study since it analyses the economics of household solar water heaters [31]. To illustrate the economic, cost-effective, and environmental impacts of adopting these technologies. Creating a 3D solar water heater model using SolidWorks fits a descriptive research design [32]. It allows precise description and visualization of system components and functions by creating a thorough representation. The major data-gathering approach in this study is secondary data analysis, which involves analyzing literature, journals, research papers, and other academic sources [33]. A descriptive design is ideal since it summarizes, organizes, and presents information to offer a complete economic and environmental overview of solar water heaters. The descriptive study approach helps describe and analyze home solar water heater financial aspects. It offers extensive cost-benefit calculations, payback durations, and environmental impact assessments, meeting research goals [34]. Therefore, the descriptive research approach is best for this study since it allows SolidWorks modeling and reliable secondary data analysis of solar water heater economics. This guarantees that the study describes and understands the economic effects of household solar water heaters.

To enhance the economic viability of solar water heaters for residential applications it is pivotal to optimize the design of solar heaters to improve the heat transfer ability for renewable energy systems. Various literature studies from [51-70] Patel Anand et al. evaluate design optimization by varying the solar collector component and materials in solar heaters to increase the heat transfer efficacy.

C. Research Approach

According to Sounder’s research onion model, the research methodology is crucial to the methodological framework. Inductive and deductive research methods are common. This study on household solar water heater economics should use logical reasoning [35]. Deduction requires empirical observation and data collecting to evaluate a hypothesis or theory. The study quantifies expenses, energy savings, and payback times to determine if solar water heaters are economically viable. This goal is met by the deductive method, which enables research planning. For solar water heater economic analysis, the deductive method is organized and systematic. The study might start with economic ideas and then apply them to home water heating. Deductive research uses empirical facts to support or invalidate economic assumptions, maintaining impartiality [36]. Thus, the study's conclusions are based on solid data and research. This study's goal is to objectively examine the economic feasibility of household solar water heaters, hence deductive research is best. This method tests economic theories and concludes using evidence.

D. Research Strategy

The Saunders research onion model states that choosing the right research approach is crucial to the research process. The main research methods are quantitative and qualitative. A quantitative research technique is best for "Economic Analysis of Solar Water Heaters for Residential Applications" since it incorporates SolidWorks modeling and economic evaluation [37]. The powerful CAD program SolidWorks is ideal for quantitative analysis. It accurately models and simulates the

solar water heater system, measuring heat transfer rates, energy efficiency, and system performance under different situations. The study focuses on quantitative solar water heater economics. Quantify expenses, energy savings, payback times, and other financial parameters [38]. A quantitative research technique is ideal for economic data collection and analysis.

The impartiality and numerical correctness of quantitative research are stressed. It measures, analyses, and presents SolidWorks modeling and secondary data quantitatively. It offers a solid platform for evidence-based decisions. Quantitative research is best for this project [39]. It perfectly meets the research aims of exact SolidWorks modeling and quantitative investigation of home solar water heater economic aspects. It generates quantitative data that may be statistically analyzed to conclude.

E. Data Collection

Data collecting techniques are crucial to this study's research approach for achieving research goals. Primary data collecting is secondary data analysis since the study uses SolidWorks software to build and simulate solar water heaters and depends on scholarly secondary data. Research focuses on creating a precise SolidWorks 3D model of solar water heaters [40]. This modeling produces rich technical data on system components, thermal performance, and structure. Analyses start with primary data. Scholarly literature, journals, research papers, and other reliable sources are used to study household solar water heater economics, environmental effects, and efficiency. Analyzing secondary data without initial data collecting yields significant insights. Overall, secondary data analysis is best for this study [41]. As it uses SolidWorks modeling data and scholarly literature, it meets research goals. This guarantees that the study is based on reliable and complete data, allowing for a thorough investigation of household solar water heater economic and environmental impacts.

F. Data analysis

Data from SolidWorks modeling and secondary data sources are used to analyze household solar water heater economics. Solar water heater 3D modeling data from SolidWorks includes complicated technical requirements and simulations [42]. The system's thermal performance, energy efficiency, and structural integrity are assessed using engineering software and tools. The study comprises heat transfer calculations, energy distribution analyses, and simulation results to evaluate the system's performance under different situations. Detailed literature reviews and content analyses are performed on secondary data from academic sources, journals, and research papers. To determine solar water heaters' economic feasibility and environmental effect, identify major themes, trends, and discoveries in the literature [43]. This combination strategy yields well-rounded, empirically validated study results that enhance topic comprehension.

G. Tools and Techniques

SolidWorks modeling dominates this study. Strong CAD software like SolidWorks allows the construction of precise and accurate 3D models of complicated systems like solar water heaters. Researchers design, visualize, and simulate the solar water heater system using SolidWorks to model its components and structure [44]. The study also uses secondary data analysis. This entails reviewing and analyzing literature, research papers, and journals on solar water heater economics and environmental impact. This method guarantees that the study has many reliable and complete sources to support its results. SolidWorks modeling and secondary data analysis provide a thorough study of the topic.

IV. RESULT AND DISCUSSION

A. Result

In this study, a flat plate solar collector was carefully developed to maximize efficiency without sacrificing affordability. Choosing the right materials for the collection parts is essential for reaching this objective.

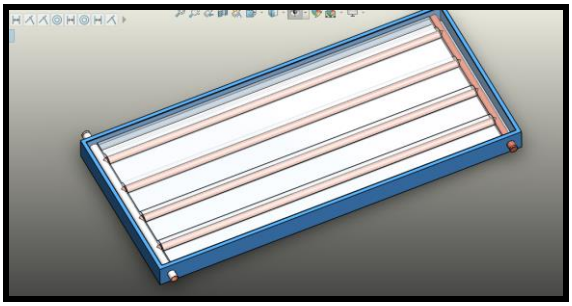

Figure 4: Flat plate solar collector

The attached figure shows the designed model in SolidWorks considering various economical parameters for residential application. After considering a wide range of materials and their costs, the following were found to be the most financially viable options for the flat plate solar collector.

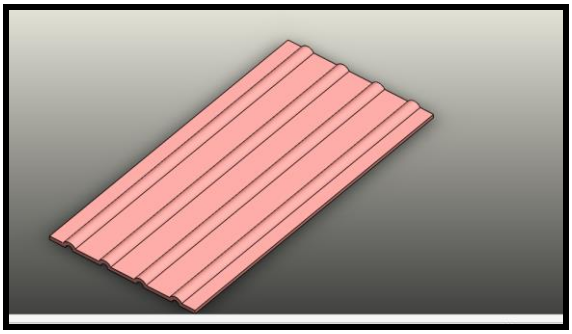

Figure 5: Absorber of the solar water heater

The attached figure shows the absorber part of the model where the absorber plates are often made of copper because of the metal's high heat conductivity. It increases the system's

efficiency by soaking up solar energy and transferring that heat to the collector's working fluid.

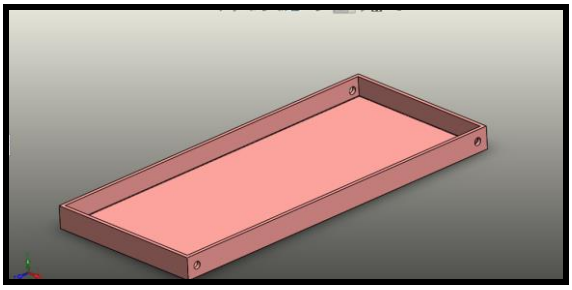

Figure 6: Cover as a box of the model

The attached figure shows the designed cover as a box for the solar collector. The cover is made of tempered glass since it is strong, transparent, and resistant to the effects of the elements. It lets in as much sunlight as possible while keeping the collector's sensitive inner workings safe.

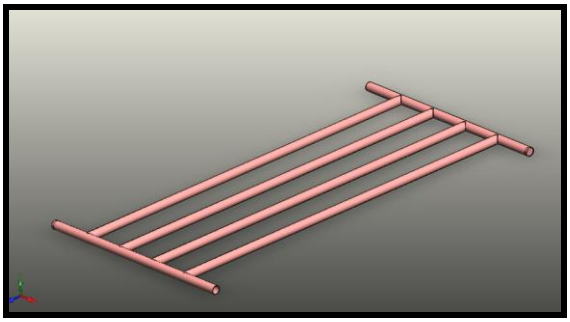

Figure 7: Piping system

The attached figure shows the piping system for the designed model where a glass-reinforced piping system has been used to improve the performance of the model.

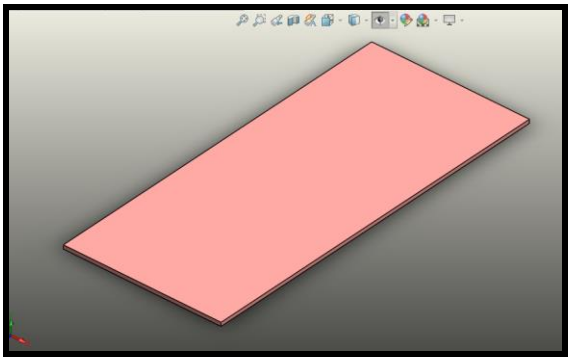

Figure 8: Absorber

The attached figure shows the absorber for the designed model. Here, choose an effective insulating material to cut down on heat loss from the collector. In order to keep heating and cooling costs to a minimum, insulating materials like polyurethane foam and rock wool have been used.

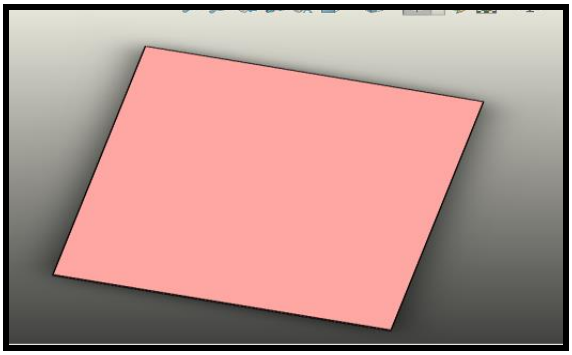

Figure 9: Upper-Frame

Aluminium has been selected for the frame because it is strong, lightweight, and corrosion-resistant. The frame of the collector is made of aluminium since it is lightweight, durable, and inexpensive.

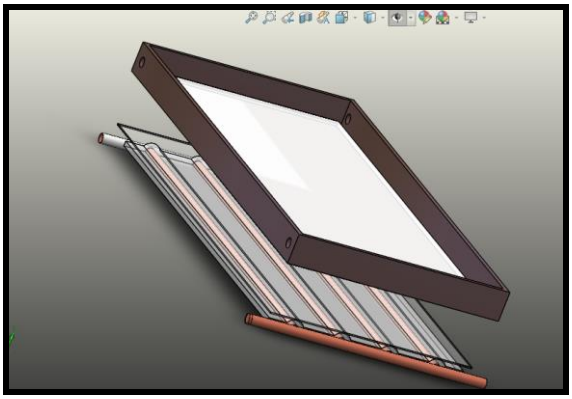

Figure 10: Exploded View

The attached figure shows an exploded view of the designed model. The study intends to find a happy medium between performance and cost by incorporating these materials into the design of the flat plate solar collector. The goals of the report are met by the optimized collector design, which guarantees high heat absorption, low heat loss, and low operating costs. The collector's efficiency and the financial sustainability of solar water heating systems for homes are both improved by the thoughtful selection of materials.

B. Discussion

Flat plate solar water heaters are promising for meeting residential hot water needs using renewable energy. This discussion covers model characteristics, advantages, and implementation concerns.

Selection of materials is key to developing an effective solar water heater. The flat plate collector's absorber plate is usually copper or aluminum to maximize heat absorption. Tempered glass traps heat while letting light through. These materials help the system capture solar energy and heat water effectively.

Cost-effectiveness is a major factor in solar water heater adoption [45]. Such systems save energy expenses over time

but need a large initial investment. Homes may repay their original investment via lower energy expenses over 12 years, according to the UK model. This makes solar water heaters cost-effective, particularly in sunny areas. Solar water heaters considerably cut water heating carbon emissions. These devices employ renewable solar energy to reduce greenhouse gas emissions from fossil fuels [46]. Emission reductions support global climate change and sustainability initiatives.

Cost Component	Amount (GBP)
Initial Purchase and Installation	£3,500
Maintenance Costs (Estimated per year)	£75
Expected Lifespan (years)	20
Total Expected Savings (Estimated per year)	£200
Payback Period (years)	12

Table 1: Payback Value

Despite their benefits, solar water heaters have drawbacks. Sunlight availability, which varies seasonally and geographically, affects system effectiveness. In gloomy or overcast weather, heater efficiency may decrease. The system's durability and effectiveness depend on adequate maintenance. Regular inspections and component repairs or replacements are essential [47].

The proposed flat plate solar water heater type may satisfy home hot water demands in an eco-friendly and cost-effective manner. By using solar energy and choosing materials, these systems may save energy expenditures and greenhouse gas emissions. Government incentives boost their attractiveness [48]. Although sunshine unpredictability and maintenance are drawbacks, solar water heaters are a promising ecological and effective water heating solution. Solar water heating technologies may become more efficient and affordable with additional study.

V. FUTURE WORK

Solar water heating system innovation and development are promising. As technology advances and environmental concerns develop, researchers and engineers may use numerous methods to improve system efficiency, cost, and sustainability [49]. Novel solar water heater component materials may be researched in the future. Finding affordable, high-performance absorber plates, insulation, and glazing may boost system efficiency. For better heat collection and retention, collectors and storage tanks may be optimized. Advanced thermal storage or batteries may improve heat utilization in solar water heaters [50]. Excess energy may be stored and utilized during low sunshine, improving system dependability. Implementing smart control and monitoring systems may give real-time system performance data. Solar water heaters may be optimized for maximum efficiency using this data. User comfort is enhanced by advanced control algorithms that allow remote monitoring and administration. Solar water heating may be used with photovoltaic panels or heat pumps in future research. Integrated systems may provide more complete home energy solutions. Researchers may analyze the full life cycle, from manufacturing to disposal, to enhance systems and reduce their environmental impact. Assessing market adoption obstacles and governmental incentives may expedite solar water heater uptake. Local restrictions and financial incentives may help researchers determine economic viability in various places. Overall, solar water heating system research should concentrate on materials innovation, energy storage integration, smart control systems, hybrid methods, environmental evaluations, and market analyses. Collaboration between academics, industry partners, and policymakers may improve this sustainable technology, reducing domestic energy usage and greenhouse gas emissions.

VI. CONCLUSION

In conclusion, this paper examined the design and economic analysis of a flat plate solar water heater, demonstrating its promise as a sustainable and cost-effective hot water solution. Flat plate solar water heaters improve solar water heating efficiency and cost. Careful selection of materials like the absorber plate and glass improves system performance. Absorptivity, emissivity, and heat loss processes improve the model's efficiency. The economic analysis in this paper shows solar water heaters' prospective cost-effectiveness. These systems may save energy and decrease water heating use over time due to payback periods, government incentives, and subsidies. Solar water heaters are financially beneficial for families and businesses due to tax benefits and subsidies that minimize payback time. Water heaters that utilize solar energy reduce greenhouse gas emissions and fossil fuel consumption. The use of these technologies supports climate change mitigation and greener energy. Comprehensive solar water heater economics studies that include cost-effectiveness, payback periods, and government subsidies are lacking. Future research should synthesize these features to help customers and policymakers comprehend the economic benefits of solar water heaters. The flat plate solar water heater's UK-based pricing table shows the installation expense. While this initial investment may seem high, these systems provide considerable long-term energy bill savings and environmental advantages. In conclusion, flat plate solar water heaters have great promise as a sustainable and cost-effective hot water solution. Solar thermal solutions like these may help the globe move to a greener, more sustainable future as it faces climate change and energy sustainability issues. Advances in materials, technology, and economic models,

along with government support and consumer education, can accelerate solar water heating system adoption and make society more environmentally and economically sustainable.

REFERENCES

[1] D. Hu et al, "Modeling and Simulation of Indirect Collector Solar Hot Water Heating System Based on TRNSYS," Journal of Physics: Conference Series, vol. 2503, (1), pp. 012066, 2023. Available: https://www.proquest.com/scholarly-journals/modeling-simulation-indirect-collector-solar-hot/docview/2815462537/se-2. DOI: https://doi.org/10.1088/1742-6596/2503/1/012066.

[2] M. J. Daryosh et al, "Energy-Environmental One-Year Dynamic Simulation and Ranking Analysis of Using Flat Plate Solar Water Heater to Supply the Heating Demand of an Apartment in the USA: A Comprehensive Review," International Journal of Photoenergy, vol. 2023, 2023. Available: https://www.proquest.com/scholarly-journals/energy-environmental-one-year-dynamic-simulation/docview/2853665828/se-2. DOI: https://doi.org/10.1155/2023/3323276.

[3] S. Wang et al, "The Influence of Storage Tank Volume on the Nighttime Heat Dissipation and Freezing Process of All-Glass Vacuum Tube Solar Water Heaters," Energies, vol. 16, (12), pp. 4781, 2023. Available: https://www.proquest.com/scholarly-journals/influence-storage-tank-volume-on-nighttime-heat/docview/2829796337/se-2. DOI: https://doi.org/10.3390/en16124781.

[4] 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.

[5] S. K. Pathak et al, "Hot Water Generation for Domestic Use in Residential Buildings via PCM Integrated U-Tube Based Solar Thermal Collector: A 4-E Analysis," Buildings, vol. 13, (5), pp. 1212, 2023. Available: https://www.proquest.com/scholarly-journals/hot-water-generation-domestic-use-residential/docview/2819417994/se-2. DOI: https://doi.org/10.3390/buildings13051212.

[6] A. B. Sidi Mohammed El et al, "Experimental Performance and Cost-Effectiveness of a Combined Heating System under Saharan Climate," Buildings, vol. 13, (3), pp. 635, 2023. Available: https://www.proquest.com/scholarly-journals/experimental-performance-cost-effectiveness/docview/2791600742/se-2. DOI: https://doi.org/10.3390/buildings13030635.

[7] A. Feyzioglu, "A Study on the Control System of Electric Water Heaters for Decarbonization," Energies, vol. 16, (5), pp. 2439, 2023. Available: https://www.proquest.com/scholarly-journals/study-on-control-system-electric-water-heaters/docview/2785193923/se-2. DOI: https://doi.org/10.3390/en16052439.

[8] K. Obaideen et al, "Solar Energy: Applications, Trends Analysis, Bibliometric Analysis and Research Contribution to Sustainable Development Goals (SDGs)," Sustainability, vol. 15, (2), pp. 1418, 2023. Available: https://www.proquest.com/scholarly-journals/solar-energy-applications-trends-analysis/docview/2767299855/se-2. DOI: https://doi.org/10.3390/su15021418.

[9] 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.

[10] P. K. Kushwaha et al, "Recent Advancements in Augmentation of Solar Water Heaters Using Nanocomposites with PCM: Past, Present, and Future," Buildings, vol. 13, (1), pp. 79, 2023. Available: https://www.proquest.com/scholarly-journals/recent-advancements-augmentation-solar-water/docview/2767189628/se-2. DOI: https://doi.org/10.3390/buildings13010079.

[11] E. Bellos, P. Lykas and C. Tzivanidis, "Performance Analysis of a Zero-Energy Building Using Photovoltaics and Hydrogen Storage," Applied System Innovation, vol. 6, (2), pp. 43, 2023. Available: https://www.proquest.com/scholarly-journals/performance-analysis-zero-energy-building-using/docview/2806463591/se-2. DOI: https://doi.org/10.3390/asi6020043.

[12] L. Djordjevicć et al, "Increasing Energy Efficiency of Buildings in Serbia—A Case of an Urban Neighborhood," Sustainability, vol. 15, (7), pp. 6300, 2023. Available: https://www.proquest.com/scholarly-journals/increasing-energy-efficiency-buildings-serbia/docview/2799793389/se-2. DOI: https://doi.org/10.3390/su15076300.

[13] 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.

[14] A. R. Omais et al, "Numerical and Experimental Analysis of a Low-GWP Heat Pump Coupled to Electrical and Thermal Energy Storage to Increase the Share of Renewables across Europe," Sustainability, vol. 15, (6), pp. 4973, 2023. Available: https://www.proquest.com/scholarly-journals/numerical-experimental-analysis-low-gwp-heat-

pump/docview/2791709695/se-2. DOI: https://doi.org/10.3390/su15064973.

[15] 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.

[16] A. B. Sidi Mohammed El et al, "Experimental Performance and Cost-Effectiveness of a Combined Heating System under Saharan Climate," Buildings, vol. 13, (3), pp. 635, 2023. Available: https://www.proquest.com/scholarly-journals/experimental-performance-cost-effectiveness/docview/2791600742/se-2. DOI: https://doi.org/10.3390/buildings13030635.

[17] A. Feyzioglu, "A Study on the Control System of Electric Water Heaters for Decarbonization," Energies, vol. 16, (5), pp. 2439, 2023. Available: https://www.proquest.com/scholarly-journals/study-on-control-system-electric-water-heaters/docview/2785193923/se-2. DOI: https://doi.org/10.3390/en16052439.

[18] A. K. Kaviti et al, "Camphor-Soothed Banana Stem Biowaste in the Productivity and Sustainability of Solar-Powered Desalination," Applied Sciences, vol. 13, (3), pp. 1652, 2023. Available: https://www.proquest.com/scholarly-journals/camphor-soothed-banana-stem-biowaste-productivity/docview/2779901075/se-2. DOI: https://doi.org/10.3390/app13031652.

[19] S. Tangwe, P. Mukumba, and G. Makaka, "An Installed Hybrid Direct Expansion Solar Assisted Heat Pump Water Heater to Monitor and Modeled the Energy Factor of a University Students' Accommodation," Energies, vol. 16, (3), pp. 1159, 2023. Available: https://www.proquest.com/scholarly-journals/installed-hybrid-direct-expansion-solar-assisted/docview/2774893088/se-2. DOI: https://doi.org/10.3390/en16031159.

[20] K. Obaideen et al, "Solar Energy: Applications, Trends Analysis, Bibliometric Analysis and Research Contribution to Sustainable Development Goals (SDGs)," Sustainability, vol. 15, (2), pp. 1418, 2023. Available: https://www.proquest.com/scholarly-journals/solar-energy-applications-trends-analysis/docview/2767299855/se-2. DOI: https://doi.org/10.3390/su15021418.

[21] 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.

[22] P. K. Kushwaha et al, "Recent Advancements in Augmentation of Solar Water Heaters Using Nanocomposites with PCM: Past, Present, and Future," Buildings, vol. 13, (1), pp. 79, 2023. Available: https://www.proquest.com/scholarly-journals/recent-advancements-augmentation-solar-water/docview/2767189628/se-2. DOI: https://doi.org/10.3390/buildings13010079.

[23] D. Barik et al, "Experimental and Computational Analysis of Aluminum-Coated Dimple and Plain Tubes in Solar Water Heater System," Energies, vol. 16, (1), pp. 295, 2023. Available: https://www.proquest.com/scholarly-journals/experimental-computational-analysis-aluminum/docview/2761184592/se-2. DOI: https://doi.org/10.3390/en16010295.

[24] S. Sevindik and C. Spataru, "An Integrated Methodology for Scenarios Analysis of Low Carbon Technologies Uptake towards a Circular Economy: The Case of Orkney," Energies, vol. 16, (1), pp. 419, 2023. Available: https://www.proquest.com/scholarly-journals/integrated-methodology-scenarios-analysis-low/docview/2761183132/se-2. DOI: https://doi.org/10.3390/en16010419.

[25] R. H. Crawford et al, "Trends in residential sustainability measures in the state of Victoria," IOP Conference Series.Earth and Environmental Science, vol. 1101, (2), pp. 022018, 2022. Available: https://www.proquest.com/scholarly-journals/trends-residential-sustainability-measures-state/docview/2747924100/se-2. DOI: https://doi.org/10.1088/1755-1315/1101/2/022018.

[26] S. Kavanaugh, "Validating the Use of Low-Cost, Direct Solar PV Water Heating," Eng. Syst., vol. 39, (10), pp. 27, 2022. Available: https://www.proquest.com/trade-journals/validating-use-low-cost-direct-solar-pv-water/docview/2724716225/se-2.

[27] S. Baskaran et al, "Modeling and optimization of photovoltaic serpentine type thermal solar collector with thermal energy storage system for hot water and electricity generation for single residential building," Environmental Science and Pollution Research, vol. 29, (39), pp. 59575-59591, 2022. Available: https://www.proquest.com/scholarly-journals/modeling-optimization-photovoltaic-serpentine/docview/2705543694/se-2. DOI: https://doi.org/10.1007/s11356-022-19957-7.

[28] Z. Cheng, "Application Prospect of Solar Water Heating System with Seasonal Thermal Storage in Rural Area of Northern China," IOP Conference Series.Earth and Environmental Science, vol. 1008, (1), pp. 012009, 2022. Available: https://www.proquest.com/scholarly-journals/application-prospect-solar-water-heating-

system/docview/2652620630/se-2. DOI: https://doi.org/10.1088/1755-1315/1008/1/012009.

[29] A. Uniyal et al, "Recent Advancements in Evacuated Tube Solar Water Heaters: A Critical Review of the Integration of Phase Change Materials and Nanofluids with ETCs," Energies, vol. 15, (23), pp. 8999, 2022. Available: https://www.proquest.com/scholarly-journals/recent-advancements-evacuated-tube-solar-water/docview/2748536141/se-2. DOI: https://doi.org/10.3390/en15238999.

[30] 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.

[31] D. Barik et al, "Experimental and Computational Analysis of Aluminum-Coated Dimple and Plain Tubes in Solar Water Heater System," Energies, vol. 16, (1), pp. 295, 2023. Available: https://www.proquest.com/scholarly-journals/experimental-computational-analysis-aluminum/docview/2761184592/se-2. DOI: https://doi.org/10.3390/en16010295.

[32] R. H. Crawford et al, "Trends in residential sustainability measures in the state of Victoria," IOP Conference Series.Earth and Environmental Science, vol. 1101, (2), pp. 022018, 2022. Available: https://www.proquest.com/scholarly-journals/trends-residential-sustainability-measures-state/docview/2747924100/se-2. DOI: https://doi.org/10.1088/1755-1315/1101/2/022018.

[33] S. Kavanaugh, "Validating the Use of Low-Cost, Direct Solar PV Water Heating," Eng. Syst., vol. 39, (10), pp. 27, 2022. Available: https://www.proquest.com/trade-journals/validating-use-low-cost-direct-solar-pv-water/docview/2724716225/se-2.

[34] Z. Cheng, "Application Prospect of Solar Water Heating System with Seasonal Thermal Storage in Rural Area of Northern China," IOP Conference Series.Earth and Environmental Science, vol. 1008, (1), pp. 012009, 2022. Available: https://www.proquest.com/scholarly-journals/application-prospect-solar-water-heating-system/docview/2652620630/se-2. DOI: https://doi.org/10.1088/1755-1315/1008/1/012009.

[35] A. Uniyal et al, "Recent Advancements in Evacuated Tube Solar Water Heaters: A Critical Review of the Integration of Phase Change Materials and Nanofluids with ETCs," Energies, vol. 15, (23), pp. 8999, 2022. Available: https://www.proquest.com/scholarly-journals/recent-advancements-evacuated-tube-solar-water/docview/2748536141/se-2. DOI: https://doi.org/10.3390/en15238999.

[36] P. Sinethemba et al, "Quantification of the Impact of Solar Water Heating and Influence of Its Potential Utilization through Strategic Campaign: Case Study in Dimbaza, South Africa," Energies, vol. 15, (21), pp. 8283, 2022. Available: https://www.proquest.com/scholarly-journals/quantification-impact-solar-water-heating/docview/2734627285/se-2. DOI: https://doi.org/10.3390/en15218283.

[37] P. Sinethemba et al, "Assessing the Feasibility and the Potential of Implementing Solar Water Heaters in Dimbaza, a Township in Eastern Cape, South Africa," Sustainability, vol. 14, (19), pp. 12502, 2022. Available: https://www.proquest.com/scholarly-journals/assessing-feasibility-potential-implementing/docview/2724319889/se-2. DOI: https://doi.org/10.3390/su141912502.

[38] 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.

[39] S. S. Nastaran et al, "Effects of Different Target Solar Fractions on Providing Heat Required for Space Heating, Sanitary Hot Water, and Swimming Pool in Iran: A Case Study in Cold Climate," Journal of Engineering, vol. 2022, 2022. Available: https://www.proquest.com/scholarly-journals/effects-different-target-solar-fractions-on/docview/2640854510/se-2. DOI: https://doi.org/10.1155/2022/2720057.

[40] Y. Liu, M. Zhang and Z. Shen, "Comprehensive Benefits Evaluation of Solar Water Heating System Application in Energy Efficiency Retrofit of Existing Residential Buildings in Cold Climate Zone," IOP Conference Series.Earth and Environmental Science, vol. 647, (1), 2021. Available: https://www.proquest.com/scholarly-journals/comprehensive-benefits-evaluation-solar-water/docview/2513107976/se-2. DOI: https://doi.org/10.1088/1755-1315/647/1/012132.

[41] E. Bellos, P. Lykas and C. Tzivanidis, "Performance Analysis of a Zero-Energy Building Using Photovoltaics and Hydrogen Storage," Applied System Innovation, vol. 6, (2), pp. 43, 2023. Available: https://www.proquest.com/scholarly-journals/performance-analysis-zero-energy-building-using/docview/2806463591/se-2. DOI: https://doi.org/10.3390/asi6020043.

[42] L. Djordjevicć et al, "Increasing Energy Efficiency of Buildings in Serbia—A Case of an Urban Neighborhood," Sustainability, vol. 15, (7), pp. 6300, 2023. Available: https://www.proquest.com/scholarly-journals/increasing-energy-efficiency-buildings-serbia/docview/2799793389/se-2. DOI: https://doi.org/10.3390/su15076300.

[43] A. R. Omais et al, "Numerical and Experimental Analysis of a Low-GWP Heat Pump Coupled to

Electrical and Thermal Energy Storage to Increase the Share of Renewables across Europe," Sustainability, vol. 15, (6), pp. 4973, 2023. Available: https://www.proquest.com/scholarly-journals/numerical-experimental-analysis-low-gwp-heat-pump/docview/2791709695/se-2. DOI: https://doi.org/10.3390/su15064973.

[44] 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.

[45] S. Sevindik and C. Spataru, "An Integrated Methodology for Scenarios Analysis of Low Carbon Technologies Uptake towards a Circular Economy: The Case of Orkney," Energies, vol. 16, (1), pp. 419, 2023. Available: https://www.proquest.com/scholarly-journals/integrated-methodology-scenarios-analysis-low/docview/2761183132/se-2. DOI: https://doi.org/10.3390/en16010419.

[46] 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.

[47] D. Huang et al, "Study on the Energy Efficiency Improvement and Operation Optimization of a Solar Water Heating System," Applied Sciences, vol. 12, (14), pp. 7263, 2022. Available: https://www.proquest.com/scholarly-journals/study-on-energy-efficiency-improvement-operation/docview/2693930772/se-2. DOI: https://doi.org/10.3390/app12147263.

[48] R. K. Ali et al, "A Comparative Thermal Performance Assessment of Various Solar Collectors for Domestic Water Heating," International Journal of Photoenergy, vol. 2022, 2022. Available: https://www.proquest.com/scholarly-journals/comparative-thermal-performance-assessment/docview/2680914007/se-2. DOI: https://doi.org/10.1155/2022/9536772.

[49] R. Alayi et al, "Thermal and Environmental Analysis Solar Water Heater System for Residential Buildings," International Journal of Photoenergy, vol. 2021, 2021. Available: https://www.proquest.com/scholarly-journals/thermal-environmental-analysis-solar-water-heater/docview/2563360572/se-2. DOI: https://doi.org/10.1155/2021/6838138.

[50] 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.

[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, Anand. "Sizing and Optimization of Solar Water Heater Systems for Different Demands." Tuijin Jishu/Journal of Propulsion Technology (ISSN: 1001-4055), vol. 44, no. 4, Oct. 2023, pp. 279–91. https://doi.org/10.52783/tjjpt.v44.i4.836.

[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, Anand. "Experimental Investigation of Oval Tube Solar Water Heater With Fin Cover Absorber Plate." International Journal of Enhanced Research in Science, Technology & Engineering, vol. 12, issue no. 7, July 2023, pp. 19–26, doi:10.55948/IJERSTE.2023.0704.

[63] Patel, Anand. "Comparative Thermal Performance Evaluation of V-shaped Rib and WShape Rib Solar Air Heater." International Journal of Research Publication and Reviews, vol. 14, issue no. 7, July 2023, pp. 1033–1039.

[64] Patel, Anand. "Experimental Evaluation of Twisted Tube Solar Water Heater." International Journal of Engineering Research & Technology (IJERT), vol. 12, issue no. 7, IJERTV12IS070041, July 2023, pp. 30–34, https://www.ijert.org/research/experimental-evaluation-of-twisted-tube-solar-water-heater-IJERTV12IS070041.pdf.

[65] Patel, Anand."Comparative Thermal Performance Investigation of the Straight Tube and Square Tube Solar Water Heater." World Journal of Advanced Research and Reviews, vol. 19, issue no. 01, July 2023, pp. 727–735. https://doi.org/10.30574/wjarr.2023.19.1.1388.

[66] Patel, Anand et al."Thermal Performance Analysis of Fin Covered Solar Air Heater", "International Journal of Engineering Science and Futuristic Technology" (2017).

[67] Patel, Anand, et al. "Thermal Performance Analysis of Helical Solar Water Heater." International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume 5, no. 3, 2015, pp. 67-69, www.ijitee.org/wp-content/uploads/papers/v5i3/C2177085315.pdf.

[68] Anand Patel. "Effect of Inclination on the Performance of Solar Water Heater." International Journal for Scientific Research and Development 11.3 (2023): 413-416.

[69] Patel, Anand. "The Performance Investigation of Square Tube Solar Water Heater", International Journal of Science & Engineering Development Research (www.ijsdr.org), ISSN:2455-2631, Vol.8, Issue 6, page no.872 - 878, June-2023, Available:http://www.ijsdr.org/papers/IJSDR2306123.pdf

[70] Anand Patel. ""Comparative Thermal Performance Investigation of Box Typed Solar Air heater with V Trough Solar Air Heater"". International Journal of Engineering Science Invention (IJESI), Vol. 12(6), 2023, PP 45-51. Journal DOI- 10.35629/6734".