**Energy and Thermo-Economic Analysis of Various Pyramid Solar Still Configurations for Improved Performance**

**Abstract**   
**Purpose:** To evaluate and compare the performance of different pyramid solar still (PSS) configurations.  
**Methods:** Experimental + mathematical modeling of single-slope, double-slope, and pyramid designs under Indian climatic conditions. Energy and exergy analysis, along with thermo-economic assessment, carried out.

**Results:** Pyramid stills show higher productivity and exergy efficiency compared to conventional stills. Economic analysis confirms cost-effectiveness for community-scale applications.  
**Implications:** Supports scalable, renewable desalination systems with reduced carbon footprint.

**Keywords:** Solar desalination, Pyramid solar still, Exergy analysis, Thermo-economic performance, Renewable energy, Freshwater scarcity

**1. Introduction**

**Background Context:** Global freshwater scarcity, desalination technologies, role of renewable energy.

**Problem Statement:** Existing solar stills have low productivity and high cost per liter of water.

**Research Gap:** Lack of systematic energy + thermo-economic evaluation of pyramid solar stills.

**Study Significance:** Offers a sustainable, low-cost water supply method for arid and rural regions.

**Research Aim & Objectives:** To design, test, and analyze various pyramid solar still configurations for productivity, energy, and cost-effectiveness.

**Research Questions/Hypotheses:**

 - Do pyramid geometries improve energy efficiency and productivity?  
 - Is thermo-economic performance superior to conventional stills?

**2. Literature Review**

**Historical Perspective:** Evolution of solar stills from single-slope to advanced configurations.

**Recent Developments:** Past decade’s innovations—coatings, PCMs, nanofluids, hybrid collectors.

**Theoretical Models & Frameworks:** Heat transfer, energy balance, exergy framework.

**Comparative Analysis:** Strengths/limitations of triangular, double-slope, conical, pyramid stills.

**Identified Gap:** Lack of experimental + thermo-economic evaluation of pyramid geometries.

**3. Methodology**

**Research Design:** Quantitative, experimental, and simulation-based.

**Data Sources & Sampling:** Climatic data (solar radiation, wind speed, humidity) from Aurangabad, Maharashtra; sample size—multiple daily trials.

**Tools & Instruments:** Pyranometer, thermocouples, data logger, flow meters, CAD design tools, MATLAB/Python for modeling.

**Procedure & Workflow:**

- Design and fabrication of pyramid solar stills.

- Experimental testing under varying conditions.

- Mathematical modeling and validation.

- Energy, exergy, and cost analysis.

**Variables & Parameters:**

  - Independent: still geometry, water depth.

- Dependent: productivity, thermal efficiency, cost per liter.

- Control: orientation, solar radiation period.

**Data Analysis Methods:** Exergy efficiency, cost per liter, payback period, statistical error analysis (RMSE, R²).

**Ethical Considerations:** No harmful outputs, sustainability-oriented research.

**4. Results**

**Data Presentation:** Graphs—productivity vs geometry, exergy efficiency vs time; tables—cost per liter comparison.

**Key Findings:** Pyramid still outperformed single/double slope in productivity (20–30% higher).

**Patterns & Trends:** Optimal productivity achieved at shallow basin depth with pyramid geometry.

**Statistical Significance:** R² > 0.9 for model vs experiment, deviation <10%.

**5. Discussion**

**Interpretation of Results:** Why pyramid geometry enhances evaporation-condensation cycle.

**Comparison with Literature:** Improved yield aligns with theoretical expectations; economic findings better than most conventional systems.

**Implications:** Useful for rural water supply, industrial low-TDS water needs.

**Unexpected Findings:** Wind cooling effect and night condensation added extra yield.

**6. Limitations**

**Methodological Constraints:** Limited experimental runs (seasonal).

**External Factors:** Fabrication material costs, climatic variations.

**7. Conclusion**

**Summary of Key Findings:** Pyramid still geometry enhances energy and thermo-economic performance.

**Practical Contributions:** Provides low-cost, sustainable design for decentralized desalination.

**Theoretical Contributions:** Extends exergy-economic analysis framework to new solar still configurations.

**8. Future Work**

**Recommendations:** Study long-term durability, hybrid integration with PCM/nanofluids.

**Applications:** Community water supply, small industries, emergency relief in water-scarce zones.

**10. References**

**Reference List:** Use SCI-approved style (Elsevier/IEEE).

**Citation Quality:** Peer-reviewed, recent (<10 years preferred).

**11. Appendices & Supplementary**

**Additional Data:** Hourly temperature/productivity data.

**Algorithms & Code:** Modeling equations in MATLAB/Python.

**Extended Figures:** CAD drawings, experimental setup photos.