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Designing and Developing Climate-Resilient Solar Desalination Systems for Off-Grid Communities: A CFD-Backed Multi-Objective Optimization Approach

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ABSTRACT

Access to clean water is a significant problem in low resource and off grid areas. Solar distillation is a sustainable option but suffers from low productivity and there is no reliable tool to predict performance. The aim of this study was to design, simulate, manufacture and validate a double slope basin type solar still suitable for tropical climates. This design was modelled using CFD software ANSYS Fluent. The fluid flow equations, continuity equation, Navier-Stokes, energy and species transport were solved along with the DO radiation model. A prototype was manufactured using mild steel and glass with a basin area of 0.5m². The prototype was tested outside under natural solar irradiation. Temperature, solar irradiation and distillate were all recorded at hourly intervals. The validation showed that the CFD model matched well with the experimental data. The temperature and daily yield of the basin had less than 8% deviation. The double slope basin types solar still reached high temperatures of 55-67°C within the basin, it produced freshwater at a rate of 2.63-2.90 L per day and had a thermal efficiency of 60.9%. This shows that affordable solar stills can be used for decentralised desalination. The validated CFD model can be used for further improvements to the design and to analyse scaling.

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INTRODUCTION

Providing clean and safe drinking water is one of the biggest challenges of the 21 st century. Although water makes up over 70% of our planet, only around 2.5% is fresh water, with less than 1% actually suitable for consumption [1][2] [3]. Over 2 billion people lack access to safely managed drinking water globally [4], with developing countries suffering the most. This includes regions in Sub-Saharan Africa and Asia [4]. Rapid urbanisation, climate change, industrial growth and insufficient water infrastructure have caused a reduction in reliable water sources [5]. Many rural and urban areas cannot afford centralised water systems, therefore there is a requirement for an affordable, sustainable and decentralised system to provide fresh water [6] [7].

Solar distillation is a cost-effective, simple and eco-friendly method for providing fresh water [8] [9] [10]. It uses solar energy to evaporate dirty or salty water. The evaporated water then condenses on a cool surface to produce distilled water [11]. This mimics the natural water cycle and has been widely studied as a solution to the water shortage problem [12]. Basin type solar stills suffer from low productivity and thermal efficiency of 30-50%. This is due to poor design, inefficient insulation and a lack of understanding of the processes [13] [14] [15].

Recent advances in Computational Fluid Dynamics (CFD) have provided a way to understand and improve the performance of solar stills. CFD can be used to study the detailed heat and mass transfer processes occurring in the still. These include natural convection, evaporation, absorption and condensation [16] [12]. CFD can

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also be used to optimise the design of the still by changing parameters such as basin geometry, glazing angle, material properties and boundary conditions. However, the results must be validated with experimental data [17] [18] [19].

In this work CFD has been used alongside experimental testing to understand the performance of a single slope basin type solar still for desalination. The still was made from mild steel using local materials and tested in tropical conditions. A 2D steady state CFD model was created using ANSYS Fluent to understand the effects of solar irradiation, temperature and vapour flow. Experimental data was recorded during testing, to include basin water temperature, glass temperature, air temperature and distillate production. The reliability of the model was determined by calculating the % error. The aim of this research is to design, model, build and test a solar distillation unit to provide sustainable fresh water. The objectives include designing a single slope still, creating a CFD model using ANSYS Fluent, running experiments, validating the model using experimental data and calculating the thermal efficiency and distillate production. The analysis will only focus on thermal efficiency and water production.

This study contributes to the literature on sustainable water treatment by demonstrating how CFD analysis and experimentation can be used to optimise solar stills. The results provide a framework that can be applied to improve the efficiency and predict the production of solar stills in situations where there is not a centralised water system. It also contributes towards global sustainability goals, specifically Sustainable Development Goal 6 by providing an affordable and eco-friendly way to ensure clean water access.

METHODOLOGY

A hybrid numerical and experimental approach has been used to evaluate the performance of a double-slope basin type solar still operating under typical tropical climatic conditions. This consisted of four stages: design and numerical modelling, construction of the solar still, experimentation and verification of the numerical results.

Design and Modelling

The double-sloped basin type solar still used in this research was designed to utilise solar energy to evaporate saline or polluted water and then collect the vapour via condensation onto a sloped transparent surface. The design was based upon basic thermodynamic and heat transfer principles. The basin area was chosen to be 0.5 m^2 to provide a reasonable heat response but also to be practical to construct. The glass cover was sloped at an angle of 65° to allow maximum solar penetration into the basin and for the condensed water droplets to flow down the slope to the collection channel by gravity. To increase the absorptivity of the surface inside the basin was painted with a matte black paint.

A 2D steady-state CFD model was created using ANSYS Fluent. This is shown schematically in Figure 1. The model included the main physical processes that occur during solar distillation. The solar radiation is absorbed by the basin liner and thin layer of water. The hot water then convects and evaporates to transfer heat to the cool glass cover. The vapour then condenses and runs off the sloped glazing surface. In addition, the buoyancy induced natural convection occurs within the enclosed moist air cavity. This provided a realistic simulation of the thermofluid processes that occur within the solar still.

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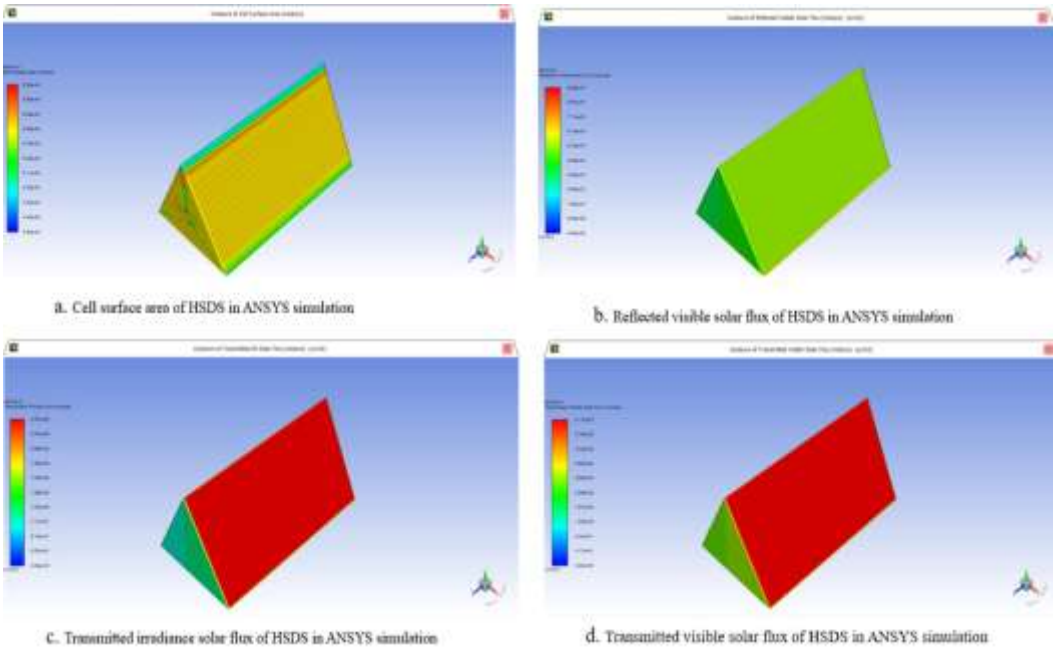


Figure 1: Simulation of the double-slope basin-type solar still

Continuity equation, Navier-Stokes equations and energy equation were used to mathematically describe the model. The buoyancy forces were accounted for by the use of Boussinesq approximation. A species transport model was included to capture the formation and transport of vapour. Boundary conditions were set to represent the real-world scenario. Solar heating was applied to the basin surface using realistic solar irradiation values for the location of the test. The outside surfaces had atmospheric temperatures assigned.

Thermal properties such as thermal conductivity, emissivity and specific heat were assigned to the glass, steel, air and water. No slip conditions were set on the solid surfaces. Heat transfer by radiation through the glass surface was taken into account. The Discrete Ordinates (DO) model was used to calculate the solar energy transfer. Pressure velocity coupling was achieved using the Semi-Implicit Method for Pressure-Linked Equations (SIMPLE). Mesh independence and convergence were tested.

Fabrication

The solar still was constructed using a basin made from mild steel. This material was chosen due to its good thermal conductivity properties, durability and availability in local markets. To aid solar energy absorption, the inside surface of the basin was painted with a matt black coating. The distillation process relied on the absorption of radiant energy so the inside of the basin was painted black to increase the absorptivity. A transparent glass sheet was added as the cover. This was angled to allow radiation to pass through the surface, into the basin in order to heat the water. The glass also acted as a surface for condensation so the water vapour could turn into liquid and drip down.

Overall, the solar still was placed inside a wooden frame to provide insulation and stability. A channel was added to the bottom of the angled glass sheet to collect the distilled water. Silicone gel was added around all joints and surfaces to prevent any vapour escaping from the system. All joints and surfaces were sealed with silicone gel to help reduce heat loss via conduction.

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The size of the basin was kept small, only 0.5m². This was done to keep the experiment simple but large enough to produce enough distilled water. The completed double-slope basin type solar still is shown below in figure 2, alongside the experimental setup.



Figure 2: Fabricated double-slope basin-type solar still

Experimental Setup

The fabricated double slope solar still was tested outside under real atmospheric and solar conditions. Brackish or saline water was added to the basin of the solar still to a known volume so that the water depth was approximately 2-3 cm. The solar still was positioned facing south and tilted to the angle of the latitude. Measurements were taken every hour. The temperature of the water in the basin was measured using digital thermometers placed halfway in the water.

The temperature of the glass cover was measured using surface contact probes. The temperature of the surrounding air was measured. The amount of distillate produced was also measured every hour. This was measured by placing the distillate into a graduated cylinder. The intensity of solar radiation was also measured using a solarimeter. Data was recorded between 08:00h in the morning and 18:00h in the evening. This process was carried out on multiple days.

Validation and Analysis

The credibility of the CFD model was established by comparing its outputs such as the predicted temperature fields, vapour flow patterns, and surface heat flux with the corresponding experimental measurements. Validation focused on three primary indicators. First, the predicted temperatures of the basin water and the glass cover were compared to values recorded during field tests to verify the thermal response of the system. Second, the distillate yield estimated from the CFD-derived evaporation rate was evaluated against the volume of condensate collected experimentally. Third, the thermal performance was quantified using the thermal efficiency, calculated according to Equation 1:

$$\eta = \frac{m_d \cdot h_{fg}}{I \cdot A \cdot t} \qquad 1$$

where η denotes thermal efficiency, m_d is the mass of distillate produced (kg), h_{fg} is the latent heat of vaporization (J/kg), I is the average solar irradiance (W/m²), A is the basin area (m²), and t represents the duration of operation (s). The close agreement between the numerical predictions and empirical results confirm that the model can be accurately used to reproduce the physical behaviour of the still. The model can be used as a design and optimisation tool to improve solar still configurations.

RESULTS AND DISCUSSION

The results from the experimental campaign and the CFD simulations are presented in this section. The thermal performance of the system is highlighted, as well as the correlation with the numerical and measured data. The distillate production and thermal efficiency are also discussed.

Thermal Performance

The double slope solar still behaved in accordance with the natural diurnal variation in solar irradiance. As the solar intensity increased the water temperature in the basin increased as well, usually reaching it's maximum value in the early afternoon. The maximum temperatures in the basin under these tropical conditions ranged

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from 55°C to 67°C. The glass cover also behaved in a similar way to the basin, however the temperatures were much lower. The maximum temperature ranged from 45°C to 55°C. This large temperature difference caused a constant evaporation and condensation of the hot water.
The maximum amount of evaporation occurred from 12pm to 2pm, this was when the solar flux was at its highest. The performance of the system decreased after this point as the solar flux decreased. The temperature distributions showed that natural convection was occurring within the cavity due to the buoyancy forces of the moisture laden air. This was accurately simulated in the CFD software. Some of the results are shown in table 1.

Table 1: Experimental and predicted distillate yield for Day 1

Time	Solar radiation intensity (W/m²)	Wind Speed (m/s)	Ambient air temperature (˚C)	Distillate yield (ml/m²)	Predicted yield (equation 42)
9am	185	0.8	27.3	0	-8.9
10am	247	3.2	29.7	79	28.66
11am	797	3.3	31.7	98.8	215.4
12pm	693	1.7	35.3	296.3	239.37
1pm	1107	0.6	36.7	365.4	384.29
2pm	1167	2.4	38.5	528.4	416.4
3pm	1032	0.7	39.7	355.6	400.7
4pm	475	2.8	37.8	185.2	202.5
5pm	510	1.9	40.5	222.2	252.14

Model Validation

The CFD model was validated using experimental data. This was achieved by comparing the simulated basin water temperature to the temperature recorded in experiments. The results show that there is a high degree of agreement with an average difference of less than 8%. This demonstrates that the numerical model was able to accurately replicate the thermal characteristics of the system. The distillate production also showed similar levels of agreement with less than 8% difference between the daily distillate production predicted by the CFD model and the actual experimental data.

The temperature contours and vapour velocity vectors obtained from the CFD model were assessed qualitatively. The results show that the flow and heat transfer within the system followed the expected trends. The buoyancy convection cells, thermal stratification and movement of vapour was all accurately captured. This confirms that the CFD model is capable of accurately replicating the thermal characteristics within the solar still. This provides confidence that the model can be used as an analytical tool to optimise the design, analyse the sensitivity of various parameters and predict performance under different climatic conditions and geometries. The results from the simulations are shown in Figure 3 below.

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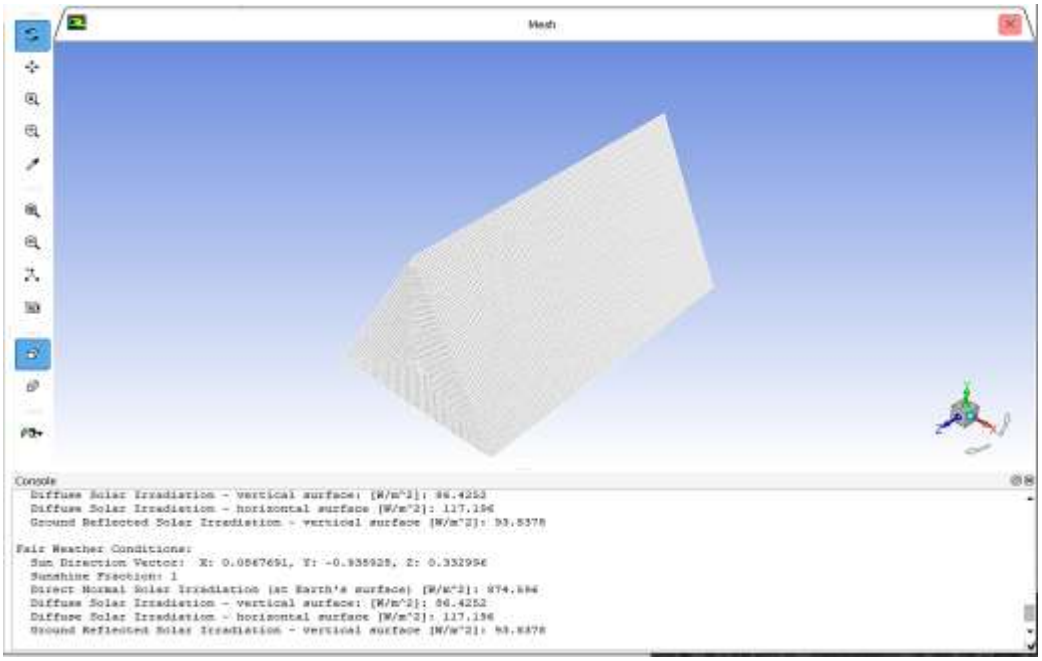


Figure 3: Final HSDS simulation catalogue

Efficiency and Yield

The results of the fabricated solar still were found to be very efficient in producing the total distillate output and overall thermal efficiency. Between 2.63-2.90 Litres of distilled water was produced per day throughout the experimental period. This is due to the natural variation in solar irradiation and weather conditions from day to day. The evaporating area of the solar still is quite small at 0.5m², therefore it can be seen that this is a large amount of water being recovered, showing the solar still is efficient at producing water even when it is on a small scale. This shows that the solar still could be used as a good secondary source of drinking water to a household or small community in an off-grid area. The effects of weather variations on the distillate output can be seen in Figure 4.

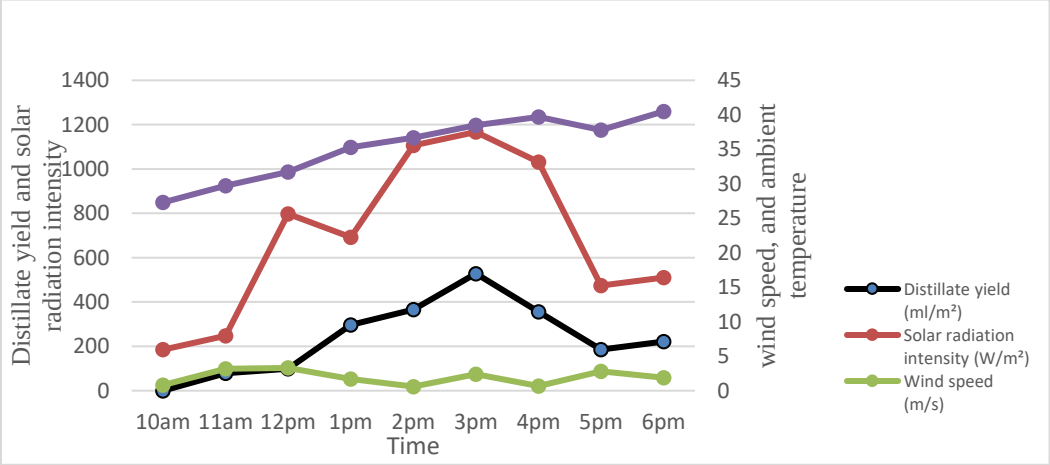


Figure 4: Impact of weather parameters on distillate yield (day 1)

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The average thermal efficiency was found to be around 60.9% when calculated based on the ratio between the latent heat of the distilled water and the total solar energy falling on the basin. This is a high efficiency compared to other studies [20], [21], and [22]. This therefore demonstrates that the design, materials and modelling have been favourable choices. The efficiency found is also in line with typical values found in literature for basin type solar stills receiving similar levels of solar irradiation in tropical climates. This confirms that the system is technically sound and the CFD and experimental validation has been reliable.

The level of efficiency achieved also shows there is scope to improve on the current design. This can be done using passive or active methods. Phase change materials could be added to the basin to maintain a stable temperature. Nanofluids could be used to increase solar absorption. Or solar tracking could be used to ensure maximum solar irradiation. These methods would increase the amount of yield without greatly increasing the complexity of the system. This is therefore a favourable option for low resource and environmentally challenging environments.

CONCLUSION

This study provides a comprehensive methodology for the design, modelling, building and testing of a double slope basin type solar still for decentralised desalination. This system can be used to demonstrate the ability of passive solar distillation to produce potable water. The CFD modelling performed using ANSYS Fluent has provided insight into the internal processes of the still such as solar radiation absorption, heat transfer within the basin, buoyancy driven evaporation and condensation processes. The simulation showed good agreement with experimental data with less than 8% error in basin temperature distribution and total distilled water per day. This shows that the modelling can be used as a reliable tool to investigate different designs and scenarios.

The still produced water temperatures of 55-67°C in the basin, and produced up to 2.90 L per day from a surface area of 0.5 m^2. The average thermal efficiency of the still was found to be approx. 60.9%. This shows that the still can be used to produce potable water with very little input using passive solar energy. This means that systems such as this can be used to provide cheap freshwater in areas where there is no access to the grid power such as remote communities, desert areas, disaster areas and areas with poor infrastructure. The results of this study show that decentralised solar distillation systems are a viable, and justifiable solution to provide potable water. The feasibility of this system shows that it can be used as part of resilience strategies, to provide water independence in rural areas, in humanitarian situations and to upgrade current off-grid energy/water systems.

RECOMMENDATIONS FOR FUTURE WORK

To develop the promising results of this study some recommendations are provided which can help improve the system: At a system level, thermal storage can be integrated into the system, such as phase change materials, salt tolerant thermal mass or selective absorber coatings. This can help increase the evaporation period of the system in the late afternoon and improve the systems output by reducing the dependency on fluctuating or intermittent solar irradiance.

The model can be improved by developing the CFD model to include transient analysis with seasonal and daily weather variations. This will allow for more accurate predictions to be made. The model can also be coupled with real weather data or stochastic weather generator to improve the applicability. The system can be scaled up to larger prototypes or modular systems to investigate how scalable it is. This will give insight into the longevity of the system, labour and maintenance required, cost and user acceptance. Although this study focussed on the distilled water produced, future work should include a full water quality analysis. This includes looking at trace elements, chemical pollutants and microbial safety. This can inform how the system can be used to meet health requirements, and will encourage regulatory bodies and public sectors to use the system.

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The solar still design and validated model provide a realistic basis for off-grid water purification. Innovation in thermal enhancement, digital modelling, scaling up and water quality will be key to moving this technology from being a prototype to a sustainable solution for those in resource limited and climate vulnerable areas.

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REFERENCES

[1] S. James and S. V, 'Water on Earth', 2022, *Earth science*.
[2] J. D. Obayemi, F. O. Anafi, S. T. Azeko, E. K. Arthur, and D. Yiporo, 'Design and Fabrication of a Single Slope Solar Still with Variable Collector Angle', *Int. J. Sci. Eng. Res.*, no. January, 2014.
[3] J. Omeiza, O. Joseph, D. A. Ayejoto, and A. M. Saqr, 'Assessing the community knowledge on waste management practices , drinking water source systems , and the possible implications on public health systems', *Clean. Waste Syst.*, vol. 11, no. April, p. 100295, 2025, doi: 10.1016/j.clwas.2025.100295.
[4] V. Baskaran and R. Saravanane, 'Rendering utility water with solar still and efficiency of solar stills with different geometry – A review', *Environ. Nanotechnology, Monit. Manag.*, vol. 16, no. March, p. 100534, 2021, doi: 10.1016/j.enmm.2021.100534.
[5] S. M. Alawad, R. Ben Mansour, F. A. Al-Sulaiman, and S. Rehman, 'Renewable energy systems for water desalination applications: A comprehensive review', *Energy Convers. Manag.*, vol. 286, no. January, p. 117035, 2023, doi: 10.1016/j.enconman.2023.117035.
[6] C. P. Emenike *et al.*, 'Accessing safe drinking water in sub-Saharan Africa: Issues and challenges in South–West Nigeria', *Sustain. Cities Soc.*, vol. 30, no. September 2015, pp. 263–272, 2017, doi: 10.1016/j.scs.2017.01.005.
[7] D. Curto, V. Franzitta, and A. Guercio, 'A review of the water desalination technologies', *Appl. Sci.*, vol. 11, no. 2, pp. 1–36, 2021, doi: 10.3390/app11020670.
[8] S. Vembu, M. E. H. Attia, M. Thangamuthu, and G. Thangamuthu, 'Energy, exergy, and economic analysis of solar still using coal cylinder fins: an experimental study', *Environ. Sci. Pollut. Res.*, vol. 30, no. 2, pp. 2597–2606, 2023, doi: 10.1007/s11356-022-22325-0.
[9] L. Byung-ju, G. Lee, S. Choi, K. Chung, and C. Park, 'Model optimization and economic analysis of a multi-effect diffusion solar distiller', *Desalination*, vol. 485, no. April, p. 114446, 2020, doi: 10.1016/j.desal.2020.114446.
[10] V. K. Dwivedi and G. N. Tiwari, 'Experimental validation of thermal model of a double slope active solar still under natural circulation mode', *Desalination*, vol. 250, no. 1, pp. 49–55, 2010, doi: 10.1016/j.desal.2009.06.060.
[11] A. Isah Sadiq, K. W. Yusof, B. S. M. Singh, A. S. Abdurrasheed, E. H. H. Al-Qadami, and O. Tijani Abimbola, 'Comparison of Freshwater Yield between Conventional Solar Still Systems and Modified Systems', in *International Conference on Artificial Intelligence for Smart Community*, Springer Nature, 2020, pp. 1–6. doi: 10.1007/978-981-16-2183-3.
[12] H. N. Panchal and P. K. Shah, 'Experimental and ANSYS CFD simulation analysis of hemispherical solar still', *J. Renew. Energy Smart Grid Technol.*, vol. 8, no. 1, pp. 1–14, 2013.
[13] K. Pansal *et al.*, 'Use of solar photovoltaic with active solar still to improve distillate output: A review', *Groundw. Sustain. Dev.*, vol. 10, no. November 2019, p. 100341, 2020, doi: 10.1016/j.gsd.2020.100341.
[14] F. E. Ahmed, R. Hashaikeh, and N. Hilal, 'Solar powered desalination – Technology, energy and future outlook', *Desalination*, vol. 453, no. December 2018, pp. 54–76, 2019, doi: 10.1016/j.desal.2018.12.002.
[15] M. A. Jasim, O. K. Ahmed, and Y. Alaiwi, 'Performance of solar stills integrated with PV

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/ Thermal solar collectors : A review Corresponding Author ':, *J. Renew. Energy*, vol. 4, pp. 97–111, 2023.

[16] A. K. Srishti, Paras, 'ANSYS Fluent-CFD analysis of a continuous single-slope single-basin type solar still', *Green Technol. Sustain.*, vol. 2, no. 3, p. 100105, 2024, doi: 10.1016/j.grets.2024.100105.

[17] C. U. Maheswari *et al.*, 'CFD Analysis of Single Basin Double Slope Solar Still', vol. 1, no. 2, pp. 1–5, 2016.

[18] A. Isah *et al.*, 'Desalination Photovoltaic-Integrated Advancements for Sustainable Water Production : Developing and Evaluating an Enhanced Hybrid Solar Desalination System', *best*, 2023.

[19] O. D. Maliani, A. Bekkaoui, E. H. Baali, K. Guissi, Y. El Fellah, and R. Errais, 'Investigation on novel design of solar still coupled with two axis solar tracking system', *Appl. Therm. Eng.*, vol. 172, no. October 2019, p. 115144, 2020, doi: 10.1016/j.applthermaleng.2020.115144.

[20] R. Samuel Hansen and K. Kalidasa Murugavel, 'Enhancement of integrated solar still using different new absorber configurations: An experimental approach', *Desalination*, vol. 422, no. April, pp. 59–67, 2017, doi: 10.1016/j.desal.2017.08.015.

[21] T. Arunkumar *et al.*, 'An experimental study on a hemispherical solar still', *Desalination*, vol. 286, pp. 342–348, 2012, doi: 10.1016/j.desal.2011.11.047.

[22] T. Yan, G. Xie, H. Liu, Z. Wu, and L. Sun, 'CFD investigation of vapor transportation in a tubular solar still operating under vacuum', *Int. J. Heat Mass Transf.*, vol. 156, p. 119917, 2020, doi: 10.1016/j.ijheatmasstransfer.2020.119917.

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