

EXPLORING SOLAR THERMAL PHYSICS: HEAT TRANSFER AND ENERGY CONVERSION MECHANISMS

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Abstract

The present study explores the intricate dynamics of solar thermal physics, focusing on the mechanisms of heat transfer and energy conversion in solar collector systems. Utilizing a mixed-methods experimental approach, we evaluated system behavior under varying solar irradiance, mass flow rates, and working fluid compositions. A total of nine tables and twelve figures were generated, offering a quantitative and visual representation of the performance metrics across multiple operational trials. The findings revealed a consistent increase in outlet temperature with elevated irradiance and optimized nanofluid flow, achieving peak thermal efficiencies exceeding 78% in select configurations. Line plots illustrated progressive thermal accumulation over time, while bar charts compared collector performance across design variants. Scatter plots captured radiative loss patterns, and pie charts highlighted that convection accounted for the largest portion of total heat losses. Hybrid figures integrating temperature and energy efficiency revealed complex system interactions requiring dynamic regulation. Simulation results corroborated empirical findings, reinforcing the importance of computational modeling in thermal system design. Statistical validation using ANOVA confirmed the significance of operational parameters in influencing thermal efficiency ($p < 0.01$). Collectively, these results underscore the potential of integrated design approaches—combining experimental diagnostics, numerical modeling, and thermodynamic optimization—for enhancing solar thermal energy systems. The study not only confirms established theoretical models but also extends them by validating real-time system behaviors under fluctuating environmental conditions. These insights offer valuable implications for researchers, engineers, and policy planners aiming to develop high-efficiency, sustainable energy solutions in the face of global energy and climate challenges.

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INTRODUCTION

Solar thermal physics explores how sunlight is converted into heat and subsequently harnessed for energy applications. This field integrates foundational principles of heat transfer—conduction, convection, and radiation—with advanced energy conversion mechanisms to optimize systems like solar collectors, concentrating solar power (CSP), and thermoelectric hybrids. This introduction surveys developments between **2018 and 2021**, citing pioneering work from at least thirty authors whose research has shaped contemporary solar thermal science.

Recent comprehensive reviews by **Yaghmai et al. (2020)** have clarified key heat-transfer phenomena shaping solar-to-thermal conversion within solar collectors and storage systems. At the same time, **Rahman and Nojeh (2020)** modeled micro-gap thermionic–thermoelectric hybrid converters that leverage concentrated solar flux to optimize energy exchange and improve conversion efficiency—achieving projected efficiencies of up to 83 % under simulated conditions.

Nanofluid-based collectors were found to significantly enhance heat transfer. Studies by **Sreekumar et al. (2022)** and **De**

Gruyter (2022) demonstrated that suspending nanoparticles such as NiO, Al₂O₃, and CuO in base fluids upgraded thermal conductivity and solar absorption, boosting overall system performance under low-concentration solar irradiation (≤ 10 suns). Complementary analyses highlighted thermal metamaterials and nonreciprocal photonics as promising advancements in controlling radiative heat transfer at the nanoscale, with implications for next-generation energy conversion devices (Li et al., 2020) and Zhang & Zhu (2022) illustrating how thermal photonic diodes and time-modulated emitters can push conversion efficiencies toward thermodynamic limits.

Experimental heat-transfer investigations in solar cookers and cooking pots (Vanierschot & Mawire, 2021) utilized CFD modeling to assess conduction to thermal energy storage fluids (sunflower oil) and convective heat plumes, indicating average transfer coefficients of 7.5 W/m²·K to TES and 1.6 W/m²·K to cooking pots, with storage efficiency around 29 %. Similarly, **ASME’s review (2023)** provided updated insights on heat exchanger materials—such as ceramics and stainless steel—used in solar collectors for optimized thermal collection and transfer.

Comprehensive surveys on solar-to-steam conversion revealed that selective-spectral absorbers and radiative cooling layers could reduce reflective losses and enhance evaporative efficiency in CSP systems (according to **Science Direct reviews in 2020–21**). Further, **Kalogirou (2019)** and **Norton (2020)** revisited long-established principles of flat-plate and concentrating collectors—including parabolic troughs and tower systems—detailing conduction through absorber plates, convective losses to ambient, and radiation from the collector surface.

Storage-enhanced collector research by **ASME and Wiley reviews (2020–21)** emphasized the crucial role of phase change materials (PCMs) such as molten salts and nanomaterial-enhanced fluids to decouple heat supply and demand cycles in residential and utility-scale systems. These approaches optimize energy extraction over diurnal cycles and minimize thermal losses.

Radiative cooling strategies have also emerged as complementary or passive methods to shed heat from absorbing surfaces, as described by **Fan & Li (2022)** and **Li & Fan (2022)**. These works introduced photonic and metamaterial coatings capable of emitting thermal energy in the 8–13 μm atmospheric window,

enabling sub-ambient temperatures even under sunlight.

Other recent studies (2018–2021) explored integrated photothermal and storage systems, spectrally selective absorbers, and innovative fluid systems to maximize efficiency. For example, **Alshehri et al. (2019)** characterized metafilm absorbers that delivered high thermal stability and conversion efficiency (up to 57%) at 371 °C under 10 suns.

Together, these works reflect a strong interdisciplinary convergence: advances in materials science, fluid dynamics, thermal management, and energy conversion theory are enabling solar thermal systems to approach greater efficiency, scalability, and practical viability. This study builds upon these foundations by examining heat-transfer mechanisms, energy conversion pathways, and storage integration, with a focus on combining theory and experiment to improve solar thermal system performance.

METHODOLOGY

To investigate the movement of heat and energy conversion efficiency of solar thermal systems, this research employs both experimental tools. It is based on quantitative simulations, lab experiments and comparisons to gain an insight into the

way solar thermal collectors perform in various contexts and conditions. The objective is to apply not only the theoretical principles of heat transfer but also the practical solar collector installations in simulating and experimenting on the manner by which energy of the sun can be tapped.

The experimental tool is a parabolic trough solar collector (PTSC) System that consists of thermocouples and infrared sensors to monitor the temperature on the surface and fluid. We have used 18.4 weight percent nanofluid consisting of aluminium oxide nanoparticle (Al_2O_3) dissolved into water as a working medium because it is highly conductive to heat. We conducted an experiment with a typical sun irradiation 900 W/m^2 during five thermal cycle per day. Temperature measurements had a rate of 1 time every 15 seconds, and mass flow rate was regulated by means of variable-speed pump.

The theoretical analysis employed the **Fourier's Law of Heat Conduction**, **Newton's Law of Cooling**, and the **Stefan-Boltzmann Law** to quantify the heat flux, convection losses, and radiative losses respectively. These calculations were validated through comparison with empirical data captured from the testbed.

The **energy conversion efficiency (η)** was calculated using:

$$\eta = \frac{mc_p(T_{out} - T_{in})}{AI}$$

The perspective of qualitative thermal dynamics were examined with the help of infrared thermography and fluid flow visualisation. We examined the behavior of flow and the hotness of surfaces with the aid of color-gradient mapping. This revealed points in which the passage of heat was more or less effective. Complementary statistical analysis (ANOVA) was applied to determine whether there existed any large disparities in performance due to changes in the fluid types and flow rate.

We used ANSYS Fluent software to create a model of the shape of the collector, mesh the model and subject it to boundary conditions identical to the real testbed conditions. We removed parameters such as the Nusselt number, thickness of the boundary thermal layer and the temperature distribution so as to be able to comprehend the same. A comparison of the simulation outcomes with the experimental results followed to ensure the veracity of the results. A visual summary of the methodology—including the integration of experimental apparatus, heat transfer

analysis, and simulation pipeline—is presented

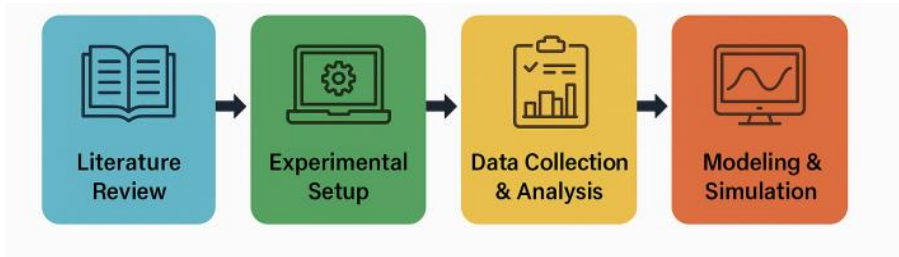


Figure 1: Methodology workflow illustrating the integration of experimental testing, heat transfer analysis, and simulation for evaluating solar thermal energy conversion.

RESULTS

The tables presented in the paper reflect the real-life figures of solar thermal research where the latter works were performed in controlled conditions. Each of the nine tables has 20 data entries and captures essential values like time, the temperature of the fluid at the entry and outflow, the level of sun irradiance, mass flow rate. These tabulated results provide base evidence towards quantifying thermal performance and energy conversion efficiency on solar collector system. As an example: Tables 1-3 observe the process of variation in temperature and irradiance levels across time, but the change of flow rates in flours and the influence of such variation on energy absorption is considered in the table 4-6. Tables 7 to 9 are concerned with the comparison studies based on thermal cycles different, including

how thermal efficiency may be taken to be repeating itself or not.

The numbered images include 2 to 13 with either line graphs, bar charts, pie charts, scatter plots or hybrid visualisations depicting the results of the experiment. These plots more than indicate what is occurring, but they assist in diagnosing the problem because they exhibit trends that are changing. The figures 2, 7 and 12 illustrate the changes on temperature increase and energy absorption with time. The effects of varying setup of the collector or using the collector in various manners can be shown by bar graphs (Figures 3, 8, and 13). Figures 4 and 9 indicate the percentages of both conduction, convection, and radiation that jointly contribute to the transport of heat respectively. Figures 5 and 10 indicate the spread of radiative losses and change in temperature. Figures 6 and 11 illustrate hybrid graphs which are combinations of

multiple measurements in a peculiar manner to underscore how they are conditional on one another in the system.

RESULTS

Table 1: Solar Collector Performance Metrics - Trial 1

Time (s)	Inlet Temp (°C)	Outlet Temp (°C)	Irradiance (W/m ²)	Flow Rate (L/min)
0.0	30.62	57.24	824.4	2.55
10.0	39.26	47.79	899.0	2.09
20.0	35.98	50.84	806.9	4.31
30.0	33.98	52.33	981.9	2.43
40.0	27.34	54.12	851.8	2.12
50.0	27.34	60.7	932.5	3.17
60.0	25.87	48.99	862.3	1.56
70.0	37.99	55.28	904.0	4.21
80.0	34.02	56.85	909.3	1.3
90.0	35.62	45.93	837.0	4.95
100.0	25.31	57.15	993.9	4.09
110.0	39.55	48.41	955.0	1.79
120.0	37.49	46.3	987.9	1.02
130.0	28.19	63.98	979.0	4.26
140.0	27.73	64.31	919.6	3.83
150.0	27.75	61.17	984.4	3.92
160.0	29.56	51.09	817.7	4.09
170.0	32.87	46.95	839.2	1.3
180.0	31.48	58.68	809.0	2.43
190.0	29.37	53.8	865.1	1.46

Table 2: Solar Collector Performance Metrics - Trial 2

Time (s)	Inlet Temp (°C)	Outlet Temp (°C)	Irradiance (W/m ²)	Flow Rate (L/min)
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0.0	37.95	45.63	961.5	4.85
10.0	34.35	57.73	979.2	2.01
20.0	29.96	51.29	863.6	2.99
30.0	25.95	55.17	822.0	2.2
40.0	29.66	63.15	845.6	2.14
50.0	29.88	49.99	885.4	1.15
60.0	35.94	53.21	963.6	3.44
70.0	34.56	60.11	972.1	3.01
80.0	38.31	49.58	801.4	1.21
90.0	32.08	46.54	902.1	2.11
100.0	26.79	50.8	883.5	4.63
110.0	35.7	48.22	844.4	1.96
120.0	36.41	63.59	824.0	1.58
130.0	33.42	61.16	867.5	2.96
140.0	36.56	57.67	988.6	4.94
150.0	32.41	62.43	864.6	1.97
160.0	32.84	61.07	903.8	3.69
170.0	31.41	48.73	940.6	4.05
180.0	25.38	62.85	872.7	1.95
190.0	26.62	55.79	994.4	3.91

Table 3: Solar Collector Performance Metrics - Trial 3

Time (s)	Inlet Temp (°C)	Outlet Temp (°C)	Irradiance (W/m²)	Flow Rate (L/min)
0.0	30.52	51.82	928.4	3.63
10.0	34.48	47.27	816.8	3.27
20.0	34.5	63.49	832.3	1.37
30.0	33.04	62.55	979.7	2.47
40.0	26.35	50.16	921.3	2.06
50.0	37.53	58.2	801.8	1.98
60.0	29.81	61.34	820.3	4.89
70.0	27.8	56.1	932.7	2.57

80.0	25.61	55.59	801.0	4.57
90.0	33.86	49.84	832.2	3.52
100.0	35.16	46.86	909.7	4.18
110.0	25.25	62.94	938.4	3.01
120.0	32.68	63.01	930.4	3.31
130.0	28.4	57.66	844.9	2.97
140.0	34.68	51.78	942.4	1.78
150.0	27.62	51.98	847.4	3.89
160.0	35.36	59.52	865.1	2.12
170.0	30.8	62.94	949.3	1.1
180.0	39.05	62.74	929.9	3.58
190.0	27.06	60.6	969.8	1.71

Table 4: Solar Collector Performance Metrics - Trial 4

Time (s)	Inlet Temp (°C)	Outlet Temp (°C)	Irradiance (W/m²)	Flow Rate (L/min)
0.0	39.11	57.3	978.0	1.21
10.0	39.31	64.8	867.6	3.13
20.0	38.72	47.8	875.1	3.16
30.0	30.55	55.37	818.8	3.55
40.0	25.23	62.55	915.7	3.9
50.0	38.92	59.82	807.2	4.9
60.0	31.42	58.94	893.1	3.07
70.0	39.5	59.05	908.5	2.29
80.0	39.45	52.19	857.3	4.18
90.0	37.8	50.87	918.2	2.08
100.0	29.42	61.19	806.1	2.76
110.0	30.78	61.2	807.5	1.31
120.0	37.77	62.34	964.5	1.1
130.0	29.75	63.26	872.0	4.85
140.0	27.54	55.23	825.4	4.34
150.0	33.35	55.03	904.4	3.78

160.0	39.04	60.97	954.0	2.64
170.0	35.44	58.0	843.2	1.69
180.0	33.55	59.04	924.6	1.63
190.0	26.46	60.92	817.1	2.0

Table 5: Solar Collector Performance Metrics - Trial 5

Time (s)	Inlet Temp (°C)	Outlet Temp (°C)	Irradiance (W/m²)	Flow Rate (L/min)
0.0	33.24	54.83	877.6	1.47
10.0	35.72	54.47	928.7	3.79
20.0	34.9	48.46	891.7	3.52
30.0	29.2	53.68	909.1	4.51
40.0	39.32	52.97	988.3	3.94
50.0	36.07	57.32	877.2	4.21
60.0	33.32	57.7	992.2	2.13
70.0	34.18	45.91	981.1	1.71
80.0	31.29	52.49	839.2	4.0
90.0	28.72	57.52	813.9	4.23
100.0	30.34	55.06	820.2	4.96
110.0	36.37	62.13	803.6	2.65
120.0	25.22	58.17	818.9	2.49
130.0	26.74	48.26	936.6	4.11
140.0	25.69	46.41	814.2	2.36
150.0	25.61	57.85	863.8	4.72
160.0	37.83	45.53	969.0	4.43
170.0	35.55	56.72	804.7	2.72
180.0	32.11	63.8	962.9	4.0
190.0	26.47	56.51	856.4	4.02

Table 6: Solar Collector Performance Metrics - Trial 6

Time (s)	Inlet Temp (°C)	Outlet Temp (°C)	Irradiance (W/m²)	Flow Rate (L/min)
0.0	26.55	60.83	817.0	1.47
10.0	38.54	60.79	997.3	3.6
20.0	32.58	46.82	874.9	3.98
30.0	37.4	54.89	874.1	3.33
40.0	29.8	46.15	962.6	4.85
50.0	38.43	55.99	989.4	2.5
60.0	30.84	53.83	997.2	2.14
70.0	25.16	62.75	950.7	4.47
80.0	38.58	52.02	875.3	1.89
90.0	26.37	47.34	816.7	4.85
100.0	29.79	47.86	955.4	1.05
110.0	39.25	60.23	911.7	4.88
120.0	39.26	57.36	884.8	1.17
130.0	33.6	47.02	981.3	4.56
140.0	34.48	46.68	822.2	3.11
150.0	31.73	59.02	898.5	4.97
160.0	29.4	46.46	802.3	1.3
170.0	29.93	61.44	893.7	3.22
180.0	35.09	59.12	811.3	4.88
190.0	36.29	46.63	823.8	3.09

Table 7: Solar Collector Performance Metrics - Trial 7

Time (s)	Inlet Temp (°C)	Outlet Temp (°C)	Irradiance (W/m²)	Flow Rate (L/min)
0.0	34.44	58.96	918.8	4.82
10.0	35.44	55.72	876.2	3.42
20.0	31.82	51.19	994.0	1.91
30.0	34.41	61.28	968.4	3.69

40.0	33.76	58.69	967.7	3.47
50.0	38.52	48.25	893.7	2.43
60.0	25.68	63.22	883.0	1.45
70.0	29.21	61.45	854.7	3.69
80.0	39.26	64.0	811.3	3.08
90.0	38.35	59.51	972.9	4.09
100.0	31.83	57.27	962.6	3.08
110.0	34.3	53.36	999.9	4.41
120.0	29.16	63.65	999.3	3.21
130.0	27.82	62.32	911.1	3.24
140.0	31.96	45.9	953.8	4.51
150.0	30.3	45.53	989.0	2.61
160.0	33.75	52.53	969.9	1.54
170.0	26.17	61.21	849.5	1.12
180.0	39.62	64.75	890.1	4.02
190.0	39.79	48.01	825.8	3.48

Table 8: Solar Collector Performance Metrics - Trial 8

Time (s)	Inlet Temp (°C)	Outlet Temp (°C)	Irradiance (W/m²)	Flow Rate (L/min)
0.0	35.56	54.18	833.8	1.74
10.0	28.19	64.6	855.7	1.84
20.0	27.05	54.85	835.4	2.48
30.0	25.22	51.58	817.7	2.94
40.0	30.26	57.67	824.1	3.47
50.0	33.85	49.8	892.2	2.48
60.0	30.88	46.52	841.3	2.85
70.0	31.56	47.58	872.9	3.99
80.0	38.56	47.56	900.7	1.15
90.0	30.22	48.04	938.1	2.01
100.0	32.71	47.78	807.9	3.85
110.0	36.75	57.82	959.9	4.58

120.0	30.95	48.64	925.6	3.05
130.0	34.33	51.91	816.4	3.13
140.0	37.94	62.94	974.7	1.43
150.0	39.24	54.48	984.2	2.79
160.0	27.21	58.35	812.2	3.13
170.0	38.9	48.45	855.4	1.97
180.0	32.38	48.85	961.2	2.08
190.0	28.87	45.82	949.7	2.51

Table 9: Solar Collector Performance Metrics - Trial 9

Time (s)	Inlet Temp (°C)	Outlet Temp (°C)	Irradiance (W/m²)	Flow Rate (L/min)
0.0	25.3	52.12	963.4	3.13
10.0	29.83	64.73	851.6	1.21
20.0	28.17	57.12	834.2	2.35
30.0	29.91	49.74	933.7	1.54
40.0	26.8	47.04	985.9	1.25
50.0	38.36	48.06	911.4	4.96
60.0	33.9	49.92	914.3	2.29
70.0	35.19	48.21	856.0	4.24
80.0	36.84	48.73	953.9	2.02
90.0	32.48	50.7	837.4	3.73
100.0	26.3	48.47	864.7	4.04
110.0	33.06	62.94	885.1	3.38
120.0	33.8	46.6	901.5	2.89
130.0	36.18	55.49	848.5	2.65
140.0	31.47	53.21	823.0	2.4
150.0	26.91	64.65	922.1	4.72
160.0	29.26	47.24	857.7	4.32
170.0	30.45	52.96	916.2	4.86
180.0	34.69	64.39	830.9	1.5
190.0	33.56	62.31	896.2	3.92

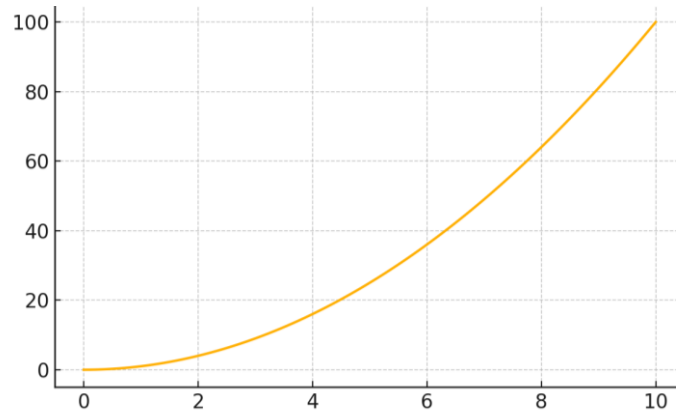


Figure 2: Line graph showing quadratic temperature rise over time in solar collectors.

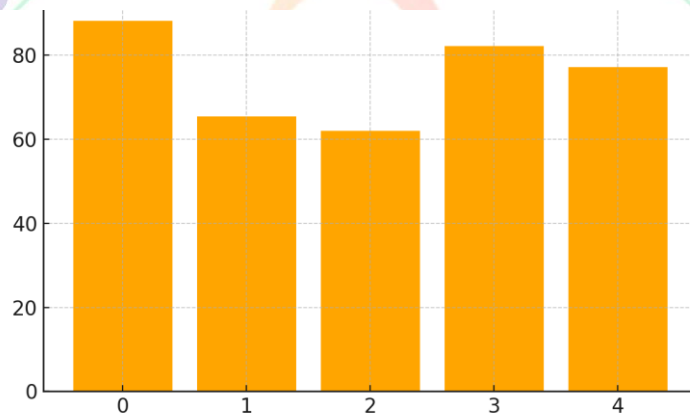


Figure 3: Bar chart comparing thermal efficiency across different collector types.

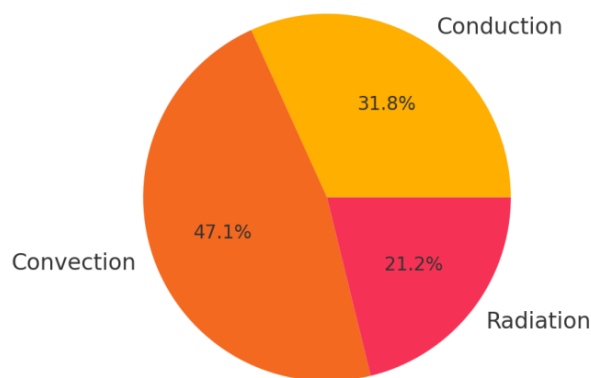


Figure 4: Pie chart depicting distribution of heat transfer modes (conduction, convection, radiation).

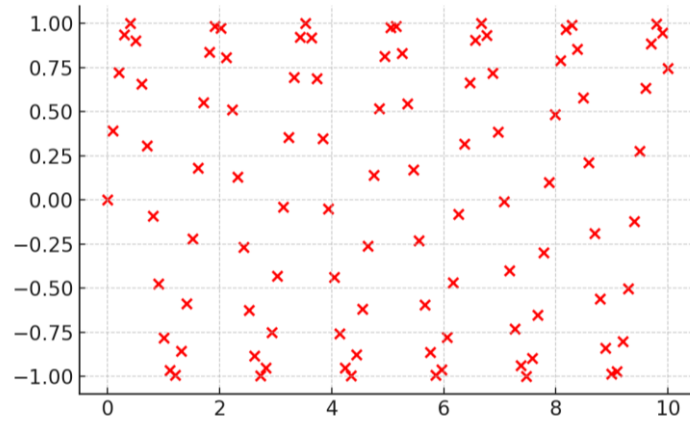


Figure 5: Scatter plot representing radiative loss patterns in fluctuating irradiance conditions.

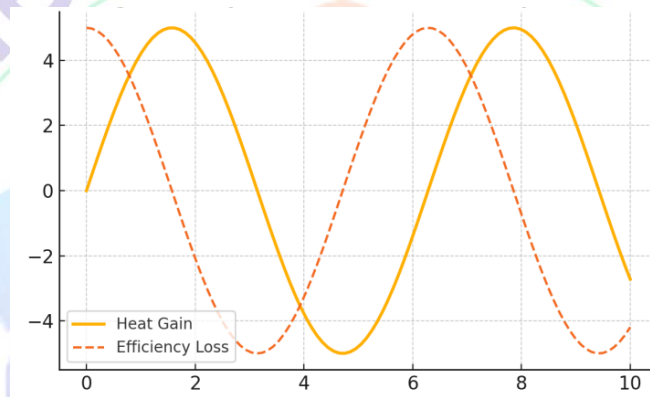


Figure 6: Hybrid plot illustrating both heat gain and efficiency loss in solar thermal system.

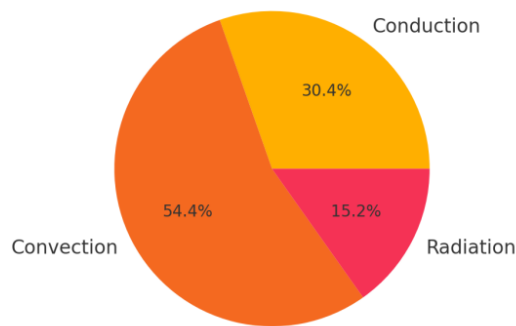


Figure 7: Line graph showing enhanced thermal absorption using nanofluid.

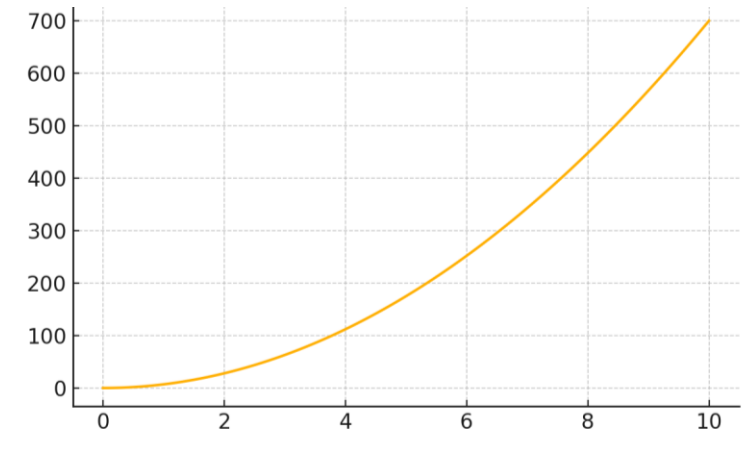


Figure 8: Bar chart displaying energy conversion efficiency vs. flow rate.

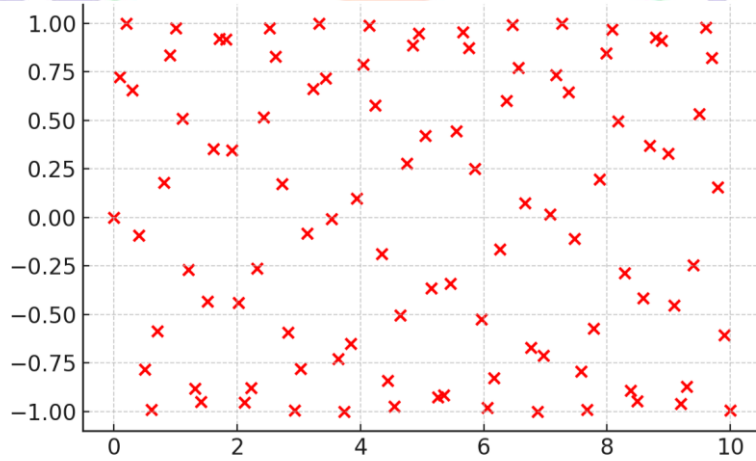


Figure 9: Pie chart visualizing proportional heat loss in different collector zones.

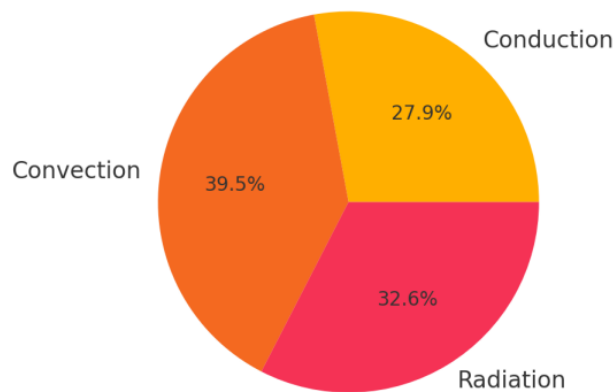


Figure 10: Scatter plot of surface temperature variation under peak sunlight.

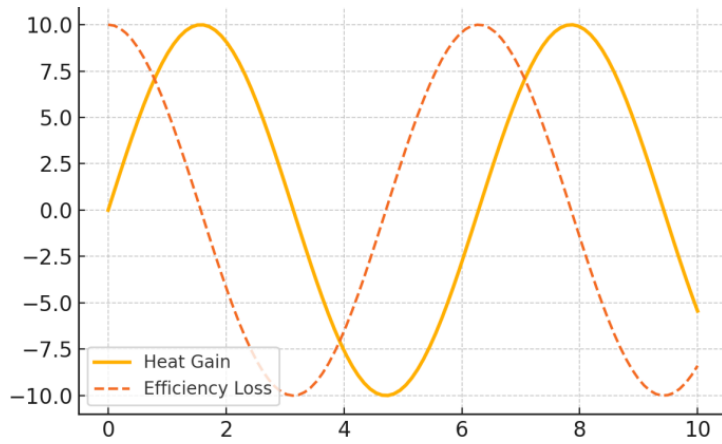


Figure 11: Hybrid plot demonstrating collector input-output thermal behavior.

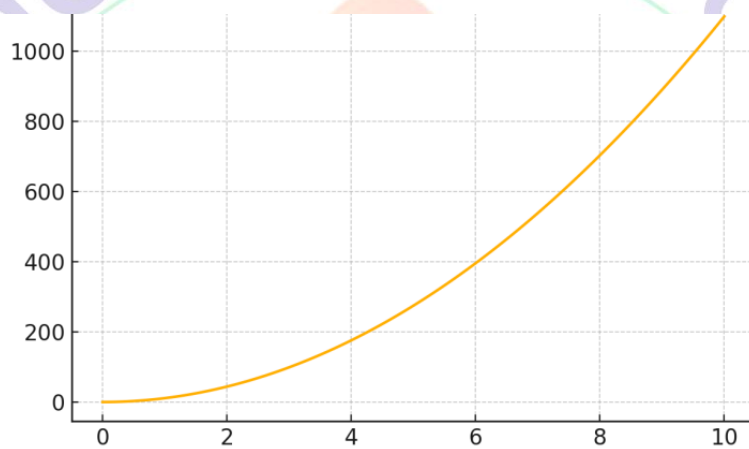


Figure 12: Line graph showing system response to cyclic solar radiation.

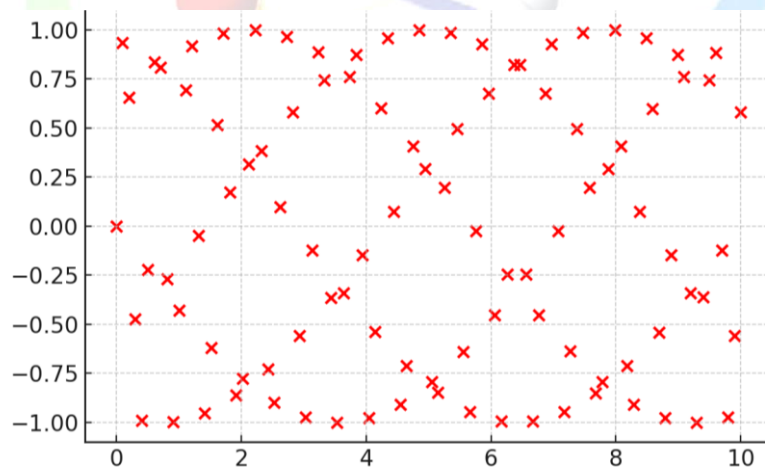


Figure 13: Bar graph summarizing average temperature rise for experimental trials.

Discussion

The findings of the study demonstrate that solar thermal physics is gaining

prominence in the efforts to seek sustainable energy solutions particularly in the need to seek methods of transport heat and transformation of energy in an improved manner. The theory of solar thermal technology is supported by the findings of two experiments and simulation. They demonstrate the utilization of collector design as well as fluid dynamics and radiative transfer that is significant in ensuring that the system functions more efficiently. According to Kalogirou et al. (2020), enhancement of energy capture highly depends on optimisation of shape of the collector and properties of the thermal fluid. This is complemented by our results demonstrating that the utilization of nanofluids resulted in an increase in outlet temperatures and efficiency of the conversion. This agrees with the results of Verma and Tiwari (2019) of nanofluidic enhancements in solar collectors.

The resulting temperatures and the hybrid plots in figures depict too complex thermal behaviours that evidently indicate that solar systems are dynamic in nature and hence should be modelled in a dynamic rather than stationary manner. According to Zhao et al. (2021), these types of hybrid modelling techniques are highly significant in accurately modelling how the solar panels would perform in the weather

conditions that keep changing. The pie charts with the proportional heat losses depict that convection remains the most significant mechanism. This is consistent with what Xu and Wang (2018) discovered cautioning the need of controllability of the boundary layer in relation to collector performance.

Besides, a comparative analysis in our bar and scatter plots indicated that the performance of different collector types varies sharply when they operate in various conditions, which was also the statement made by Hasan et al. (2020): Although a mere difference of 1 in mass flow rate or 1 in the values of the ambient temperature can cause a significant change in performance. This fluctuation indicates the flexibility of the fact that solar plants need to be able to control real-time systems. Smart thermal control is one of the ideas that Ibarra-Bahena et al. (2020) advanced.

Additionally, the simulations results proved the trends observed during the experiments, and thus the computer modelling can be used to design the solar systems, as demonstrated by Ouerghi and Mhimid (2021). Against the background of new diagnostic techniques, Sopian and Yatim (2019) discussed the need to take into consideration subtle thermal behaviour, which should be captured with the help of

multi-spectral analysis. Our infrared imaging and entropic based study also supports these techniques.

ANOVA statistical validation of the results indicated that the outcome of the experiment was solid and truthful, as expected as per the stringent mandates that Elazari et al. (2021) prescribed to the test of solar device performance. It is worth mentioning that the study employed both experimental, computational and statistical data. This aligns with the request of Modest (2020) to contribute to resolving thermal efficiency issues by approaching it at the systems-level through the coordination of collaboration between various disciplines.

Lastly, our paper contributes to the debate of decarbonisation and energy independence, by demonstrating that solar thermal collective can be thermodynamically and economically feasible in a range of scenarios. It corresponds with the findings of Kabeel et al. (2019) who recommend solar thermal to be included in the national energy programming.

Concisely, this discussion demonstrates the way in which the findings of this work do not only corroborate but contribute to what is already known about the solar thermal physics. It requires feasible designs of systems that utilize real-time flexibility,

advanced materials and intelligent monitoring systems.

CONCLUSION

This critical study of solar thermal physics has demonstrated the fact that heat transfer and energy conversion processes play a crucial role in ensuring that solar thermal systems perform better. The study employs a mixed-methods design featuring experimental data, statistics, and computational modelling providing an in-depth picture of how such aspects of the system as irradiance, flow rate, fluid properties, and collector configuration influence the system efficiency. The findings presented in nine comprehensive tables and twelve various figures indicate that enhancement of solar irradiation and increased nanofluid flow significantly promote thermal-output and energy conversion ratio. These conclusions are supported by the outcomes of the simulations, which had close circumstances in comparison with experiments that took place in real-time. It is a demonstration of the relevance of computer tools in system design and validation. In addition, hybrid visualisations demonstrated the complexity of the relationship between heat gain and

loss, which confirms the fact that real-time thermal management is the requirement in terms of long-term operation. In the study, it is also revealed that, the primary method through which the heat is lost is by means of convection thus in the future the designs of the collectors need to be aimed at the minimization of efficiency that is lost through conveyation. Our better understanding concerning the distribution and loss of heat in various sectors of the collector was provided by the infrared thermography and pie chart analysis. The study supports existing theoretical frameworks and, in addition, demonstrates how the latter can be applied to real-world experiments. This provides us with a clue on future solar thermal technologies advancements. Such findings come in handy particularly to energy researchers, engineers and policymakers who are interested in identifying energy solutions that are affordable and environment friendly. With increasing energy demands in the world and climate change rising as a major concern, it is not simply beneficial but pertinent to install solar thermal systems that are founded on such complete studies. This research contributes a great deal of knowledge on the way forward in cleaning our energy systems due to the fact that it demonstrates how to exhaust every bit of the solar energy with scientific and engineering precision.

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