China Petroleum Processing and Petrochemical Technology

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

INTEGRATING SOLAR HEATERS INTO RENEWABLE ENERGY SYSTEMS: A CASE STUDY

Anand Kishorbhai Patel

Mechanical Engineer, Mechanical and Energy Engineering Department, University of North Texas, USA

Abstract- This case study investigates the integration of solar heaters into renewable energy systems as a means to enhance energy sustainability and mitigate climate change. It highlights the pressing issue of underutilization, emphasizing the timeliness of this research amid global efforts to transition to cleaner energy sources. The study assesses the current state of integration, identifies barriers, and explores the environmental and economic benefits. Furthermore, it delves into innovative strategies and policy recommendations to optimize solar heater integration. The findings provide valuable insights for policymakers, energy planners, and stakeholders to accelerate the shift towards a more sustainable and efficient energy landscape, ultimately reducing greenhouse gas emissions and promoting renewable energy adoption.

Keywords- Solar heaters, Renewable energy systems, solar thermal energy, Integration, Sustainability, Climate change mitigation, Energy efficiency, Environmental benefits, Policy recommendations, Greenhouse gas emissions.

I. INTRODUCTION

A. Introduction

The most cutting-edge development in sustainable energy is the use of solar heaters in renewable energy systems. Utilizing solar thermal energy has emerged as a critical approach to address crucial global issues like climate change, depleting fossil fuel reserves, and the urgent need to reduce carbon emissions. Solar heaters are a crucial component of the renewable energy jigsaw since they are made to collect and transform solar heat for use in practical processes like producing hot water and space heating.

B. Background

Globally, there is an urgent need to switch to renewable energy sources in order to prevent climate change, lessen negative environmental effects, and ensure long-term energy sustainability. Solar energy stands out among these renewable resources as one of the most prevalent and easily available. Their effectiveness and usefulness have been revolutionized by recent technological breakthroughs, nevertheless [1]. This integration is essential for increasing energy independence, lowering greenhouse gas emissions, and optimizing energy output.

C. Rationale

What is the issue?

The problem at hand is that solar heaters are not used to their full potential in renewable energy systems. Solar heaters have the potential to be fully integrated into existing renewable energy infrastructures.

Why is it an issue?

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

This is a concern because it prevents solar energy from being used to its full potential, which would otherwise significantly equipment's of the system

Why is it an issue now?

This topic is especially urgent right now because of the worsening global climate catastrophe and the growing demand for sustainable energy alternatives. The integration of solar heaters becomes a contemporary and pertinent topic for research as the need to switch to renewable energy sources grows more pressing [2].

D. Problem Statement

The key issue under consideration is the insufficient integration of solar heaters into renewable energy systems, which presents a multidimensional difficulty [6]. This is especially important in the context of the global transition to sustainability, where decreasing greenhouse gas emissions and optimizing renewable energy use is critical.

E. Research Aim & Objectives

Aims

The purpose of this case study is to evaluate the current level of solar heater integration into renewable energy systems, highlighting difficulties, opportunities, and potential benefits

Objectives

- To identify and analyze the main obstacles and limitations preventing the broad use of solar heaters in renewable energy infrastructure.
- To assess the degree of solar heater integration in current renewable energy systems, including installation types and size.
- To investigate and assess the potential environmental and economic benefits of effectively integrating sun heaters into renewable energy systems.
- To investigate best practices and novel ideas for optimizing the integration of solar heaters in order to improve overall system efficiency and sustainability.
- To provide policymakers, energy planners, and stakeholders with concrete ideas and guidelines to facilitate the smooth integration of solar heaters and speed the shift to cleaner and more sustainable energy sources.

F. Research Questions

What are the main technological, economic, and regulatory impediments to the widespread use of solar heaters in renewable energy infrastructure?

What quantitative environmental benefits can be attributed to the effective integration of solar heaters into renewable energy systems, such as reduced carbon emissions and energy savings?

What novel technologies and tactics are being used to improve the efficiency and performance of solar heaters when they are incorporated into larger renewable energy systems?

How can policy frameworks and incentives be improved to encourage the seamless integration of solar heaters, facilitating the transition to a more sustainable and environmentally friendly energy landscape?

G. Research Significances

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

This study can help policymakers and energy planners develop effective strategies for reducing greenhouse gas emissions and promoting sustainable energy practices [3]. Furthermore, it assists in the global transition to renewable energy sources, assisting in meeting climate targets and assuring a cleaner, more energy-efficient future [4]. Finally, the findings have the potential to spur innovation and investment in solar heating technologies, hastening their deployment in renewable energy infrastructures around the world [26].

H. Summary

The underutilization of solar heaters in the context of the current worldwide shift to greener energy sources is examined in this case study, which also addresses the problem. By examining the current status, issues, advantages, and optimization options, this project seeks to offer substantial insights into a future of renewable energy that is more sustainable and effective.

II. LITERATURE REVIEW

A. Introduction

The topic “Integrating Solar Heaters into Renewable Energy Systems: A Case Study” is crucial because it has laid a basis for comprehension of the body of information and research that already exists on the subject. This investigation's objective is to assess pertinent literature on the incorporation of solar heaters into renewable energy systems. Particularly in terms of sustainable energy options and the mitigation of climate change, solar heaters have gained significance.

B. Solar Heater Technology Integration

Integrating solar heater technology into renewable energy systems has been used for utilizing the sun’s plentiful energy to satisfy heating demands [5]. This procedure has included creating new energy systems that maximize the effectiveness of solar heaters or integrating them into current energy systems [27].

Fig 1: Solar Thermal Collectors

Solar collectors take in solar energy and transform it into heat [6]. This heat energy has been transferred to a heat transfer fluid, usually a solution of water, and utilized to heat the intended application [7]. Thermal storage options, including solar thermal tanks, make it possible to store extra heat for use later on when there is less sunshine.

Studies from [56, 57, 58] Patel Anand et al. for Hybrid combination for heat exchanger and solar heater; [59, 60, 61, 62] Anand Patel et al. [63] Thakre, Shekhar et al. for heat exchanger; [64, 65, 66, 67, 68, 69, 70, 71, 72] Anand Patel et al. for solar water & air heater includes various conditions by varying components dimensions and raw material for renewable energy system.

C. Energy Efficiency and Sustainability

In order to effectively handle global energy and environmental concerns, it is essential to understand sustainability and energy efficiency [8]. “Energy efficiency” is the process of maximizing energy utilization to supply energy while reducing energy waste. Buildings, transportation, and manufacturing are some industries that have benefited from energy-efficient methods [9].

Fig 2: Energy Efficiency and Sustainability

In the context of energy efficiency and sustainability, sustainability has been referred to as the use of energy resources and technologies that have minimal effects on the environment and these are also long-term economically feasible [10]. Energy efficiency with sustainability has been balanced and enables the development of a more sustainable and clean energy system for future generations [28].

D. Cost-Benefit Analysis and Economic Viability

Investments in sustainable energy have depended on doing "cost-benefit analyses (CBAs)" as well as evaluating the financial sustainability of incorporating solar heaters into renewable energy systems. It has aimed to explain the essential elements of CBA as well as emphasize the elements that affect the integration's economic viability [11].

Initial Investment Costs

Within a renewable energy system, the initial cost of purchasing and installing solar heaters is a critical factor [25]. This has involved the acquisition of heat exchangers, solar panels, and related hardware.

Operational and Maintenance Costs

It has become crucial to evaluate how much it costs to maintain and run solar heaters [12]. This has included costs for regular upkeep, repairs, and any required modifications.

Fig 3: Cost-Benefit Analyses of Solar Energy

The above figure depicts the cost-benefit analysis of solar energy with respect to various components.

Energy Production and Savings

It has also been crucial to estimate how much energy solar heaters produce and the cost savings that occur from using less conventional electricity [13].

The "Return on Investment (ROI)" has also been very high in the context of this because the investment has been done only once time and the return has been fetching out throughout along with the maintenance also being very low [24].

E. Conceptual framework

Fig 4: Conceptual Framework

F. Literature gap

Although there have been significant advances in the literature on incorporating solar heaters into renewable energy systems, certain important gaps still exist [14]. Research has the potential to dive more deeply into the economic elements, concentrating notably on cutting-edge financing structures and their effect on adoption rates [15].

G. Summary

The incorporation of solar heaters into renewable energy systems has become an issue for increased sustainability and minimizing environmental impacts. It is clear through a rigorous cost-

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

benefit analysis and economic viability evaluation that the long-term advantages, both economic and environmental, surpass these difficulties.

III. RESEARCH METHODOLOGY

A. Introduction

The important role played by the district heating infrastructure is that it helps to increase energy efficiency and this is why people use scarce resources to supply demands for future needs. The methods are a process of utilizing the energy and use it for the people and uses in district heating systems.

B. Research philosophy

The purpose of this research is to save the energy of the Earth from non-renewable resources that pose a threat to the Earth and also increase the Earth's temperature because of global warming [16]. The importance of building solar heaters in the form of renewable resources can help a whole city to use this energy and fewer greenhouse gasses are to be emitted from the houses or factories [23].

C. Research approach

The grid lines are connected to the central grid system in the center of the city to connect all the grid systems and perform stabilization for the grid system to be intact [17]. The centralized part of the city helps to distribute the whole energy throughout the city and helps the workers and people by providing them with renewable energy that does not dissipate and is also easy to use again and again [22].

D. Research design

The research aims to make the grid system and support the other places to try out the grid systems to check the amount of energy it is producing which is able to support the daily household commodities and appliances for checking the information and also helps to collect the data [18]. The constant use of energy gives a balance between the energy the people need during winter and summer.

E. Data collection method

The capacity of the grid production and heat therefore helps to allow more buildings to be used in every structure or building. The insulation of every building gives the comfort of people is also possible using lower temperatures. This helps to reduce the losses of the energy grid systems and increases the heat that is recycled within every industry, making it efficient for production work [21].

F. Data Analysis

The data analysis is done with a group of experts and finds the amount of energy the grid systems are able to reuse over and over again and the energy also lost [19]. The energy is measured concerning the temperature because the higher temperature tends to use and lose most of the energy whereas the cold temperature helps the grid to reuse the same renewable energy over and over again that is not the same with the higher temperature.

G. Ethical considerations

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

The study has been implemented using a secondary data collection method and, in that case, there has been a selected public platform. All the procedures have been implemented by maintaining all the government rules and regulations [29]. The resulting outcomes are not harmful to the society and deliver a positive impact all over the society.

H. Research limitations

This study's concentration on a single case study poses a constraint in terms of how broadly the results have been applied to other geographical locations [30]. The research's timeline, based on data up to September 2021, does not account for current advancements in solar heating technology or regulation changes. The thorough knowledge of solar heater integration techniques in various locations and the changing nature of the renewable energy environment has been hampered by these restrictions [31].

I. Summary

The research provides a discussion of smart thermal grids as a network of pipes that connects the buildings in a town, city, or neighborhoods to check the amount of energy used to get the data and analyze those data to get a piece of knowledge about the smart grid structure [20].

IV. RESULTS AND FINDINGS

Introduction

The research is used in solar heater which is implemented in the thermal grids to check the power output and the use of renewable energy by using internal intelligent temperature [32]. The grid is situated in the system's center, like in the center of a city, town, or neighbourhood [33]. The central part of the grid system helps to stabilize the power and helps to distribute the power throughout the city and all the subsystems [34]. Another possible finding is able to be found from the research object is creating hybrid CSP-CHP plants, conventional thermal power plants, wind farms, and PV plants [35]. The heat source of the primary heating network is the main other than the CSP-CHP plant. This plant gives an accurate representation of the use of renewable energy by using wind energy to use the PV plant [36].

Critical Analysis

The CSP-CHP plant uses wind farms to focus on wind energy and helps to push the energy to implement the electrical energy [37]. Wind farms are applicable for the change in weather depending on how the weather is able to be, the data is being collected and analysed generously to check the data [38]. The data depends on the change in the weather, the weather according to the atmosphere changes in clouds, windy, sunny, and no wind at all [39]. The analysis is being done with the multi-day operational model technique, however the cost of applying the use of the many variations of energy plants that the cost is more than smart grid power systems used in cities and neighbourhoods [40]. The case of the smart grid sub-system the analysis is done with a group of researchers and scientists [41]. The temperature also makes up a factor due to the fact the smart grid tends to lose energy when it is in a hot state and vice versa in a cold state [42].

Findings

The VRE decreases every time an output is checked in CSP-CHP. The hybrid CSP-CHP uses multi-time scale SUCE which results in a decrease in energy [43]. The total number of energy

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

from wind farms and checking is regulated every day and the data is being collected which gives an interesting set of results [44]. Someday the results show the loss of energy due to the wrong collection of data due to the proposed hybrid of the CSP-CHP plant with a multi-time scale SUCE dispatch model being applied [45]. The best possible outcome is to put stand-alone CSP-CHP plants operating in combination with the unified system [46].

The proposed theme about the stand-alone is that is much cheaper to use renewable energy less use of VRE to implement and easy to use [47]. The smart grid systems on the other hand use all of the grid system to provide an output from which the main system is always located in the center [48]. The grid systems support one another to provide work energy and check the energy by using experts and researchers to find the amount of energy by tracking the smart grid and calculating the number energy that is saved and lost [49]. The energy is measured with the change in the temperature, for higher temperatures the smart grid is likely to be inclined to dissipate the energy and heat loss while in cold temperatures the energy does not dissipate and also helps to stabilize the renewable energy [50].

Discussion and Evaluation

The appropriate strategies used in a hybrid CSP-CHP help increase energy consumption reuse the energy and combine and adapt the VRE installation in the system [51]. This procedure helps the model to increase its storage and make demands to the other technologies to respond at its command [52]. This makes the system work together and harmoniously for the use of VRE and technologies to work for a full load for three hours [53]. Use of further models is being created to check the work path forwarding the energy system feature on renewable resources and technology responses [54]. The smart grid on the other hand is a better option for saving the earth from global warming but the implementation and integration into the smart grid system as it causes fluctuations and less stability [55]. In the future, the use of other methods is experimentation provided to make it more stable and provide less energy for make it work.

Summary

Solar heater integration into current renewable energy infrastructures has not yet fully realized its potential, though. With its abundance and environmentally beneficial attributes, solar energy has a huge potential for resolving urgent global issues like climate change and the depletion of fossil fuel supplies. The price of VRE decreases every year which is a good thing cause future VRE systems are important to make resources renewable and use of CSP-CHP. The economic prices of these products are able to be much lower than the present day and with lower the prices of these machines it is very much prominent that energy-efficient and cost-efficient to work and uplift the society.

V. CONCLUSION AND RECOMMENDATIONS

A. Conclusion

This has been concluded that the study has illuminated the critical issue of solar heater underutilization in renewable energy systems. The study sought to determine the existing degree of solar heater integration, pinpoint impediments to wide-scale adoption, analyze the

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

environmental and financial advantages, investigate optimization techniques, and offer practical advice for stakeholders and policymakers. The results of this study have a big impact on the field of renewable energy and more general environmental activities.

B. Recommendations

Depending on the research findings, the researcher provides some recommendations for this research. The recommendations are

1. Promote Research and Development: Support more research and development in solar heating technologies to increase their effectiveness, lower their prices, and increase the number of consumers who can use them.
2. Financial Incentives: The installation of solar heaters in residential, commercial, and industrial settings should be encouraged by governments and organizations through the provision of financial incentives, tax breaks, and subsidies.
3. Awareness and Education: Conduct public relations efforts and educational initiatives to raise knowledge of the advantages of solar heaters and the significance of integrating renewable energy sources.

C. Research limitations

Even while this study has shed important light on how solar heaters might be integrated into renewable energy systems, it is not without its limits. Among the restrictions are:

1. Scope

The research's case study emphasis has not adequately represented the complete range of opportunities and problems associated with integrating solar heaters in various locales and circumstances.

2. Data Availability

In some areas, such as the financial advantages of solar heaters, a lack of data has limited the depth of investigation.

3. Timeframe

Any advancements in solar heating technology or policy changes after September 2021 have not been taken into account because the research is based on data and information that is currently accessible.

D. Future scope

Future investigations can take into account the following topics to expand on this study's findings and fix its shortcomings

1. Comparative research

Determine the regional and national variations in solar heater integration techniques and difficulties and conduct comparative research across numerous locations and nations.

2. Long-Term Impact Assessment

Examine the long-term economic and environmental effects of the broad adoption of solar heaters, including lowered carbon emissions and lower energy costs.

3. Technological Developments

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

Examine new solar heating techniques and how well they could integrate with other renewable energy sources.

V. REFERENCES

[1] Mahsa Daraei, Pietro Elia Campana, Eva Thorin,Power-to-hydrogen storage integrated with rooftop photovoltaic systems and combined heat and power plants, Applied Energy, Volume 276, 2020, 115499, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2020.115499.

[2] Koti Reddy B, Singh AK. Optimal Operation of a Photovoltaic Integrated Captive Cogeneration Plant with a Utility Grid Using Optimization and Machine Learning Prediction Methods. Energies. 2021; 14(16):4935. https://doi.org/10.3390/en14164935

[3] K. Lepiksaar, V. Mašatin, E. Latõšov, A. Siirde, A. Volkova, Improving CHP flexibility by integrating thermal energy storage and power-to-heat technologies into the energy system, Smart Energy, Volume 2, 2021, 100022, ISSN 2666-9552, https://doi.org/10.1016/j.segy.2021.100022.

[4] E. Mokaramian, H. Shayeghi, F. Sedaghati, A. Safari and H. H. Alhelou, "An Optimal Energy Hub Management Integrated EVs and RES Based on Three-Stage Model Considering Various Uncertainties," in IEEE Access, vol. 10, pp. 17349-17365, 2022, doi: 10.1109/ACCESS.2022.3146447.

[5] E. A. Martínez Ceseña, E. Loukarakis, N. Good and P. Mancarella, "Integrated Electricity–Heat–Gas Systems: Techno–Economic Modeling, Optimization, and Application to Multienergy Districts," in Proceedings of the IEEE, vol. 108, no. 9, pp. 1392-1410, Sept. 2020, doi: 10.1109/JPROC.2020.2989382.

[6] L. A. Roald, K. Sundar, A. Zlotnik, S. Misra and G. Andersson, "An Uncertainty Management Framework for Integrated Gas-Electric Energy Systems," in Proceedings of the IEEE, vol. 108, no. 9, pp. 1518-1540, Sept. 2020, doi: 10.1109/JPROC.2020.3005505.

[7] B. Miao et al., "Day-Ahead Energy Trading Strategy of Regional Integrated Energy System Considering Energy Cascade Utilization," in IEEE Access, vol. 8, pp. 138021-138035, 2020, doi: 10.1109/ACCESS.2020.3007224.

[8] Y. Zhang, X. Wang, J. He, Y. Xu and W. Pei, "Optimization of Distributed Integrated Multi-energy System Considering Industrial Process Based on Energy Hub," in Journal of Modern Power Systems and Clean Energy, vol. 8, no. 5, pp. 863-873, September 2020, doi: 10.35833/MPCE.2020.000260.

[9] Z. Hassan et al, "Techno-economic assessment of evacuated flat-plate solar collector system for industrial process heat," Energy Science & Engineering, vol. 11, (6), pp. 2185-2201, 2023. Available: https://www.proquest.com/scholarly-journals/techno-economic-assessment-evacuated-flat-plate/docview/2822921003/se-2. DOI: https://doi.org/10.1002/ese3.1447.

[10] 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.

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

[11] 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.

[12] 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.

[13] S. Wang et al, "On the State-of-the-Art of Solar, Wind, and Other Green Energy Resources and Their Respective Storage Systems," Eng, vol. 4, (1), pp. 857, 2023. Available: https://www.proquest.com/scholarly-journals/on-state-art-solar-wind-other-green-energy/docview/2791619103/se-2. DOI: https://doi.org/10.3390/eng4010052.

[14] 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.

[15] 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.

[16] H. Chao, S. Oren and R. Wilson, "Priority Pricing for Clean Power Under Uncertainty," Current Sustainable / Renewable Energy Reports, vol. 9, (3), pp. 52-64, 2022. Available: https://www.proquest.com/scholarly-journals/priority-pricing-clean-power-under-uncertainty/docview/2713860450/se-2. DOI: https://doi.org/10.1007/s40518-022-00202-1.

[17] 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.

[18] 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.

[19] 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.

[20] S. Wang et al, "On the State-of-the-Art of Solar, Wind, and Other Green Energy Resources and Their Respective Storage Systems," Eng, vol. 4, (1), pp. 857, 2023. Available: https://www.proquest.com/scholarly-journals/on-state-art-solar-wind-other-green-energy/docview/2791619103/se-2. DOI: https://doi.org/10.3390/eng4010052.

[21] 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.

[22] N. S. Mohammad Sajad et al, "Experimental Investigation on Solar Water Heater Integrated with Thermal Battery Using Phase Change Material and Porous Media," Sustainability, vol. 15, (8), pp. 6439, 2023. Available: https://www.proquest.com/scholarly-journals/experimental-investigation-on-solar-water-heater/docview/2806619306/se-2. DOI: https://doi.org/10.3390/su15086439.

[23] S. Jafarinejad et al, "The Intertwined Renewable Energy–Water–Environment (REWE) Nexus Challenges and Opportunities: A Case Study of California," Sustainability, vol. 15, (13), pp. 10672, 2023. Available: https://www.proquest.com/scholarly-journals/intertwined-renewable-energy-water-environment/docview/2836498638/se-2. DOI: https://doi.org/10.3390/su151310672.

[24] P. P. Gohil et al, "Current Status and Advancement in Thermal and Membrane-Based Hybrid Seawater Desalination Technologies," Water, vol. 15, (12), pp. 2274, 2023. Available: https://www.proquest.com/scholarly-journals/current-status-advancement-thermal-membrane-based/docview/2829889519/se-2. DOI: https://doi.org/10.3390/w15122274.

[25] 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.

[26] 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.

[27] 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.

[28] 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.

[29] 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.

[30] H. Alsaif et al, "Numerical Simulation and Structure Optimization of Multilayer Metamaterial Plus-Shaped Solar Absorber Design Based on Graphene and SiO2 Substrate for Renewable Energy Generation," Mathematics, vol. 11, (2), pp. 282, 2023. Available: https://www.proquest.com/scholarly-journals/numerical-simulation-structure-optimization/docview/2767236728/se-2. DOI: https://doi.org/10.3390/math11020282.

[31] 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.

[32] 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.

[33] I. Sarbu, M. Mirza and D. Muntean, "Integration of Renewable Energy Sources into Low-Temperature District Heating Systems: A Review," Energies, vol. 15, (18), pp. 6523, 2022. Available: https://www.proquest.com/scholarly-journals/integration-renewable-energy-sources-into-low/docview/2716531218/se-2. DOI: https://doi.org/10.3390/en15186523.

[34] N. Tasmin et al, "Integration of Solar Process Heat in Industries: A Review," Clean Technologies, vol. 4, (1), pp. 97, 2022. Available: https://www.proquest.com/scholarly-journals/integration-solar-process-heat-industries-review/docview/2642352226/se-2. DOI: https://doi.org/10.3390/cleantechnol4010008.

[35] D. Cardoso et al, "Intelligent Micro-Cogeneration Systems for Residential Grids: A Sustainable Solution for Efficient Energy Management," Energies, vol. 16, (13), pp. 5215, 2023. Available: https://www.proquest.com/scholarly-journals/intelligent-micro-cogeneration-systems/docview/2836394037/se-2. DOI: https://doi.org/10.3390/en16135215.

[36] 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.

[37] F. Calise et al, "Dynamic Simulation and Thermoeconomic Analysis of a Novel Hybrid Solar System for Biomethane Production by the Organic Fraction of Municipal Wastes," Energies, vol. 16, (6), pp. 2716, 2023. Available: https://www.proquest.com/scholarly-journals/dynamic-

simulation-thermoeconomic-analysis-novel/docview/2791650855/se-2. DOI: https://doi.org/10.3390/en16062716.

[38] N. M. Manousakis et al, "Integration of Renewable Energy and Electric Vehicles in Power Systems: A Review," Processes, vol. 11, (5), pp. 1544, 2023. Available: https://www.proquest.com/scholarly-journals/integration-renewable-energy-electric-vehicles/docview/2819482380/se-2. DOI: https://doi.org/10.3390/pr11051544.

[39] 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.

[40] B. Taheri, A. F. Asghar and F. Jabari, "Design and performance optimization of a tri-generation energy hub considering demand response programs," Energy Science & Engineering, vol. 11, (2), pp. 675-684, 2023. Available: https://www.proquest.com/scholarly-journals/design-performance-optimization-tri-generation/docview/2774672923/se-2. DOI: https://doi.org/10.1002/ese3.1353.

[41] 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.

[42] N. Azizi et al, "Critical review of multigeneration system powered by geothermal energy resource from the energy, exergy, and economic point of views," Energy Science & Engineering, vol. 10, (12), pp. 4859-4889, 2022. Available: https://www.proquest.com/scholarly-journals/critical-review-multigeneration-system-powered/docview/2755636376/se-2. DOI: https://doi.org/10.1002/ese3.1296.

[43] A. Patnaik et al, "Sustainable Rural Development through Renewable Energy Technologies: Identification of Potential Methods to Increase Rural Incomes," IOP Conference Series.Earth and Environmental Science, vol. 1084, (1), pp. 012020, 2022. Available: https://www.proquest.com/scholarly-journals/sustainable-rural-development-through-renewable/docview/2726960750/se-2. DOI: https://doi.org/10.1088/1755-1315/1084/1/012020.

[44] 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.

[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.

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

[46] D. García et al, "Experimental and Numerical Characterisation of a Non-Tubular Stirling Engine Heater for Biomass Applications," Sustainability, vol. 14, (24), pp. 16488, 2022. Available: https://www.proquest.com/scholarly-journals/experimental-numerical-characterisation-non/docview/2756819913/se-2. DOI: https://doi.org/10.3390/su142416488.

[47] M. Nájera-Trejo et al, "Pre-Feasibility Assessment Tool for Solar Industrial Process Heating," Processes, vol. 11, (6), pp. 1663, 2023. Available: https://www.proquest.com/scholarly-journals/pre-feasibility-assessment-tool-solar-industrial/docview/2829870547/se-2. DOI: https://doi.org/10.3390/pr11061663.

[48] I. Lazanyuk et al, "Diffusion of Renewable Microgeneration on the Side of End-User: Multiple Case Study," Energies, vol. 16, (6), pp. 2857, 2023. Available: https://www.proquest.com/scholarly-journals/diffusion-renewable-microgeneration-on-side-end/docview/2791650450/se-2. DOI: https://doi.org/10.3390/en16062857.

[49] S. M. Pegah et al, "A comprehensive framework for solar panel technology selection: A BWM- MULTIMOOSRAL approach," Energy Science & Engineering, vol. 10, (12), pp. 4595-4625, 2022. Available: https://www.proquest.com/scholarly-journals/comprehensive-framework-solar-panel-technology/docview/2755636551/se-2. DOI: https://doi.org/10.1002/ese3.1292.

[50] L. Li and K. W. Lange, "Planning Principles for Integrating Community Empowerment into Zero-Net Carbon Transformation," Smart Cities, vol. 6, (1), pp. 100, 2023. Available: https://www.proquest.com/scholarly-journals/planning-principles-integrating-community/docview/2779654541/se-2. DOI: https://doi.org/10.3390/smartcities6010006.

[51] T. Z. Musawenkosi Lethumcebo, P. C. Rudiren and R. Tiako, "A Comprehensive Review: Study of Artificial Intelligence Optimization Technique Applications in a Hybrid Microgrid at Times of Fault Outbreaks," Energies, vol. 16, (4), pp. 1786, 2023. Available: https://www.proquest.com/scholarly-journals/comprehensive-review-study-artificial/docview/2779543446/se-2. DOI: https://doi.org/10.3390/en16041786.

[52] N. Kannan et al, "Experimental Investigation on Incorporation of Zinc-Ferrite Nanocoated Baffles for Improving the Performance of Field Power Electrical Transformer Integrated with a Solar Air Heater," Advances in Materials Science and Engineering, vol. 2023, 2023. Available: https://www.proquest.com/scholarly-journals/experimental-investigation-on-incorporation-zinc/docview/2807762920/se-2. DOI: https://doi.org/10.1155/2023/5657609.

[53] M. Hook et al, "HYDROGEN'S POTENTIAL ROLE IN LDCS' TRANSITION TO A LOW-CARBON FUTURE," Energy Law Journal, vol. 44, (1), pp. 31-64, 2023. Available: https://www.proquest.com/scholarly-journals/hydrogens-potential-role-ldcs-transition-low/docview/2814052290/se-2.

[54] G. Nema and K. Karunamurthy, "A comprehensive review on the productivity enhancement of a solar desalination system through parameters and techniques," IOP Conference Series.Earth and Environmental Science, vol. 850, (1), 2021. Available: https://www.proquest.com/scholarly-journals/comprehensive-review-on-productivity-enhancement/docview/2597838683/se-2. DOI: https://doi.org/10.1088/1755-1315/850/1/012040.

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

[55] E. Congiu et al, "Web-Based Management of Public Buildings: A Workflow Based on Integration of BIM and IoT Sensors with a Web–GIS Portal," Buildings, vol. 13, (5), pp. 1327, 2023. Available: https://www.proquest.com/scholarly-journals/web-based-management-public-buildings-workflow-on/docview/2819418048/se-2. DOI: https://doi.org/10.3390/buildings13051327.

[56] 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."

[57] 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.

[58] 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

[59] Anand Patel. TheEffect of Moisture Recovery System on Performance of Cooling Tower. International Journal for Modern Trends in Science and Technology 2023, 9(07), pp. 78-83. https://doi.org/10.46501/IJMTST0907013.

[60] 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.

[61] Patel, Anand. “EFFECT OF PITCH ON THERMAL PERFORMANCE SERPENTINE HEAT EXCHANGER.” INTERNATIONAL JOURNAL OF RESEARCH IN AERONAUTICAL AND MECHANICAL ENGINEERING (IJRAME), vol. 11, no. 8, Aug. 2023, pp. 01–11. https://doi.org/10.5281/zenodo.8225457.

[62] 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.

[63] Thakre, Shekhar, Pandhare, Amar, Malwe, Prateek D., Gupta, Naveen, Kothare, Chandrakant, Magade, Pramod B., Patel, Anand, Meena, Radhey Shyam, Veza, Ibham, Natrayan L., and Panchal, Hitesh. "Heat transfer and pressure drop analysis of a microchannel heat sink using nanofluids for energy applications" Kerntechnik, 2023. https://doi.org/10.1515/kern-2023-0034.

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

[65] 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

Catalyst Research Volume 23, Issue 2, September 2023 Pp. 1050-1065

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

[67] 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

[68] 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.

[69] 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.

[70] 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.

[71] 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.

[72] 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.