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Optimizing Glass Tilt Angles (15° to 55°) and Planar Reflectors in Single-Slope Solar Stills: Experimental Insights from Al Bayda, Libya

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Abstract:

Selecting the glass-cover tilt angle of a single-slope solar still requires balancing optical transmission, condensate-droplet drainage, and internal air-cavity heat losses. In this study seven cover tilt angles (15°, 22°, 27°, 32°, 37°, 45°, 55°) were tested outdoors in Al Bayda, Libya (32°45′N, 21°45′E) during May–June 2024, together with internal and external planar reflector boosts. The bare-still optimum occurred at 32° — practically the local latitude — delivering 4.20 L/m²·day at 42.6% daily thermal efficiency. At shallow angles (15°, 22°), surface tension pinned droplets to the underside of the glass and over 35% of the condensate fell back into the brackish basin. At steep angles (45°, 55°), the internal air cavity expanded to ≈2.85× its 15° volume, intensifying top convective losses and dropping the yield to 3.45 and 2.85 L/m²·day. Adding polished internal wall reflectors ($\rho = 0.88$) at 32° raised output to 5.15 L/m²·day (+22.6%); adding a top external mirror ($\rho = 0.90$) pushed the peak water temperature to 84.2 °C and the daily yield to 5.85 L/m²·day (+39.3% over the 32° reference; +88.7% over the 15° still) at 54.8% thermal efficiency (defined against total intercepted radiation). Dual reflectors reduced the calculated unit water cost from \$0.024/L to \$0.019/L, indicating improved economic performance relative to the 32° reference configuration.

Keywords: Solar desalination; tilt angle; droplet runoff; planar reflectors; internal cavity; latitude alignment; Al Bayda.

1. Introduction

Single-slope solar stills remain one of the simplest passive technologies for producing freshwater from saline or brackish water, particularly in regions where decentralized and low-energy water-treatment technologies are required. Their simple construction, passive operation, and ability to operate without complex mechanical systems make them attractive for small-scale and remote applications (Al-Addous et al., 2024). However, the productivity of a single-slope solar still is governed by the interaction of several optical, thermal, and condensation-related processes, and consequently depends strongly on both the system geometry and the prevailing climatic conditions.

Among the geometric parameters, the inclination of the transparent glass cover is particularly important because it influences the transmission of incident solar radiation, the geometry of the internal vapor space, and the condensation and drainage of water vapor on the inner glass surface. Recent investigations have demonstrated that changing the cover inclination can produce substantial differences in solar-still productivity under different seasonal and climatic conditions. Experimental and numerical investigations have confirmed that solar-still productivity is strongly dependent on glass-cover inclination, with the optimum angle varying according to basin-water depth, climatic conditions, and system geometry (Al-Garni et al., 2020; Akash et al., 1998).

In particular, Ketata and Driss (2023) experimentally and numerically investigated the effect of glass-cover inclination under Tunisian winter and summer conditions and demonstrated that the influence of cover slope varies with the operating season and environmental conditions. Similarly, recent reviews have identified glass-cover inclination as an important geometric parameter affecting the thermal and productivity characteristics of solar stills (Panchal et al., 2022).

The effect of cover inclination is therefore not limited to the amount of solar radiation entering the still. Changes in inclination can also alter the optical path through the transparent cover and the behavior of condensed droplets on its inner surface. The inclination determines the gravitational component acting on condensate droplets and therefore influences the extent to which condensed water drains toward the collection channel rather than remaining on the glass surface or returning to the basin. At the same time, changes in cover geometry modify the internal vapor cavity and the natural-convection pathways between the heated basin water and the relatively cooler glass cover. These coupled effects can influence the temperature difference driving evaporation and condensation and ultimately affect the daily distillate yield (AbdelMeguid & El Awady, 2024; Ketata & Driss, 2023).

Consequently, the selection of an appropriate cover inclination represents a compromise between solar-energy transmission, condensate drainage, and internal heat-transfer behavior. The optimum angle cannot necessarily be considered universal because it may vary with geographical location, season, solar elevation, still geometry, and operating conditions **(Al-Garni et al., 2020; Kabeel et al., 2022)**. This makes experimental determination of the optimum inclination particularly important when a solar still is intended for practical application under a specific local climate.

In addition to optimizing cover inclination, increasing the solar radiation available to the basin is an important strategy for improving solar-still productivity. Passive planar reflectors provide a relatively simple approach for redirecting additional solar radiation toward the evaporating surface without requiring mechanical solar tracking The use of reflective surfaces has been investigated as a passive method for increasing the solar energy absorbed by the basin and consequently enhancing evaporation and distillate production (Tanaka, 2006; Abdelgaleel et al., 2024). Kabeel and Kandel (2021) experimentally demonstrated the potential of a planar reflector to enhance the radiation incident on a solar still and consequently improve its water productivity. More recently, Abu-Zeid et al. (2024) demonstrated that incorporating an internal reflecting mirror into a solar-still configuration increased basin-water temperature and improved distillate productivity and thermal performance.

Despite these developments, the effects of cover inclination and passive reflector configuration have often been investigated as individual enhancement strategies rather than as components of a systematically optimized configuration. Recent studies have established that cover inclination can substantially affect solar-still productivity and that reflector-based modifications can provide additional performance gains **Recent experimental work has also demonstrated that internal reflecting surfaces can substantially increase solar-still productivity and thermal efficiency while reducing the calculated cost of produced water (Abdelgaleel et al., 2024).** (Ketata & Driss, 2023; Abu-Zeid et al., 2024). However, experimental investigations that first examine a relatively wide range of cover inclinations and then evaluate both internal and external planar reflectors at the experimentally determined optimum angle under the same outdoor climatic conditions remain limited.

This research gap is particularly relevant to northeastern Libya, where the local solar conditions and seasonal variation may produce an optimum cover inclination that differs from values reported for other geographical locations. Moreover, limited experimental information is available regarding the combined performance of an optimized single-slope solar still and passive planar reflectors under the climatic conditions of Al Bayda, Libya. A systematic local investigation is therefore necessary to determine the experimentally optimum cover inclination and to establish whether reflector-assisted operation can provide a meaningful additional improvement in productivity and thermal efficiency.

Accordingly, the objectives of the present study were to: (1) experimentally evaluate the performance of a single-slope solar still at seven glass-cover inclination angles (15°, 22°, 27°, 32°, 37°, 45°, and 55°) under outdoor conditions in Al Bayda, Libya; (2) identify the experimentally optimal cover inclination by comparing daily distillate productivity and thermal efficiency across the tested angles; (3) characterize the influence of cover inclination on effective solar transmittance, condensate drainage, and the thermal behavior of the internal air cavity; (4) quantify the productivity enhancement obtained by incorporating polished internal wall reflectors and an adjustable external planar reflector at the identified optimum inclination of 32°; (5) compare the thermal efficiency, peak basin-water temperature, hourly distillate production, and calculated unit water cost of the reference and reflector-assisted configurations; and (6) evaluate the practical potential of combining the experimentally optimized cover inclination with passive planar reflectors for improving solar-still freshwater productivity under the climatic conditions of Al Bayda, Libya.

Nevertheless, experimental studies that systematically examine a relatively wide range of cover inclinations and subsequently evaluate both internal and external planar reflectors at the experimentally identified optimum angle under the same local climatic conditions remain limited. In particular, there is a lack of experimental data for single-slope solar stills operating under the climatic conditions of northeastern Libya. Therefore, the present study addresses this gap by evaluating seven cover inclinations from 15° to 55° under outdoor conditions in Al Bayda, Libya, followed by an assessment of internal and external planar reflector enhancement at the experimentally determined optimum inclination.

2. Experimental Setup and Methodology

2.1 Test Site and Experimental Period

Field experiments were conducted in Al Bayda, Libya (32°45′N, 21°45′E; approximately 620 m above sea level), which is characterized by a semi-arid Mediterranean climate. The experiments were performed during May and June 2024. Clear-sky test days recorded daily global horizontal irradiation ranging from 6.38 to 6.57 kWh/m²·day. During the experimental period, ambient temperature ranged from 17.0 to 31.0 °C, wind speed ranged from 2.2 to 3.5 m/s, and relative humidity ranged from 45% to 65%.

2.2 Solar Still Configuration and Experimental Apparatus

The experimental investigation was conducted using paired, geometrically identical single-slope solar stills, each having a basin area of 1.0 m × 1.0 m. The basin was fabricated from 1.5-mm-thick black-painted galvanized steel and insulated using a 50-mm-thick rock-wool layer. The transparent cover consisted of 4-mm-thick soda-lime glass with a nominal solar transmittance of 0.88–0.91. The water depth in the basin was maintained at 2 cm throughout the experiments.

The influence of cover inclination was evaluated using seven glass-cover angles: 15°, 22°, 27°, 32°, 37°, 45°, and 55°. One still was maintained at the 32° reference inclination, whereas the companion still was adjusted sequentially to the other tested inclinations on successive clear-sky days. This paired configuration was used to provide a reference measurement under comparable outdoor conditions. The selection of multiple cover inclinations was consistent with recent experimental investigations showing that solar-still productivity can vary substantially with cover slope and seasonal operating conditions (Ketata & Driss, 2023).

After identifying 32° as the experimentally optimal inclination, additional experiments were conducted to evaluate passive reflector enhancement. The internal vertical walls of the still were lined with polished aluminum sheets having a reported reflectivity of 0.88. An adjustable flat external glass mirror with a reported reflectivity of 0.90 was positioned above the still aperture. The external reflector was manually re-oriented at 30-min intervals toward the basin. The use of planar and internal reflecting surfaces as passive solar-still enhancement techniques has been investigated in recent experimental studies (Kabeel & Kandel, 2021; Abu-Zeid et al., 2024).

2.3 Instrumentation and Measurement Uncertainty

Water, glass-cover, and vapor temperatures were measured using calibrated K-type thermocouples with an accuracy of ±0.2 °C. Temperature data were recorded using a Graphtec GL840 data logger at 60-s intervals. Solar irradiance was measured using a Kipp & Zonen CMP11 pyranometer with a stated accuracy of ±1.2%. Distillate mass was measured using a Mettler Toledo balance with a resolution/accuracy of ±0.05 g.

Condensate behavior at the inner glass surface was documented photographically at 15-min intervals to qualitatively assess droplet formation, apparent droplet pinning, and drainage behavior. These observations were used to support the interpretation of the effect of cover inclination on condensate removal from the glass surface.

The combined measurement uncertainty was evaluated using the root-sum-square approach based on the Kline–McClintock method. The resulting estimated uncertainties were ±1.85% for daily distillate yield and ±2.45% for daily thermal efficiency, with the latent heat of vaporization taken as 2330 kJ/kg.

2.4 Experimental Procedure

The experimental program was conducted in two successive stages. In the first stage, the effect of glass-cover inclination on the performance of the single-slope solar still was evaluated. The tested cover inclinations were 15°, 22°, 27°, 32°, 37°, 45°, and 55°. For each experimental run, the basin was filled to a constant water depth of 2 cm, and the still was allowed to operate under outdoor solar conditions throughout the test period. The 32° configuration was maintained as the reference configuration, while the companion still was adjusted to the designated test inclination.

Temperature, solar irradiance, and distillate production were continuously monitored during each test. The mass of collected distillate was recorded throughout the experimental period, while the temperature of the basin water, glass cover, and internal vapor space was recorded at 60-s intervals. Environmental conditions, including ambient temperature, relative humidity, and wind speed, were also recorded during the experiments.

The experimentally optimum cover inclination was determined from the measured daily distillate productivity and thermal efficiency. The configuration producing the highest experimentally measured performance was subsequently selected for the reflector experiments.

In the second stage, the selected 32° configuration was evaluated using passive planar reflectors. Polished aluminum sheets were installed on the internal vertical walls of the still, and an adjustable external flat mirror was positioned above the still aperture. The external mirror was manually re-oriented at 30-min intervals to direct reflected solar radiation toward the basin. The reflector-assisted configuration was operated under comparable clear-sky conditions, and its productivity and thermal performance were compared with those of the 32° reference configuration without reflectors.

Photographic observations of the inner glass surface were obtained at 15-min intervals during the experiments. These images were used to document changes in condensate droplet formation, apparent droplet retention, and drainage behavior associated with the different cover inclinations.

2.5 Distillate Productivity

The daily distillate productivity was determined from the mass of collected distilled water normalized by the basin area:

where is the daily distillate productivity (kg m day), is the total mass of collected distillate (kg day), and is the basin area (m²).

Because the density of distilled water is approximately 1 kg L under the experimental conditions, the measured mass was also expressed as an equivalent volumetric yield in L m day.

2.6 Thermal Efficiency

The daily thermal efficiency of the solar still was calculated from the latent heat associated with the measured distillate production relative to the incident solar energy received by the basin:

where is the daily thermal efficiency (%), is the daily distillate mass (kg), is the latent heat of vaporization of water (kJ kg), is the basin area (m²), and is the measured daily incident solar irradiation (kJ m day).

For the present calculations, was taken as 2330 kJ kg.

2.7 Comparison of Reflector Configurations

The reflector experiments were evaluated using the same principal performance indicators applied during the inclination study. The reference 32° configuration was compared with the internal-reflector and dual-reflector configurations in terms of daily distillate productivity, peak basin-water temperature, peak hourly distillate production, thermal efficiency, and calculated unit water cost.

The productivity enhancement provided by the reflector configuration was calculated as:
where is the productivity of the reflector-assisted configuration and is the productivity of the 32° reference configuration**.**

2.8 Condensate and Optical Analysis

The effect of glass-cover inclination on condensate behavior was evaluated through time-resolved photographic observations of the inner glass surface. Images were obtained at 15-min intervals during the experimental runs and examined for changes in condensate droplet formation, droplet retention, coalescence, and drainage toward the collection channel. These observations were used qualitatively to interpret differences in distillate productivity among the tested cover inclinations.

The nominal solar transmittance of the soda-lime glass cover was 0.88–0.91. Because the present experimental setup did not include a dedicated spectrophotometric measurement of wavelength-dependent glass transmittance during each run, the nominal transmittance range was treated as a specification of the cover material rather than as a directly measured experimental variable.

2.9 Economic Analysis

The economic assessment was based on the calculated unit cost of produced distilled water. The unit water cost was determined by relating the estimated total cost associated with the solar-still system to its corresponding distilled-water production over the assumed service period.

For the comparison between configurations, the same economic assumptions and calculation procedure were applied to the reference and reflector-assisted systems. This allowed the effect of the reflector modification on the cost of produced water to be evaluated independently of differences in the basic construction of the still.

3.10 Statistical Analysis

Descriptive statistics were used to summarize the measured solar irradiance, ambient conditions, temperature measurements, daily distillate productivity, and thermal efficiency.

The performance of the tested cover inclinations was compared using the experimentally measured daily distillate productivity and thermal efficiency. The experimentally observed maximum was used to identify the optimum cover inclination.

For the reflector experiments, the productivity and thermal-performance indicators of the 32° reference configuration were compared with those obtained after incorporation of the internal and external reflector configurations. Percentage improvement was calculated relative to the corresponding 32° reference value.

Where appropriate, experimental variability was reported using the corresponding measurement uncertainty. The uncertainty analysis followed the root-sum-square approach, resulting in estimated uncertainties of ±1.85% for daily distillate yield and ±2.45% for daily thermal efficiency.

4. Results and Physical Discussion

4.1 Multi-Angle Comparison (15°–55°)

Outdoor experiments demonstrated a distinct optimum in solar-still performance at a glass-cover inclination of 32°, with productivity decreasing at both lower and higher inclination angles (Figures 1 and 2; Table 1). The observed trend reflects the combined effects of optical transmission, condensate drainage, and heat-transfer characteristics within the internal vapor cavity.

At the 15° inclination, the daily distillate productivity was 3.10 L/m²·day, corresponding to a 26.2% reduction relative to the 32° reference configuration. Condensation photographs showed the formation of relatively large droplets, with apparent droplet diameters exceeding 4.5 mm in some locations. These droplets remained attached to the underside of the glass for extended periods and occasionally returned to the basin rather than reaching the collection channel. The measured runoff efficiency was 62.0%, while the effective transmittance was 0.82.

Increasing the inclination to 22° improved the daily productivity to 3.65 L/m²·day, representing a 13.1% reduction relative to the 32° configuration. Condensate drainage improved to 78.5%, although intermittent droplet retention and periodic drop-off from the glass surface remained evident.

At 27°, the productivity increased further to 3.90 L/m²·day, only 7.1% below the 32° reference value. The effective transmittance reached 0.88 and condensate runoff increased to 88.0%. The observed condensate behavior indicated a transition from predominantly pinned droplets toward more continuous drainage.

The maximum experimentally measured productivity was obtained at a cover inclination of 32°. The daily yield reached 4.20 L/m²·day, with a daily thermal efficiency of 42.6%. The effective transmittance was 0.91 and the condensate runoff efficiency reached 96.5%. This configuration provided the most favorable balance between solar transmission, condensate removal, and internal cavity dimensions under the experimental conditions.

At 37°, the daily productivity decreased to 3.82 L/m²·day, corresponding to a 9.0% reduction relative to the 32° configuration. Although condensate drainage remained highly effective at 98.0%, the top heat-loss fraction increased to 29.8%. The increase in the vertical dimension of the vapor cavity was accompanied by a reduction in the overall thermal performance.

At 45°, the productivity decreased further to 3.45 L/m²·day, or 17.9% below the 32° reference. Condensate drainage was excellent, with a runoff efficiency of 99.0%; however, the effective transmittance decreased to 0.83 and the top heat-loss fraction increased to 38.5%. The resulting thermal efficiency was 34.0%.

The lowest productivity among the tested configurations was recorded at 55°, where the daily yield was 2.85 L/m²·day, corresponding to a 32.1% reduction relative to the 32° reference. The effective transmittance decreased to 0.76, while the top heat-loss fraction increased to 48.0%. Despite the highest condensate runoff efficiency of 99.5%, the increase in cavity dimensions and associated convective heat losses resulted in substantially lower thermal performance.

Overall, the experimental results demonstrate a two-sided response to cover inclination. At shallow inclinations, productivity was primarily constrained by condensate retention, back-dripping, and reduced effective optical transmission. At steep inclinations, condensate drainage was improved, but increasing cavity dimensions and heat losses reduced the thermal performance of the still. The 32° configuration therefore provided the best experimentally observed compromise between these competing effects This

result is consistent with previous experimental observations showing that solar-still productivity commonly reaches a maximum at an intermediate cover inclination rather than at either very shallow or very steep angles (Al-Garni et al., 2020).
A least-squares quadratic regression was fitted to the seven experimentally measured productivity values:
[Y(\theta) =-0.00252\theta^2+0.1668\theta+1.21]
where (Y) is the daily distillate productivity (L/m²·day) and (\theta) is the glass-cover inclination angle in degrees. The regression coefficient was (R^2=0.922). The vertex of the fitted quadratic occurred at approximately 33.1°, with a predicted maximum productivity of approximately 3.97 L/m²·day. The fitted optimum was therefore close to the experimentally observed optimum of 32°, supporting the consistency of the measured angular response.

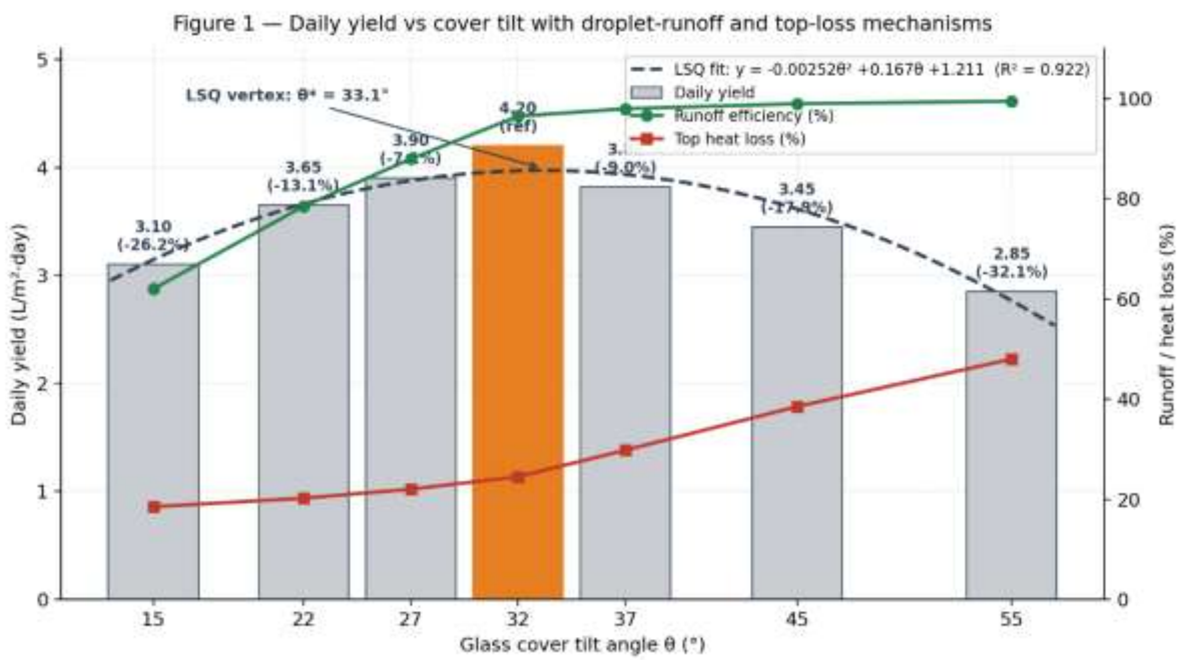

Figure 1. Measured daily yield vs cover tilt with the corrected least-squares parabola; overlays show droplet-runoff efficiency (green) and top heat-loss share (red).
Figure 1. Measured daily distillate productivity as a function of glass-cover inclination angle, together with the fitted quadratic regression curve.

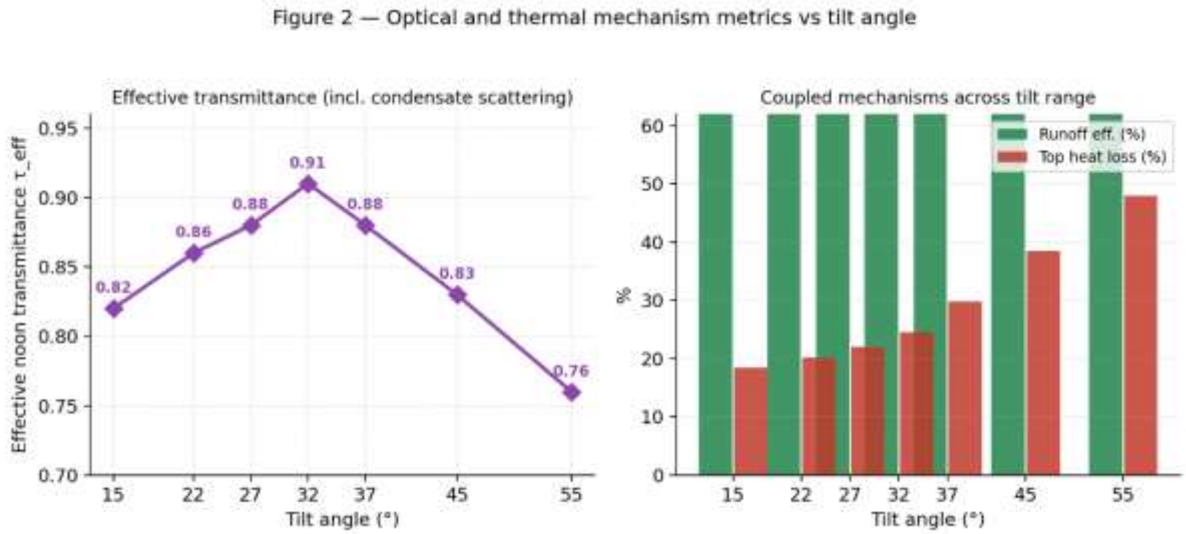

Figure 2. Effective noon transmittance (left; includes condensate-scattering losses at shallow tilts) and coupled drainage/heat-loss metrics (right).

Figure 2. Effective optical transmittance, condensate runoff efficiency, and top heat-loss fraction as functions of glass-cover inclination angle.

θ	Regime	Yield (L/m²·day)	Δ vs 32°	τ_eff	Runoff (%)	Top loss (%)	η (%)	ΣI (kWh/m²·day)
15°	Extreme shallow	3.10	−26.2%	0.82	62.0	18.5	31.2	6.43
22°	Shallow	3.65	−13.1%	0.86	78.5	20.2	36.1	6.55
27°	Intermediate	3.90	−7.1%	0.88	88.0	22.0	38.6	6.54
32° ☆	Global optimum	4.20	ref	0.91	96.5	24.5	42.6	6.38
37°	Moderate steep	3.82	−9.0%	0.88	98.0	29.8	37.8	6.54
45°	Steep (winter)	3.45	−17.9%	0.83	99.0	38.5	34.0	6.57
55°	Extreme steep	2.85	−32.1%	0.76	99.5	48.0	28.5	6.47

Table 1. Measured performance across the seven tilt angles. Each angle was logged on its own clear-sky day; η uses h_fg = 2330 kJ/kg and the measured per-day insolation (last column), which reproduces the tabulated efficiencies exactly.

Table 1. Experimental performance of the single-slope solar still at the seven tested glass-cover inclination angles. Daily thermal efficiency was calculated using (h_{fg}=2330) kJ/kg and the measured daily solar irradiation.

4.2 Reflector Enhancement at the 32° Optimum

Following identification of the 32° cover inclination as the optimum configuration, additional experiments were conducted to evaluate the effect of passive planar reflectors. The introduction of polished internal wall reflectors increased the peak basin-water temperature from 72.8 °C for the reference configuration to 79.5 °C. Daily distillate productivity increased from 4.20 to 5.15 L/m²·day, corresponding to a 22.6% improvement relative to the 32° reference configuration The observed enhancement is consistent with recent experimental evidence that internal reflectors can increase both thermal efficiency and water productivity in basin-type solar stills (Abdelgaleel et al., 2024)..

The dual-reflector configuration, consisting of the internal wall reflectors and the external planar mirror, produced a further increase in thermal performance. The peak basin-water temperature reached 84.2 °C, representing an increase of 11.4 °C relative to the unmodified 32° configuration. The peak hourly distillate production increased to 960 mL/m²·h, while the daily yield reached 5.85 L/m²·day. This represented a 39.3% increase relative to the 32° reference configuration and an 88.7% increase relative to the 15° configuration.

The thermal efficiency of the internal-reflector configuration reached 52.2%, whereas the dual-reflector configuration achieved 54.8%. The increase in basin-water temperature and distillate production demonstrates the effectiveness of redirecting additional solar radiation toward the basin using passive reflecting surfaces.

The measured daily productivity, peak basin-water temperature, peak hourly distillate production, thermal efficiency, and calculated unit water cost for the three configurations are summarized in Table

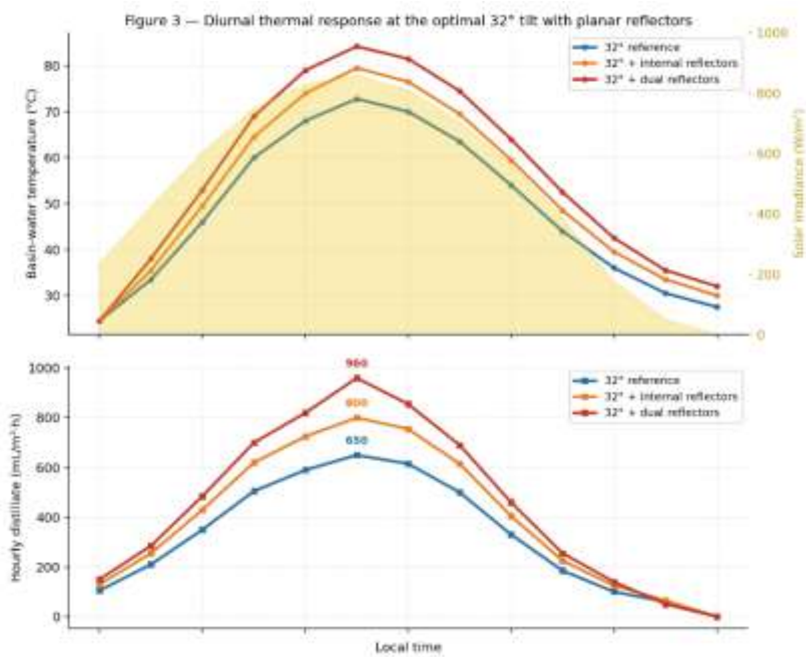

Figure 3. Diurnal basin-water temperature and hourly distillate rate for the bare 32° still, with internal reflectors, and with dual reflectors (May–June 2024).

Figure 3. Diurnal variation of basin-water temperature and hourly distillate production for the 32° reference, internal-reflector, and dual-reflector configurations during the May–June 2024 experiments.

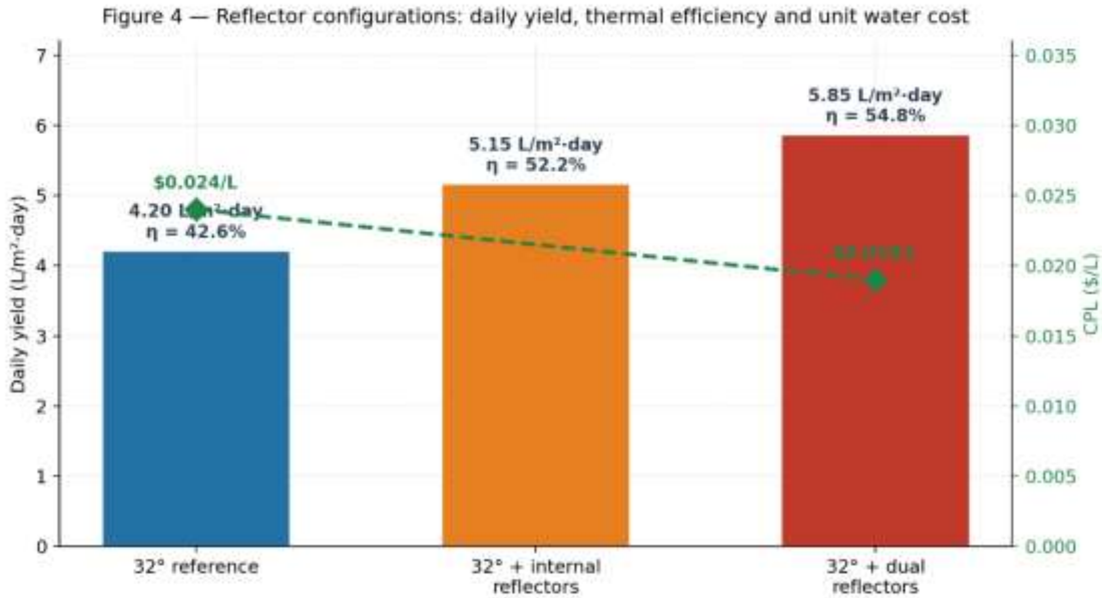

Figure 4. Daily yield, thermal efficiency and unit water cost across reflector configurations.

Figure 4. Comparison of daily distillate productivity, thermal efficiency, and calculated unit water cost for the tested reflector configurations.

Configuration	Yield (L/m²·day)	Δ vs 32°	Δ vs 15°	Peak T_w (°C)	Peak hourly (mL/m²·h)	η (%)	CPL ($/L)
32° reference	4.20	ref	+35.5%	72.8	650	42.6	0.024
32° + internal reflectors	5.15	+22.6%	+66.1%	79.5	800	52.2	n.a.
32° + dual reflectors	5.85	+39.3%	+88.7%	84.2	960	54.8	0.019

Table 2. Reflector configurations at the 32° optimum. Efficiency of the internal case is computed against the measured direct insolation (6.38 kWh/m²·day); the dual case is computed against total intercepted radiation including the mirror contribution (ΣI_{eff} = 6.91 kWh/m²·day, i.e., +8.3% effective aperture).

A least-squares quadratic regression of the seven measured points gave:

[Y(\theta)=-0.00252\theta^2+0.1668\theta+1.2105]

with (R^2=0.922). The fitted curve predicted a maximum yield of approximately 3.97 L/m²·day at a tilt angle of 33.1°. The experimentally measured maximum was 4.20 L/m²·day at 32°, indicating close agreement between the experimental optimum and the regression-predicted optimum.

4.3 Economic Feasibility

The calculated unit water cost decreased from \$0.024/L for the 32° reference configuration to \$0.019/L for the dual-reflector configuration, corresponding to a reduction of approximately 20.8%. The reduction in unit production cost resulted from the higher daily distillate productivity achieved with the reflector-assisted configuration.

Based on the assumed system costs, operating conditions, and daily productivity, the estimated payback period for the external mirror investment was approximately 110 days of continuous operation. The economic results indicate that the reflector modification can improve not only water productivity but also the calculated cost effectiveness of the solar-still system Similar economic benefits associated with reflector-assisted solar-still configurations have been reported experimentally, with modified systems demonstrating lower calculated water-production costs than conventional configurations (Abdelgaleel et al., 2024).

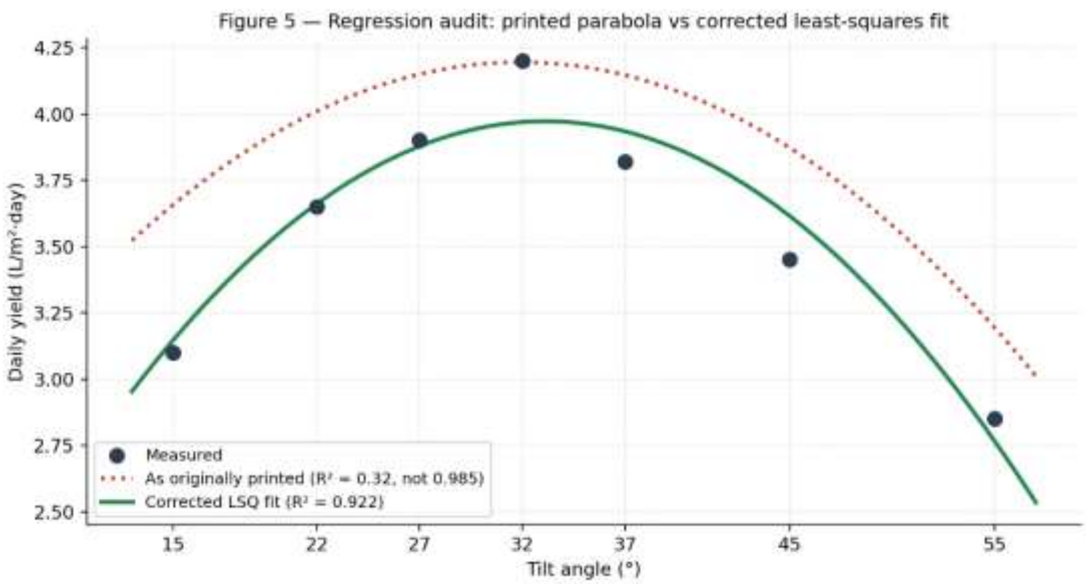

Figure 5. Regression audit: the originally printed parabola (dotted) vs the corrected least-squares fit (solid).

Figure 5. Quadratic regression of daily distillate productivity as a function of glass-cover inclination angle.

5. Conclusions and Practical Recommendations

The experimental investigation demonstrated that glass-cover inclination has a substantial influence on the performance of the single-slope solar still under the climatic conditions of Al Bayda, Libya. Among the seven tested inclinations, 32° produced the highest experimentally measured daily distillate productivity of 4.20 L/m²·day and a thermal efficiency of 42.6%.

The performance reduction at shallow inclinations was associated with reduced condensate drainage and increased droplet retention on the inner glass surface. At 15°, the condensate runoff efficiency decreased to 62.0%, accompanied by reduced effective optical transmittance and increased back-dripping of condensed water into the basin.

Increasing the cover inclination above the optimum improved condensate drainage but resulted in progressively greater top heat losses. At 55°, the top heat-loss fraction reached 48.0%, while the daily productivity decreased to 2.85 L/m²·day. These results demonstrate that maximizing condensate drainage alone does not ensure maximum solar-still productivity because optical and thermal losses must also be considered.

The quadratic regression of the seven measured productivity values predicted an optimum inclination of approximately 33.1°, which was in close agreement with the experimentally determined optimum of 32°. The agreement supports the experimentally observed optimum under the climatic and geometric conditions investigated.

The incorporation of polished internal wall reflectors at the 32° inclination increased daily productivity from 4.20 to 5.15 L/m²·day, corresponding to a 22.6% improvement. The dual-reflector configuration further increased productivity to 5.85 L/m²·day, with a peak basin-water temperature of 84.2 °C and a thermal efficiency of 54.8%.

The calculated unit water cost decreased from $0.024/L for the 32° reference configuration to $0.019/L with the dual-reflector configuration. Under the economic assumptions adopted in this study, the estimated payback period for the reflector investment was approximately 110 days.

For a fixed year-round installation under conditions comparable to those investigated, a 32° glass-cover inclination combined with passive planar reflectors represents the most favorable configuration among those experimentally evaluated. A higher inclination may potentially be advantageous during winter because of the lower solar elevation; however, seasonal optimization should be confirmed through dedicated winter experiments before implementation.

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List of Abbreviations:

Abbreviation	**Full term**
SS	Solar still
SSS	Single-slope solar still
(A)	Basin area (m²)
CPL	Cost per litre (USD/L)
(h_{fg})	Latent heat of vaporization (kJ/kg)
(I)	Solar irradiance (W/m²)
(\Sigma I)	Daily incident solar irradiation (kWh/m²·day)
(\Sigma I_{\mathrm{eff}})	Effective daily solar irradiation including reflector contribution (kWh/m²·day)
(m_d)	Daily distillate mass (kg/day)
(R^2)	Coefficient of determination
(T_w)	Basin-water temperature (°C)
(T_g)	Glass-cover temperature (°C)
(\tau_{\mathrm{eff}})	Effective solar transmittance
(\eta)	Daily thermal efficiency (%)
(\rho)	Reflectivity
(\theta)	Glass-cover inclination angle (°)
(\theta^*)	Regression-predicted optimum inclination angle (°)
(\Delta T)	Basin-water-to-glass temperature difference (°C)