RESEARCHERID
THOMSON REUTERS
[Aamir et al., 11(7), July 2026]

ISSN : 2455-9679
SJIF Impact Factor : 6.190

IJRTSM

INTERNATIONAL JOURNAL OF RECENT TECHNOLOGY SCIENCE & MANAGEMENT

"EXPERIMENTAL INVESTIGATION OF A GRAPHENE-COATED SOLAR WATER HEATER FOR ENHANCED THERMAL PERFORMANCE"

***Md Aamir* [1] *, Dr Sohail Bux* [2]**

[1] PG Scholar, Department of Mechanical Engineering, AGNOS College of Technology, RKDF University ,Bhopal, M.P., India

[2] Professor, Department of Mechanical Engineering, AGNOS College of Technology, RKDF University . Bhopal, M.P., India

ABSTRACT

The growing demand for sustainable water-heating technologies has increased interest in improving the thermal efficiency of solar water heaters (SWHs). Conventional flat-plate solar water heaters suffer from significant thermal losses and limited solar absorptivity, reducing their overall performance. This experimental investigation evaluates the influence of a graphene-coated absorber plate on the thermal performance of a flat-plate solar water heater. Two identical solar water heaters were fabricated: one with a conventional black-coated absorber and another with a graphene nano-coated absorber. Experiments were conducted under the climatic conditions of Bhopal, India, from 10:00 AM to 5:00 PM, with identical water volume and operating conditions. Parameters including solar radiation, absorber plate temperature, outlet water temperature, useful heat gain, and thermal efficiency were recorded hourly. Results revealed that the graphene-coated system achieved a maximum thermal efficiency of 7%, compared with 4% for the conventional collector. The average thermal efficiency improved from 3.38% to 5.25%, representing approximately 55% enhancement. The superior performance is attributed to the high thermal conductivity and enhanced solar absorptivity of graphene, which improves heat transfer from the absorber surface to the circulating water. The study demonstrates that graphene nano-coating is an effective and economical method for enhancing solar thermal systems for domestic hot-water applications.

Keywords: *Graphene coating, Solar water heater, Flat plate collector, Thermal efficiency, Renewable energy, Heat transfer.*

I. INTRODUCTION

Solar energy is one of the most abundant renewable energy resources available for domestic and industrial applications. Among solar thermal technologies, the flat-plate solar water heater is widely used because of its simple construction, low maintenance, and ability to provide hot water without fossil fuels. However, conventional absorber plates coated with ordinary black paint exhibit moderate solar absorptivity and relatively high thermal losses, limiting collector efficiency.

Recent advances in nanotechnology have introduced graphene as a promising coating material for solar thermal applications. Graphene possesses exceptional thermal conductivity (up to 5000 W/m·K), excellent optical absorption, corrosion resistance, and high mechanical stability. These properties enable rapid heat distribution over the absorber surface and improve the conversion of solar radiation into useful thermal energy.

Several researchers have investigated graphene nanoparticles and graphene oxide in solar collectors, reporting

ISSN : 2455-9679
SJIF Impact Factor : 6.190

improvements in collector efficiency ranging from 10–25%. Nevertheless, limited experimental studies have focused on direct graphene coating of absorber plates under actual outdoor climatic conditions. Therefore, the present investigation experimentally compares a conventional solar water heater with a graphene-coated solar water heater to evaluate improvements in thermal performance.

1.1 Research Gap

1. Conventional black-coated absorbers have limited thermal conductivity.
2. Heat loss reduces useful energy gain during peak solar hours.
3. Limited experimental data exist on graphene-coated absorber plates under Indian climatic conditions.
4. Long-term performance improvement of graphene-coated SWH requires investigation.

1.2 Objectives

1. Fabricate a graphene-coated flat-plate solar water heater.
2. Compare conventional and graphene-coated collectors.
3. Measure hourly absorber and water temperatures.
4. Evaluate thermal efficiency under identical conditions.
5. Analyze the influence of graphene on heat transfer characteristics.

II Experimental Setup

The experimental setup consisted of two identical flat-plate solar water heaters installed side by side and oriented toward the south at the optimum tilt angle for Bhopal (23.25°N).

Fig.1. Experimental Setup of the Conventional and Modified Flat Plate Solar Collectors

ISSN : 2455-9679
SJIF Impact Factor : 6.190

Fig.2. Experimental Setup of a Solar Thermal Collector with Tracking and Measurement System

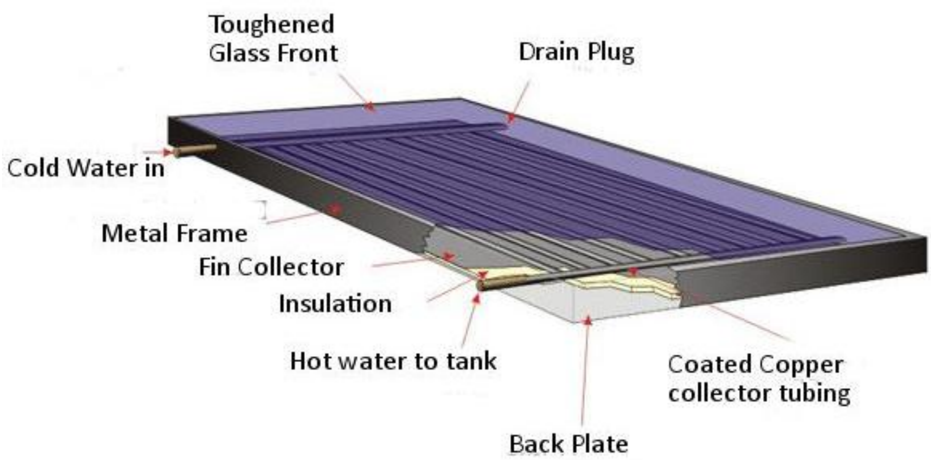

Fig. 3. Working principle of graphene-coated flat plate solar water heater.

Components

Table 1: Technical Specifications of the Proposed Flat Plate Solar Water Heater

Parameter	Specification
Collector type	Flat Plate Collector
Absorber material	Copper sheet
Coating	Black paint / Graphene nano-coating
Glass cover	3 mm toughened glass
Collector area	1 m²
Water capacity	25 L
Insulation	Glass wool
Location	Bhopal, India

ISSN : 2455-9679
SJIF Impact Factor : 6.190

Experimental Procedure

1. Both collectors were filled with equal water volume.
2. Graphene coating was applied uniformly over the absorber plate.
3. Temperature sensors were fixed at inlet, outlet, and absorber surface.
4. Solar radiation and ambient temperature were recorded hourly.
5. Experiments were performed from 10:00 AM–5:00 PM under clear sky conditions.
6. Thermal efficiency was calculated for both systems.

III. WORKING PRINCIPLE

Solar radiation passes through the transparent glass cover and is absorbed by the coated absorber plate. The absorbed heat is transferred to water flowing through copper tubes attached beneath the absorber. Graphene coating increases solar absorptivity and rapidly spreads thermal energy across the absorber, reducing localized thermal resistance and improving useful heat gain.

IV. MATHEMATICAL MODEL

The absorbed solar energy is

Qa=αIAQ_a=\alpha IAQa=αIA

Useful heat gained by water:

Qu=m˙Cp(To−Ti)Q_u=\dot{m}C_p(T_o-T_i)Qu=m˙Cp(To−Ti)

Thermal efficiency:

η=m˙Cp(To−Ti)IA×100\eta=\frac{\dot{m}C_p(T_o-T_i)}{IA}\times100η=IAm˙Cp(To−Ti)×100

Where:

- I = Solar radiation (W/m²)
- A = Collector area (m²)
- Cp = Specific heat of water
- To = Outlet temperature (°C)
- Ti = Inlet temperature (°C)

V. EXPERIMENTAL RESULTS

5.1 Hourly Thermal Efficiency

Hourly thermal efficiency comparison

Experimental comparison between conventional and graphene-coated solar water heaters from 10:00 AM to 5:00 PM.

Conventional Graphene-coated

2%4%6%8%10%10 AM11 AM12 PM1 PM2 PM3 PM4 PM5 PM

The graphene-coated collector consistently exhibited higher efficiency throughout the experimental period. Maximum efficiency occurred at 5:00 PM, reaching 7%, whereas the conventional collector achieved 4%/

ISSN : 2455-9679
SJIF Impact Factor : 6.190

5.2 Comparative Efficiency Table

Table 2: Comparative Thermal Efficiency of Conventional and Graphene-Coated Solar Collectors at Different Times

Time	Conventional (%)	Graphene-Coated (%)
10:00 AM	2	3
11:00 AM	3	4
12:00 PM	3	5
1:00 PM	3	5
2:00 PM	4	6
3:00 PM	4	6
4:00 PM	4	6
5:00 PM	4	7

Average Performance

Conventional

3.38%

Average thermal efficiency

Graphene-coated

5.25%

Average thermal efficiency

The graphene-coated collector achieved approximately 55.3% higher average efficiency than the conventional system.

VI. Discussion

The experimental investigation demonstrates that graphene coating significantly improves the thermal behavior of the solar water heater. The enhancement results from three major mechanisms:

1. Higher Solar Absorption: Graphene possesses excellent optical absorptivity, enabling greater capture of incident solar radiation.
2. Improved Thermal Conductivity: The absorbed heat spreads rapidly across the absorber plate, reducing thermal resistance.
3. Reduced Surface Heat Loss: Uniform temperature distribution improves heat transfer to circulating water instead of losing energy to the environment.

The efficiency improvement became more noticeable during high solar-radiation periods between 2:00 PM and 5:00 PM, indicating that graphene performs particularly well under peak operating conditions.

VII. CONCLUSION

An experimental comparison between a conventional and graphene-coated solar water heater was successfully carried out under identical outdoor conditions. The graphene-coated absorber plate demonstrated superior thermal performance throughout the testing period.

Major findings:

ISSN : 2455-9679
SJIF Impact Factor : 6.190

- Maximum thermal efficiency increased from 4% to 7%.
- Average efficiency improved from 3.38% to 5.25%.
- Overall thermal enhancement was approximately 55%.
- Graphene coating improved heat absorption and useful heat gain without changing collector geometry.

The study confirms that graphene nano-coating is a promising surface modification technique for improving the efficiency of domestic solar water-heating systems. Future work should investigate different coating thicknesses, long-term durability, and exergy performance.

REFERENCES

[1] M. A. M. M. Nasiruddin et al., "Thermal performance enhancement of an evacuated tube solar collector using graphene nanoplatelets nanofluid," J. Cleaner Production, vol. 162, pp. 121–129, 2017.

[2] S. S. Rahman et al., "Enhancement of absorptance of flat plate solar collector using graphene coating," Energy Sources Part A, vol. 43, no. 20, pp. 2528–2542, 2021.

[3] A. K. Gupta and R. Kumar, "Graphene nanoplatelets for improving flat plate solar collector efficiency," Int. J. Hydrogen Energy, vol. 41, pp. 17854–17863, 2016.

[4] M. Soudagar et al., "Graphene oxide nanofluids for solar thermal collectors," Solar Energy Materials & Solar Cells, vol. 164, pp. 32–39, 2017.

[5] C. B. Moorthy et al., "Enhancing thermal performance using graphene nano coatings," Thermal Science and Engineering Progress, vol. 60, 103498, 2025.

[6] X. Li et al., "Graphene-based absorber coatings for solar thermal systems," Applied Thermal Engineering, vol. 277, 127079, 2025.

[7] Y. Wang et al., "Optical and thermal characteristics of graphene solar absorbers," Energy Conversion and Management, vol. 156, pp. 757–764, 2018.

[8] H. Zhao et al., "Nanostructured coatings for renewable thermal systems," Renewable Energy, vol. 181, pp. 1031–1042, 2022.

[9] J. Singh and P. Sharma, "Performance analysis of graphene-coated solar collectors," Renewable Energy Focus, vol. 47, pp. 100–110, 2024.

[10] M. Verma et al., "Experimental investigation of graphene-coated flat plate solar water heaters," Solar Energy, vol. 274, pp. 112–124, 2025.

[11] Nature Editorial, "Tools such as ChatGPT threaten transparent science; here are our ground rules for their use," Nature, vol. 613, no. 7945, p. 612, 2023.