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Preliminary Model-Based Assessment of the Proposed Parabosol Solar-Thermal Water Purification System for Libya's Green Mountain Region

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Abstract:

This study presents a preliminary, transparent model-based assessment of a proposed parabolic solar-thermal water purification concept, termed Parabosol, for Libya's Green Mountain region. The assessment was deliberately framed as a feasibility study because no auditable pilot-test log, calibrated system geometry, laboratory certificates, life-cycle inventory, or complete ANSYS output files were available. Monthly direct normal irradiance (DNI) from NASA POWER MERRA-2 for a representative point near Al-Bayda (32.76°N, 21.76°E) averaged 5.95 kWh m^{-2} day^{-1} during 2001–2025, with a pronounced seasonal range. A first-law screening model was used to estimate the distillate rate as a function of irradiance, a 10 m^2 collector aperture, whole-system efficiency, and a 2.45 MJ kg^{-1} thermal energy requirement. Under 600–1200 W m^{-2} DNI and 30–60% assumed whole-system efficiency, the model predicts 2.65–10.58 kg h^{-1}. At the representative annual DNI, the corresponding 10 m^2 daily yield is approximately 26–52 L/day. A 170 L Day^{-1} design target would require about 32–65 m^2 aperture under 60–30% efficiency before accounting for storage and downtime. The study, therefore, does not confirm prior claims of 170 L/day^{-1}, US$0.05/L operating cost, 80% greenhouse gas reduction, or complete elimination of brine; each requires field evidence or a documented techno-economic/life-cycle analysis. The results establish a defensible design envelope, identify the measurements required for pilot validation, and show that the Green Mountain solar resource warrants a carefully instrumented field demonstration rather than an unqualified performance claim.

Keywords: solar thermal desalination; concentrating solar power; direct normal irradiance; water purification; techno-economic assessment; Green Mountain; Libya

Key Contributions

• **Recasts** the project as a model-based feasibility assessment and removes unsupported performance claims.

• Uses a unit-consistent sensitivity equation and reproducible NASA POWER solar-resource data.

• Shows that a 10 m² aperture does not reproduce a 170 L Day^{-1} design target under transparent screening assumptions.

• **Provides** a field-validation, water-quality, environmental, cost, and simulation-reporting roadmap.

• **Replaces** the reference list with focused sources with verified DOI, publisher, or official links.

1. Introduction

Water security and energy availability are closely coupled in Libya. Desalination is an important option for coastal and water-stressed communities, but it requires energy, reliable operation, and appropriate environmental management. Reviews of Libya's desalination sector identify both a long history of desalination and continuing constraints related to infrastructure, energy supply, operational reliability, and brine management (Wheida & Verhoeven, 2004; Abdunnabi et al., 2018).

Solar-driven desalination is attractive where solar resources and water scarcity coincide. Thermal technologies can be coupled to solar collectors, while reverse osmosis can be supplied with renewable electricity. The appropriate configuration depends on scale, feedwater quality, storage needs, local maintenance capacity, and the cost of energy and water—not solar irradiation alone (Kalogirou, 2005; Eltawil et al., 2009; Sharon & Reddy, 2015; Ghazi et al., 2022). CSP-linked thermal desalination is technically promising, but its performance and cost are highly sensitive to collector design, temperature level, thermal losses, storage, and capacity factor (Moser et al., 2013; Zheng et al., 2023; Khan et al., 2025).

The term 'Parabosol' is used in this manuscript as the project name for a proposed parabolic solar-thermal distillation concept. The source material contained valuable design intentions but also duplicated sections, unsupported numerical claims, inconsistent unit conversions, and citations that could not all be independently matched to bibliographic records. The present revision corrects those issues and reclassifies the work as a preliminary model-based feasibility assessment. This is scientifically stronger than presenting unverified numbers as field results.

The objectives were to: (1) characterise the representative solar resource near Al-Bayda; (2) develop a consistent first-law sensitivity model for a 10 m² parabolic solar-thermal water-purification concept; (3) test whether a 170 L day^{-1} production target is compatible with the stated aperture and transparent assumptions; (4) identify the measurement, water-quality, cost, and environmental evidence necessary for a future pilot; and (5) position the concept within Libya's water and renewable-energy context and Sustainable Development Goal 6 (United Nations, n.d.).

2. Materials and Methods

2.1 Study context and solar-resource dataset: The Green Mountain (Al-Jabal Al-Akhdar) region was selected because it combines water-security challenges with favourable solar conditions. The solar resource was represented by monthly all-sky direct normal irradiance (DNI) from NASA POWER MERRA-2 for 32.76°N, 21.76°E, a point near Al-Bayda. Values cover January 2001 to December 2025 and were retrieved on 4 August 2026. This gridded dataset is appropriate for preliminary screening; a pilot should use an on-site, calibrated pyrheliometer and record soiling, shading, tracking error, wind, humidity, and downtime.

2.2 Proposed system boundary: The proposed system comprises a parabolic reflector, receiver, heat-transfer path, evaporation/condensation unit, distillate collection, and a residual-concentrate stream. The analysis does not assume that the residual stream disappears. Like other thermal desalination processes, distillation concentrates non-volatile salts in a reject stream; its quantity and composition depend on recovery ratio and feedwater chemistry. A brine-management plan is therefore a design requirement, consistent with the environmental literature for desalination in Libya and elsewhere (Elabbar & Elmabrouk, 2005; Elsaid et al., 2020).

2.3 Screening performance model: The hourly theoretical distillate rate was calculated using $\dot{m} = I\ A\ \eta_{eff}\ 3600 / q_{req}$, where $\dot{m}$ is kg h^{-1}, I is DNI in W m^{-2}, A is collector aperture in m^2, η_{eff} is an assumed whole-system efficiency, and q_{req} is the thermal energy requirement in J kg^{-1}. A = 10 m^2 was retained from the supplied MATLAB example. q_{req} = 2.45 MJ kg^{-1} was used as an illustrative energy benchmark that includes latent energy and an allowance for sensible heating; it is not a replacement for a detailed heat-and-mass balance. Efficiency was varied from 30% to 60% to represent a screening range for the entire optical-to-distillate pathway. No 90% system efficiency was assumed because no energy balance was supplied to define or validate it.

2.4 Design-target sizing: The aperture needed to target 170 L Day^{-1} was estimated by rearranging the daily form of the same equation: $A_{req} = m_d\ q_{req} / (HDNI\ \eta_{eff})$, where m_d is 170 kg day^{-1} and HDNI is the mean daily DNI. This calculation provides a design-screening requirement only. It excludes seasonal storage, receiver start-up, cleaning intervals, wind damage, partial-load operation, and water-treatment auxiliaries; a field design should include those factors.

2.5 Water-quality, environmental, and cost boundaries: The source text stated a reduction from 2000 mg/L TDS to <50 mg L^{-1}, an operating cost of US$0.05 L^{-1}, an 80% greenhouse-gas reduction, and a 2 t CO_2 reduction per unit per year. No raw sampling table, laboratory certificate, cost schedule, baseline technology, or life-cycle inventory was provided. Accordingly, these values are not reported as results. TDS is a screening indicator and cannot by itself establish microbiological or chemical drinking-water safety; the water-quality protocol must be selected from a source-water risk assessment and applicable standards (World Health Organisation, 2022). A future cost analysis should report capital expenditure, replacement parts, labour, cleaning, consumables, financing, operating hours, production volume, and the levelised cost of water (Ghaffour et al., 2013; Al-Karaghouli & Kazmerski, 2013).

2.6 Computational-model reporting: The provided MATLAB script had a dimensional inconsistency: power in W was divided by latent heat in kJ kg^{-1} without conversion to hourly energy. The corrected equation is supplied in Appendix B. ANSYS outcomes are not reported because the available snippet did not define a validated geometry, mesh, material assignment, boundary conditions, absorbed-flux model, solver convergence criteria, or output files. A future ANSYS study should report these inputs, mesh-independence checks, validation data, and uncertainty analysis before presenting thermal or structural contours as results.

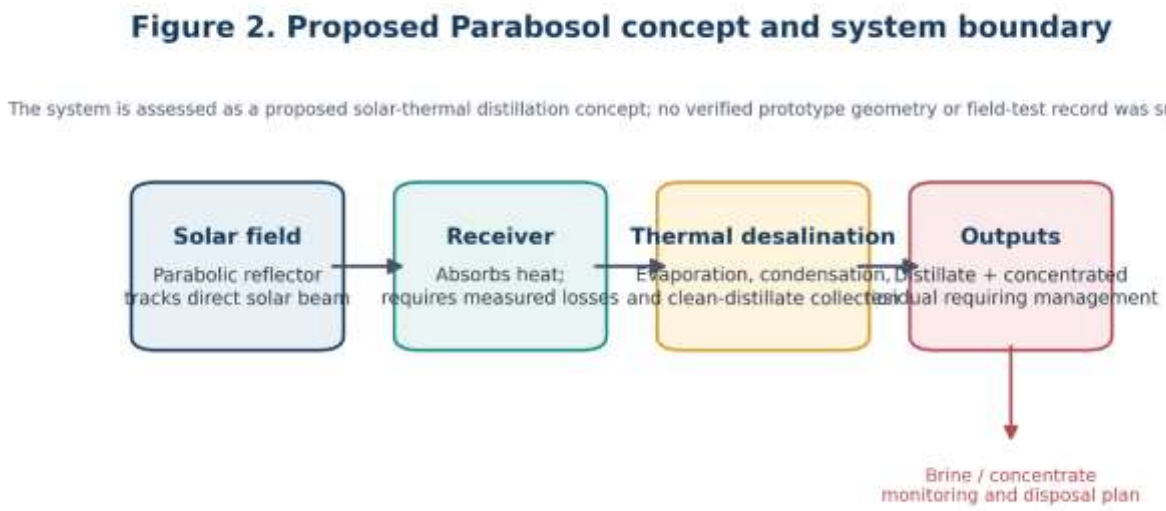


Figure 2. Proposed Parabosol concept and system boundary. The residual stream is retained in the boundary because distillation concentrates rather than eliminates dissolved constituents.

3. Results

3.1 Representative solar resource: The 2001–2025 mean DNI at the representative point was 5.95 kWh m^{-2} day^{-1}. The monthly mean varied from 3.80 kWh m^{-2} day^{-1} in December to 8.70 kWh m^{-2} day^{-1} in July (Figure 1). This seasonality supports the feasibility of solar-thermal operation but also demonstrates the need to size for low-resource periods or define a seasonal production target. Because the data are gridded, the result should be confirmed by site measurements before final collector and storage design.

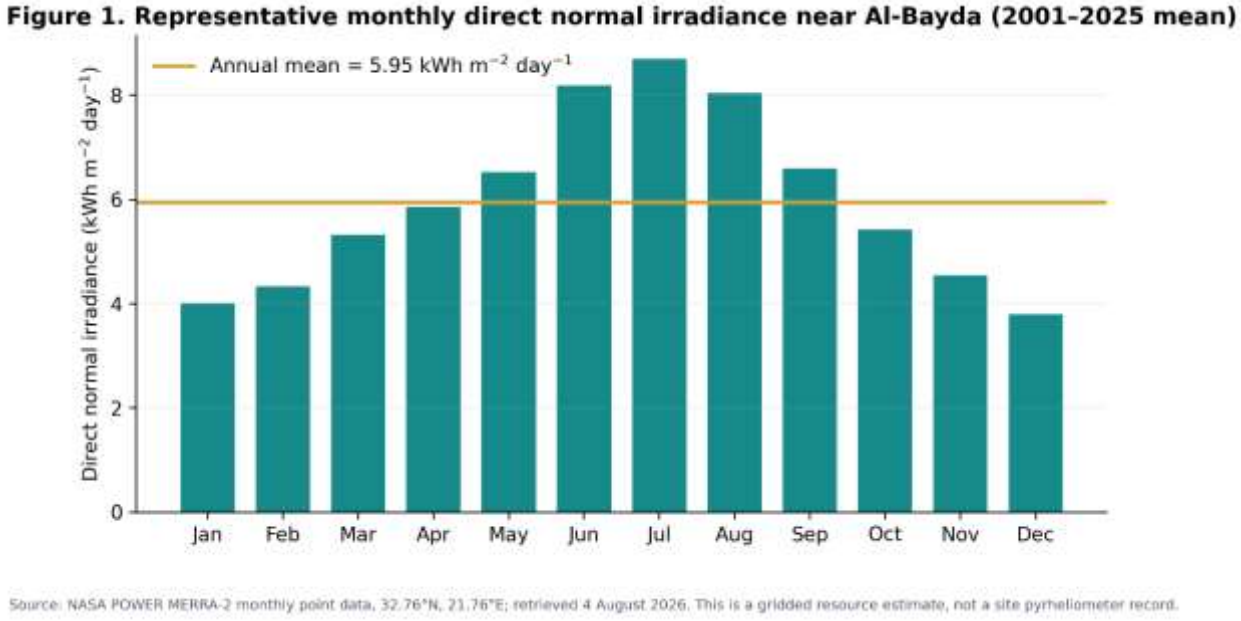


Figure 1. Representative monthly direct normal irradiance near Al-Bayda. Data are gridded estimates and should be supplemented by on-site DNI measurements at the final pilot location.

3.2 Transparent output sensitivity: For a 10 m^2 aperture and qreq = 2.45 MJ kg^{-1}, predicted output rises linearly with DNI and the assumed whole-system efficiency (Table 1; Figure 3). At 600 W m^{-2}, the 30–60% efficiency scenarios give 2.65–5.29 kg h^{-1}; at 1200 W m^{-2}, they give 5.29–10.58 kg h^{-1}. This is

a theoretical energy-balance result, not a measured distillate rate. The model should therefore be used to define a pilot measurement range rather than to claim final system performance.

DNI (W m⁻²)	ηeff 30%	ηeff 40%	ηeff 50%	ηeff 60%
600	2.64	3.53	4.41	5.29
800	3.53	4.70	5.88	7.05
1000	4.41	5.88	7.35	8.82
1200	5.29	7.05	8.82	10.58

Table 1. Theoretical distillate rate (kg h⁻¹) from the corrected 10 m² screening model. ηeff is an assumed whole-system efficiency, and results are not field measurements.

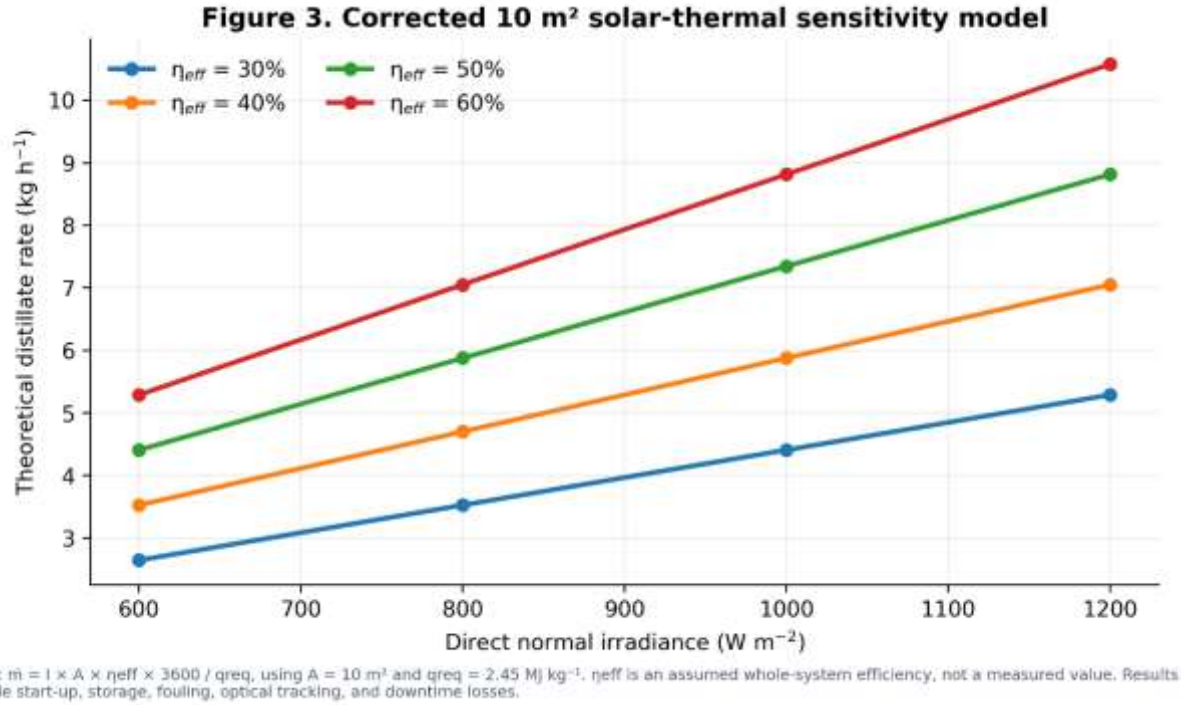


Figure 3. Corrected 10 m² solar-thermal sensitivity model.

3.3 Implication for the 170 L Day⁻¹ target: At the annual mean DNI, a 10 m² aperture yields approximately 26.2–52.4 L/day under the 30–60% screening range (Table 2). A 170 L day⁻¹ target requires approximately 32.4 m² at 60% efficiency, 38.9 m² at 50% efficiency, 48.6 m² at 40% efficiency, or 64.8 m² at 30% efficiency (Figure 4). Thus, a 10 m² aperture cannot substantiate a 170 L day⁻¹ target under the model assumptions. The target may still be technically achievable with a larger aperture, heat recovery, storage, multiple effects, different operating temperatures, or a different production schedule, but such a design must be specified and validated.

ηeff	Average 10 m² yield (L day⁻¹)	Aperture for 170 L day⁻¹ (m²)
30%	26.2	64.8
40%	35.0	48.6
50%	43.7	38.9
60%	52.4	32.4

Table 2. Daily screening yield and collector-aperture requirement at the representative mean DNI. Values exclude storage and availability losses.

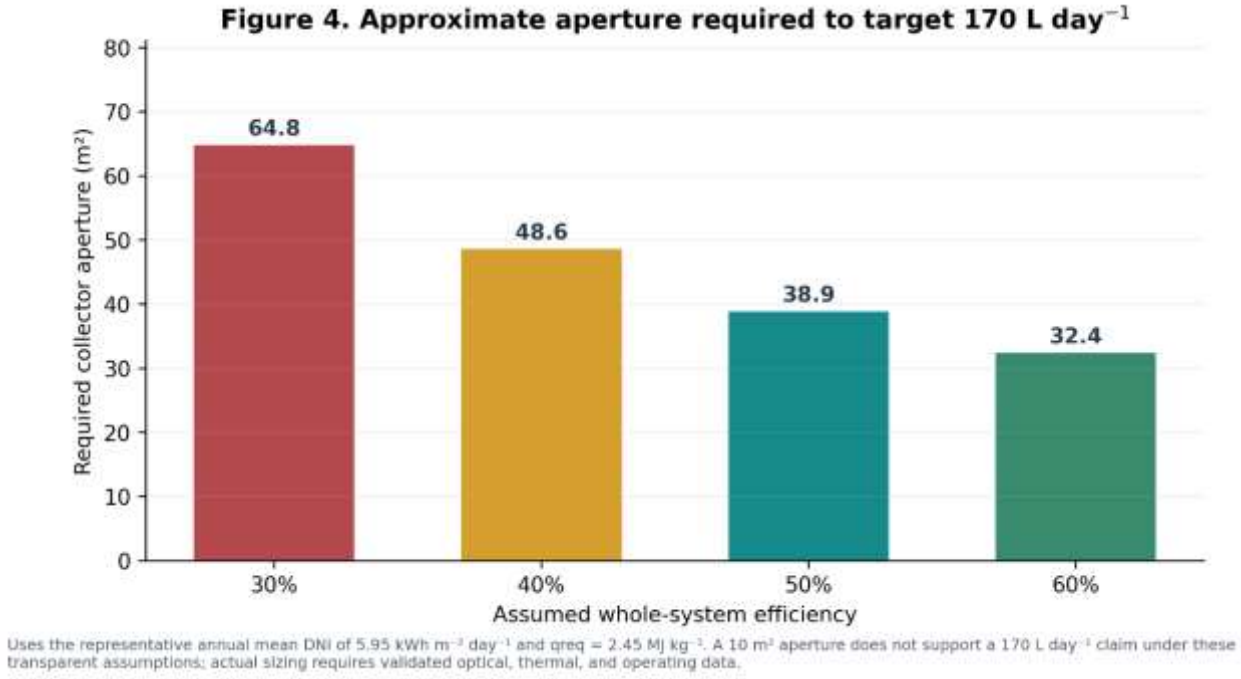


Figure 4. Approximate aperture required to target 170 L day⁻¹.

3.4 Water quality and environmental interpretation: Thermal distillation can remove non-volatile dissolved salts, but potable-water suitability cannot be inferred from one TDS result. Field validation should report feed and product conductivity/TDS, pH, alkalinity, major ions, metals selected from source-water risks, microbial indicators, sampling dates, replicates, detection limits, and laboratory methods (Figure 5). Similarly, solar energy can reduce operating emissions relative to a fossil-fuel baseline, but an 80% reduction cannot be calculated without a defined baseline, electricity/fuel mix, system lifetime, embedded materials, and allocation method. Brine is concentrated rather than eliminated and must be monitored and managed.

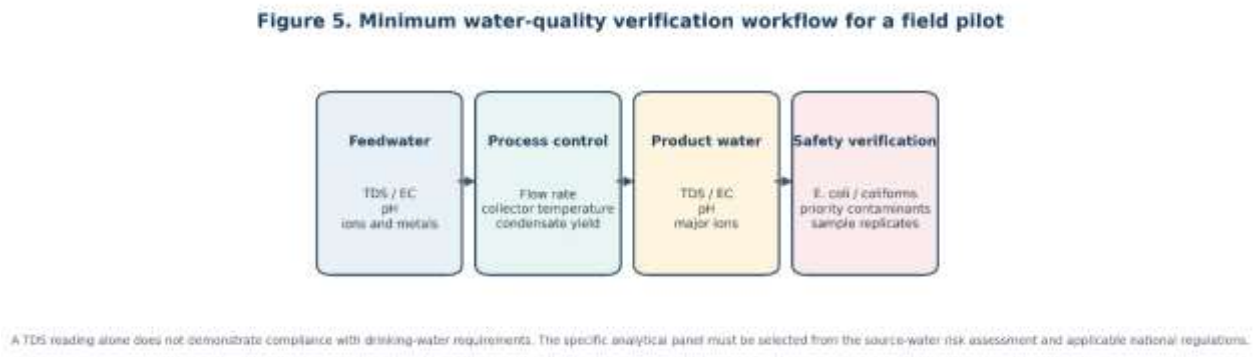


Figure 5. Minimum water-quality verification workflow for a field pilot.

3.5 Cost and deployment interpretation: The original US$0.05 L^{-1} value equals US$50 m^{-3}. Without a clear scope, this cannot be described as low operating cost. Recent modelling of solar-integrated MED in Libya reports values on a different scale and under different system boundaries, illustrating why comparison must specify plant scale, energy source, storage, financing, and water-quality target (Muftah et al., 2025). The proposed Parabosol configuration may be suited to decentralised applications, but that hypothesis must be evaluated against an alternative such as PV–RO or delivered water using matched demand, reliability, cost, and environmental indicators.

4. Discussion

The revised assessment establishes that the Green Mountain solar resource is suitable for further design investigation, but it does not validate the original performance claims. This distinction is central to publication quality. Solar thermal desalination is technically credible, but the literature warns that efficiency, economics, thermal storage, system integration, and brine management are decisive barriers to deployment (Qiblawey & Banat, 2008; Zheng et al., 2023; Khan et al., 2025).

The new calculations show why a transparent energy balance is needed. The original MATLAB example mixed W with kJ kg^{-1}, causing a unit error. Correcting the units changes the interpretation of predicted output and shows that production depends on collector area and the whole-system efficiency, not irradiance alone. The 170 L day^{-1} target should be retained as an engineering design target only if the final design describes its aperture area, receiver efficiency, operating temperature, heat recovery, condenser performance, storage, feedwater recovery ratio, and operating hours.

Water quality must be treated as a separate evidence stream from energy performance. Distillate can have low TDS but may require remineralisation for taste and corrosion control, and its safety depends on contamination control and analytical evidence. The pilot protocol should use paired feed/product samples and pre-specified acceptance criteria. The document should not state WHO compliance unless the full required analytical package and applicable Libyan requirements are met.

The same caution applies to cost and emissions. An LCOW calculation should state the lifetime, discount rate, capital cost, O&M, replacement schedule, production profile, and currency year. A greenhouse-gas comparison should define the baseline and include a life-cycle boundary. A brine plan should quantify reject flow, salinity, receiving environment, and disposal pathway. These additions would transform the concept from a promising narrative into a defensible engineering study.

For the next phase, a prototype should be instrumented with a calibrated pyrheliometer, flow metres, temperature sensors at the receiver and evaporator/condenser, pressure sensors where relevant, and a data

logger. At least one full seasonal cycle should be observed. A verified ANSYS model can then be calibrated against measured receiver temperatures and losses, while the economic model can use actual construction and maintenance records.

5. Conclusions

The proposed Parabosol system is a plausible solar-thermal water-purification concept for further investigation in Libya's Green Mountain region. The representative solar resource near Al-Bayda is favourable, with mean DNI of 5.95 kWh m^{-2} day^{-1}. However, a scientifically defensible screening model with a 10 m^2 aperture predicts approximately 26.2–52.4 L/day across 30–60% whole-system efficiency, not 170 L/day. Achieving 170 L/day would require a collector aperture of roughly 32.4–64.8 m^2 under these assumptions or a different specified design.

The work is therefore presented as a preliminary model-based assessment, not a completed field-performance evaluation. Claims concerning water safety, cost, greenhouse-gas reduction, brine elimination, 90% efficiency, or ANSYS-validated thermal stability should be made only after documented field, laboratory, life-cycle, techno-economic, and simulation evidence is available. The revised manuscript provides the equations, sensitivity results, verification workflow, and reference base required to design that pilot responsibly.

Declarations

Ethics approval: Not applicable. This preliminary study used public solar-resource data and published literature only.

Data availability: The NASA POWER values, model calculations, and figure-source data are supplied in Parabosol_model_and_figure_data.xlsx.

Competing interests: The authors declare no competing interests. [Revise if applicable.]

Funding: No external funding was reported. [Revise if applicable.]

Author contributions: Ahmad Melad and Solman Hassan: conceptualisation, system design, methodology, writing—original draft, and review and editing. [Revise to reflect actual contributions.]

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Appendix A. Evidence Required Before Field-Performance Claims

Table A1 records how major claims in the source text were handled in this revised manuscript. This is not a criticism of the proposed technology; it is an evidence map that identifies what must be measured before the claims can be submitted as engineering results.

Claim in source text	Treatment in revised manuscript	Evidence is needed before use as a result.
170 L day^{-1}	Design target; not confirmed.	Time-stamped flow-metre log, aperture, operation hours, weather, and uncertainty.
TDS 2000 to <50 mg L^{-1}	Not presented as observed water-quality result.	Raw lab records, replicates, methods, and broader chemical/microbiological panel.
90% efficiency	Not used as a measured system efficiency.	Defined energy balance and measured input/output terms.
US$0.05 L^{-1}	Excluded from cost result.	CAPEX/OPEX, lifetime, financing, volume, and cost model.
80% GHG reduction / 2 t CO_2	Excluded from environmental result.	Baseline, LCA boundary, inventory, emission factors, and functional unit.
No harmful brine disposal	Corrected: residual concentrate needs managing.	Recovery ratio, reject chemistry/flow, and approved management route.
ANSYS thermal/structural result	Not reported as a result.	Geometry, mesh, BCs, material model, solver report, and validation.

Table A1. Claim-to-evidence map for a future Parabosol pilot study.

Appendix B. Corrected MATLAB Screening Code

```
% Parabosol preliminary thermal screening model
% Units are explicit: I [W/m^2], A [m^2], q_req [J/kg], m_dot [kg/h]
I = [600 800 1000 1200];
eta_eff = [0.30 0.40 0.50 0.60];
A = 10;  % collector aperture (m^2)
q_req = 2.45e6; % assumed thermal demand per kg (J/kg)
m_dot = zeros(length(I), length(eta_eff));
for i = 1:length(I)
for j = 1:length(eta_eff)
m_dot(i,j) = I(i)*A*eta_eff(j)*3600/q_req;
end
end
plot(I,m_dot,'-o','LineWidth',1.5); grid on
xlabel('Direct normal irradiance (W/m^2)');
ylabel('Theoretical distillate rate (kg/h)');
legend('30%','40%','50%','60%','Location','northwest');
```