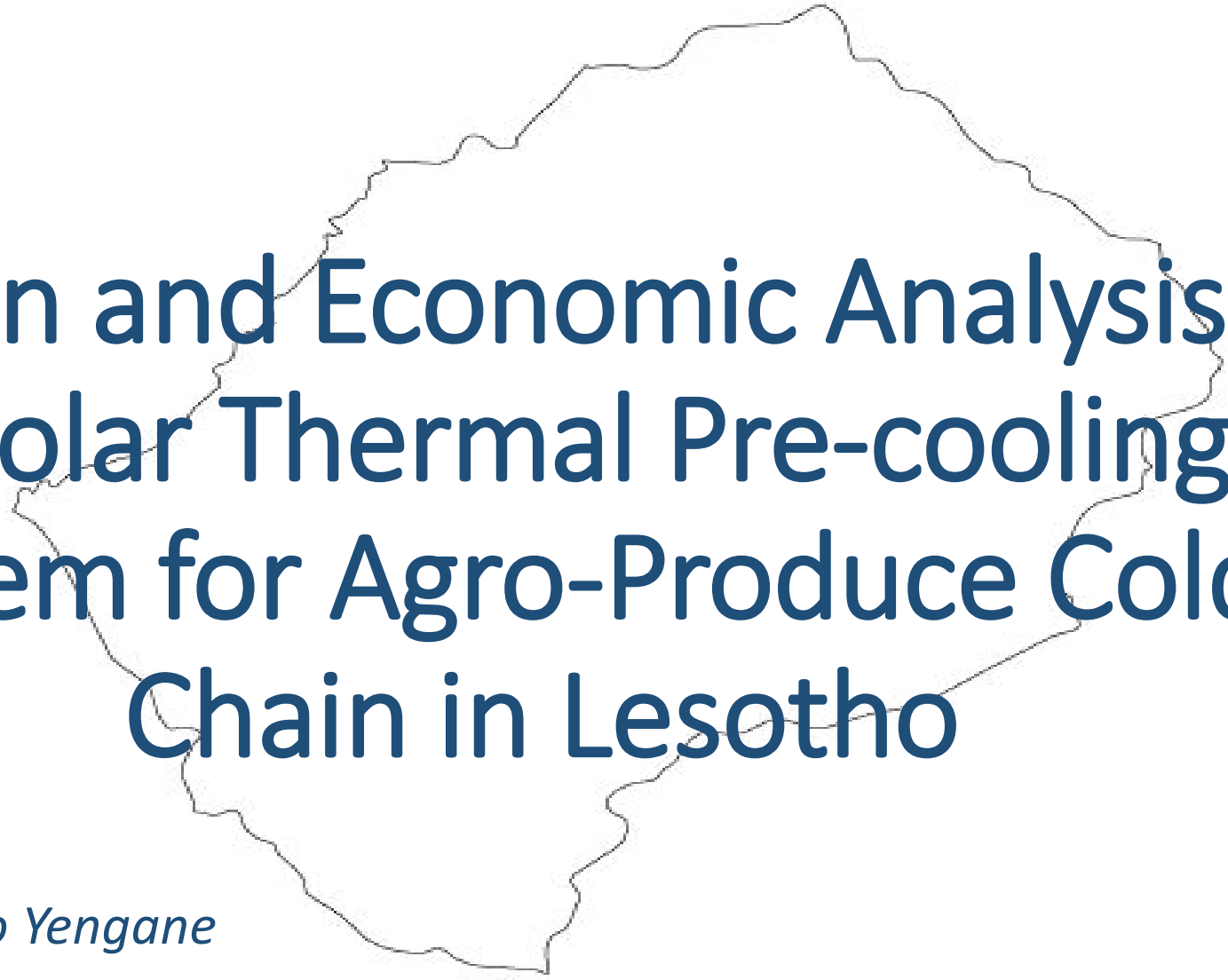
ISEC 3rd INTERNATIONAL SUSTAINABLE ENERGY CONFERENCE 2024

SOLTRAIN Southern African Solar Thermal Training & Demonstration Initiative



Design and Economic Analysis of a Solar Thermal Pre-cooling System for Agro-Produce Cold-Chain in Lesotho

Name: Mpho Yengane

Institution: Energy Research Centre at National University of Lesotho

Co-Authors: M. Mpholo, S. Mokeke

Date: 10.04.24

Presentation Structure

- Problem statement, Research Question & Objectives
- Literature Review & Gaps
- Research Methods
- Findings
- Conclusions, Future Work & Recommendations

Problem statement, Research Question & Objectives

Problem Statement:

- Prelude
  - Agriculture contributes 17% to GDP in Lesotho.
  - Over 70% of Basotho rely on crop production for food & income.
- Lesotho faces 30-40% post-harvest losses
  - Exacerbating 49.7% poverty rate.
- Traditional cold storage is costly, impacting small-scale farmers.
  - Electricity Cost: $50,000 per 20 m^2 p/a.
- Solar thermal cooling not implemented due to awareness gaps, lack of research, & financial constraints.

Problem statement, Research Question & Objectives

Research Question:

- What is the feasibility (design, integration, & economic impact) of solar thermal refrigeration in Lesotho's agro-produce cold chain?

Objectives:

- Evaluate potential for solar thermal pre-cooling in agro-produce cold-chain
- Design technically efficient & cost-effective system (Considering Collector efficiency, Coefficient of performance, Solar fraction, Exergy efficiency & Primary energy savings).
  - Achieve 0-12°C pre-cooling for vegetables
- Evaluate economic benefits (Using Levelized cost of energy, Net present value, & Discounted pay-back period).

Literature Review & Gaps:

Gaps

- No Lesotho-specific studies (Also limited studies in SSA).
- Economic viability unclear, especially for farmers.
- Focus is mainly on HVAC.
- Existing Studies lack design & economic analysis (Only Socio-Economic).
- Implementation in Kenya showed better economic performance for B to B model – 30% profit margin

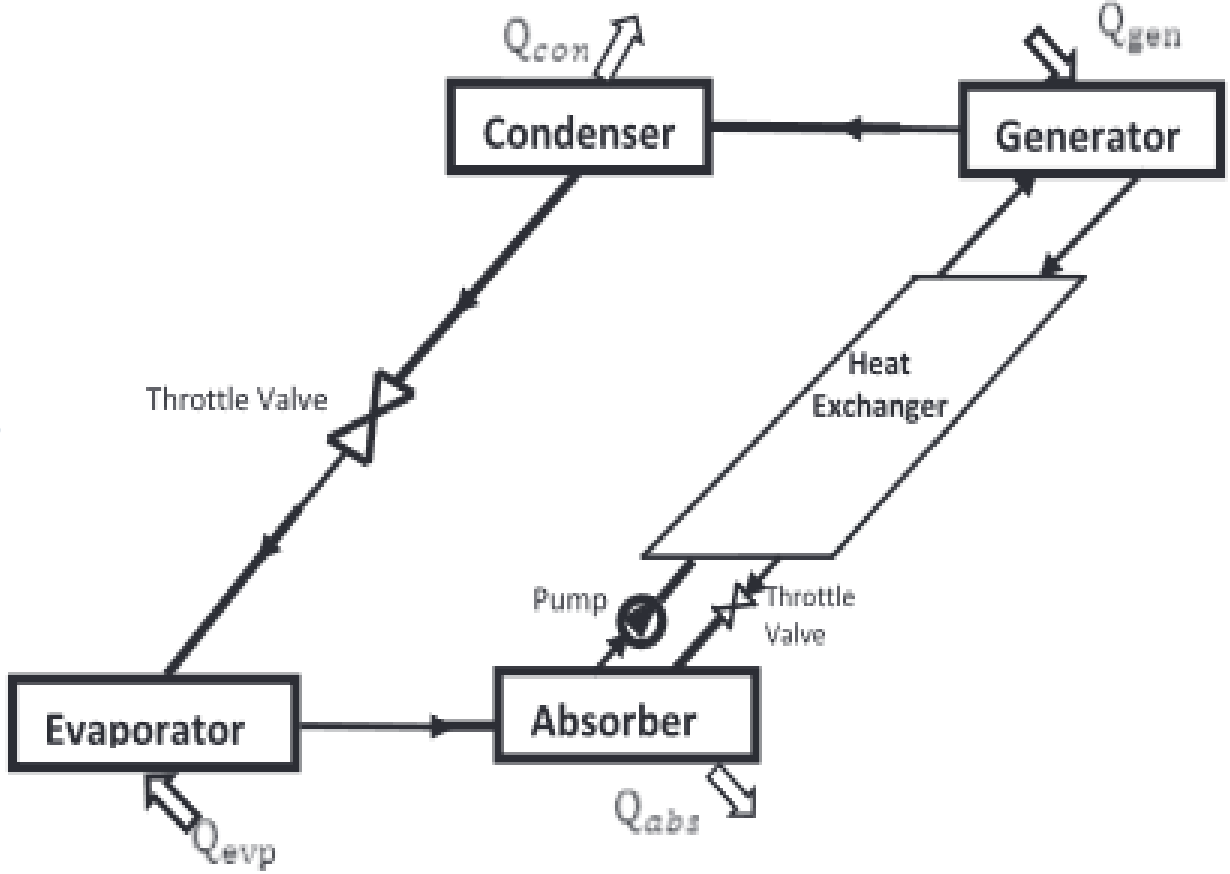
System Design: *Cooling Technology*

Coefficient of performance (COP): Ratio of useful heating or cooling provided to work (energy) required.

*Only COP values from 0.5 – 0.8 used

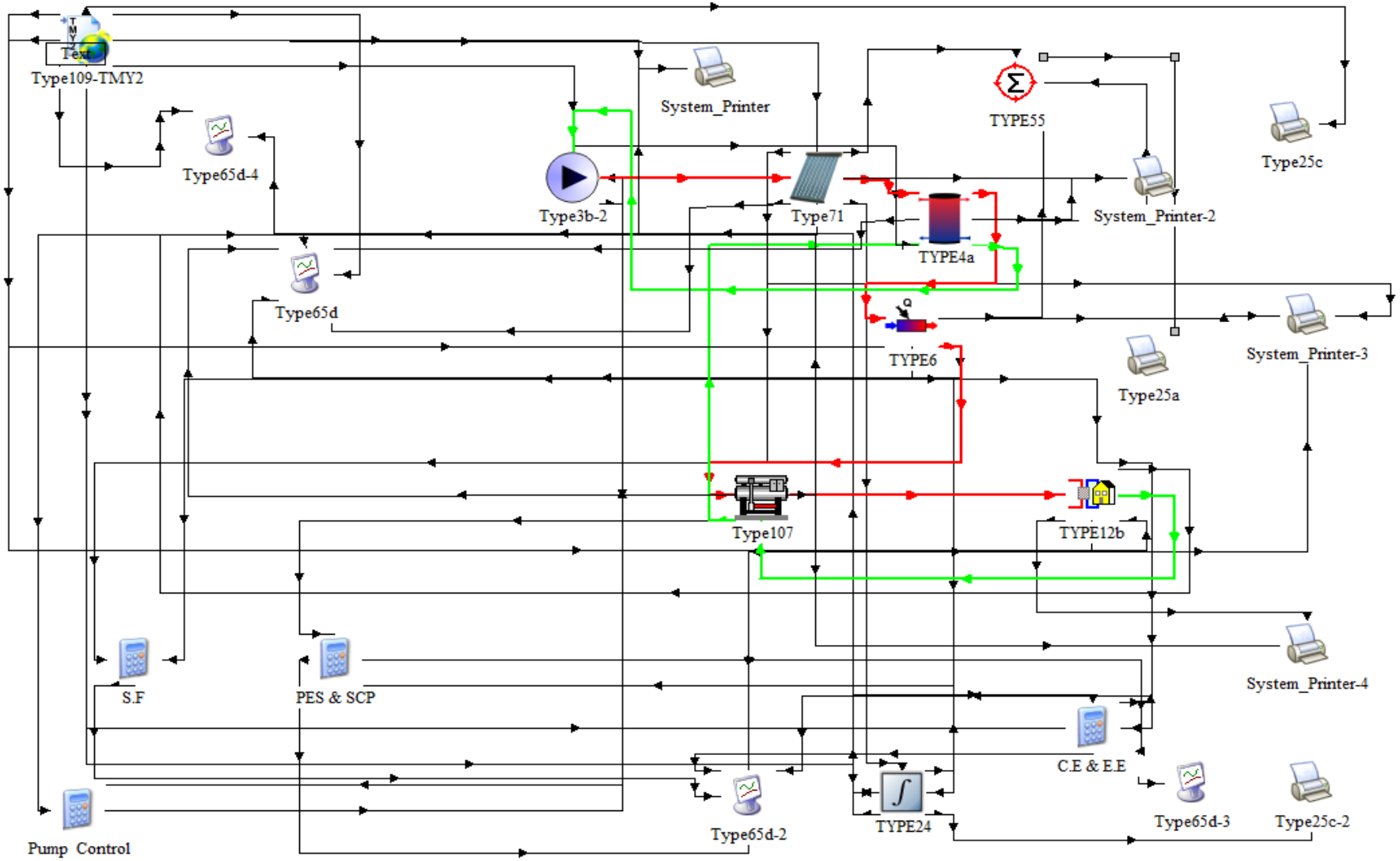
- Desiccant Cooling (Low COP)
- Adsorption Cooling (Low COP)

✓**Absorption Cooling (High COP**



Research Methods: *Configuration*

TRNSYS Schematic



Research Methods: *Sizing*

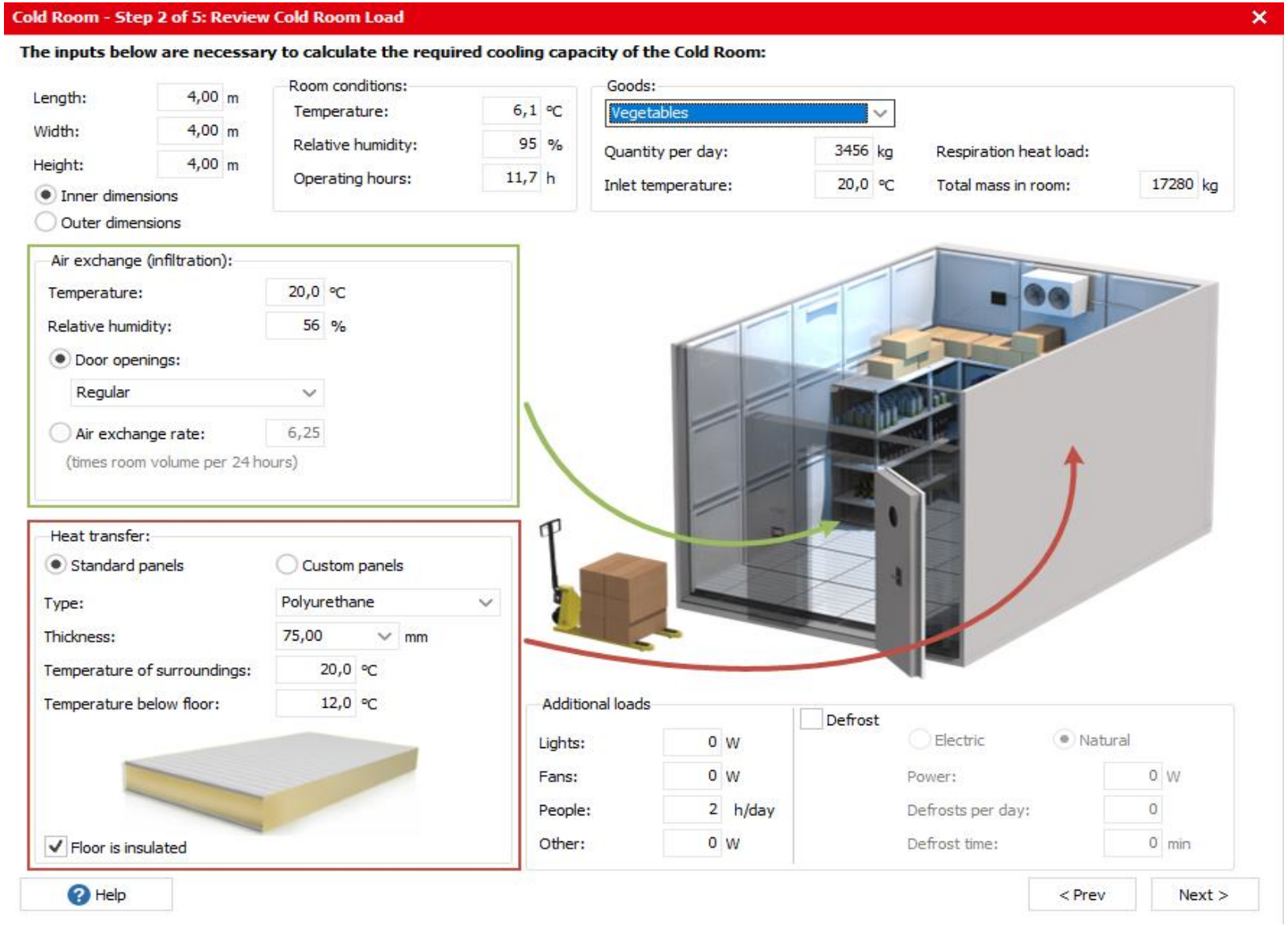
CoolSelector Sizing

Gives a visual representation of the cold-room

- Cooling requirement:

  7.318 kW

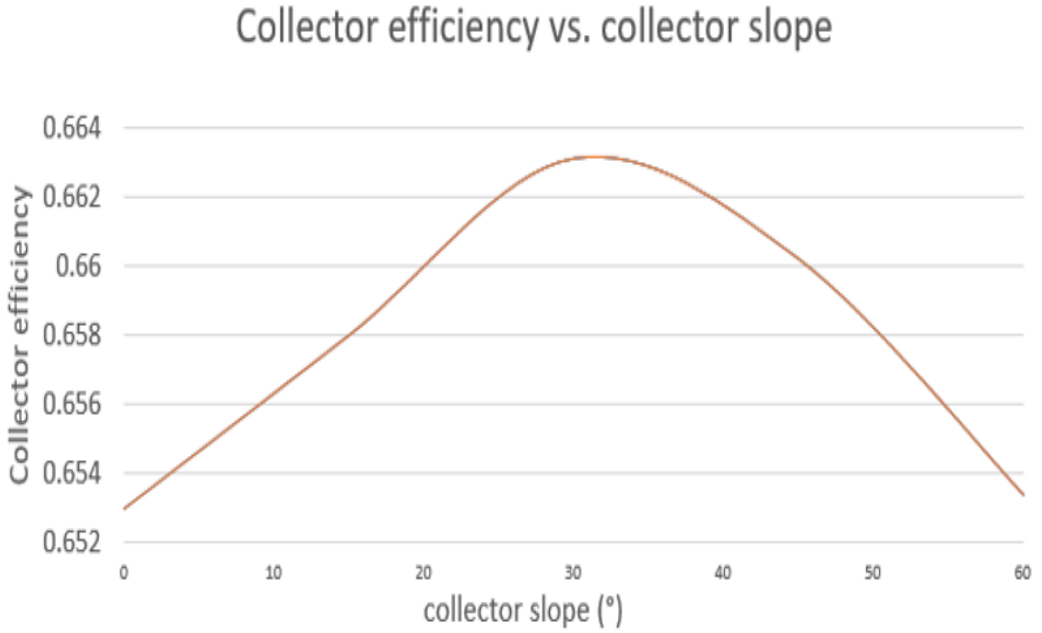
- Target Produce:
  - Tomato
  - Green beans
  - Green pepper
  - Cabbage



Findings: *System Performance (1)*

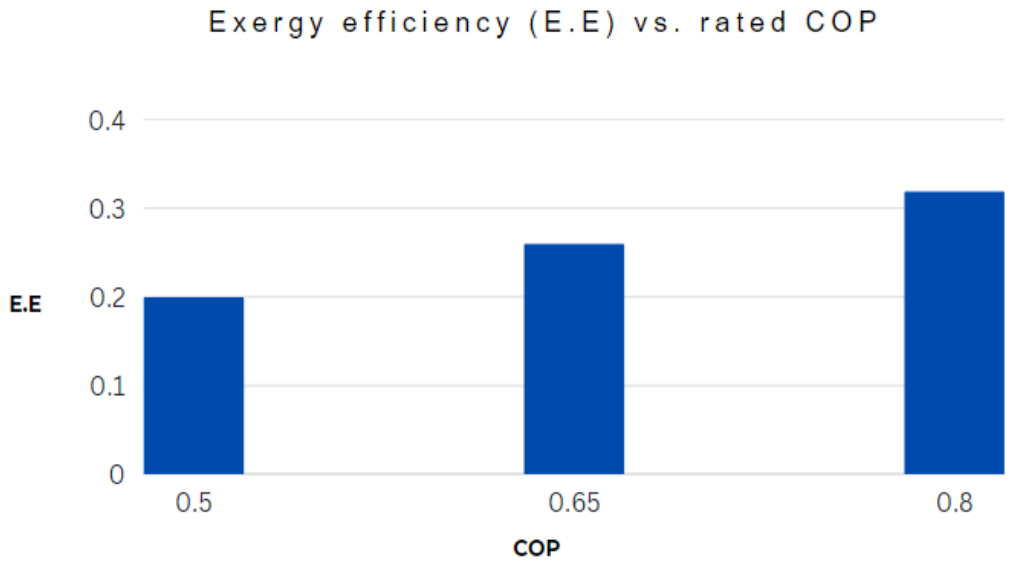
Collector efficiency (C.E): Ratio of the energy produced in the form of heat by the collector to the total solar energy received by it.

- Highest Collector efficiency at 30°



Exergy efficiency (E.E): Evaluate the effectiveness of the system relative to an idealized or reversible system equivalent

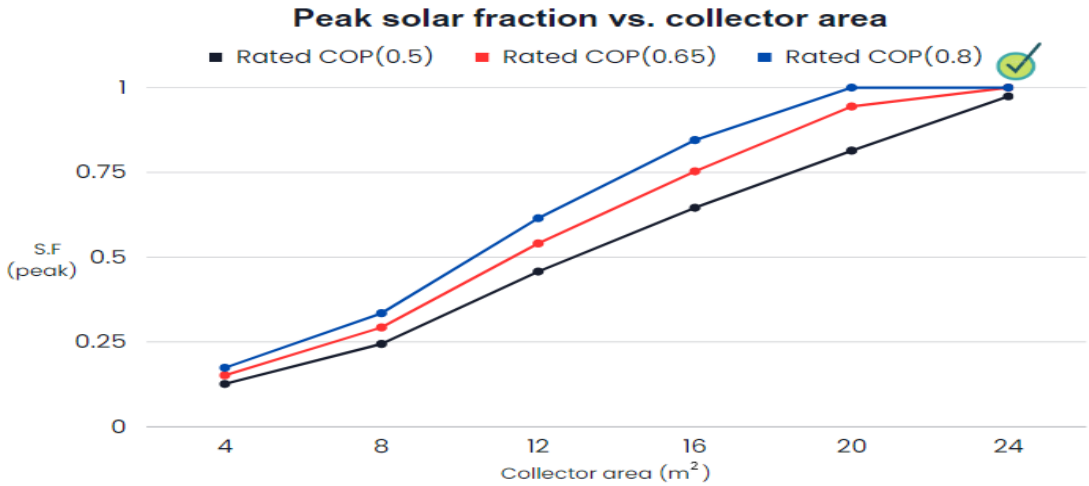
- High COP => High E.E



Findings: *System Performance (2)*

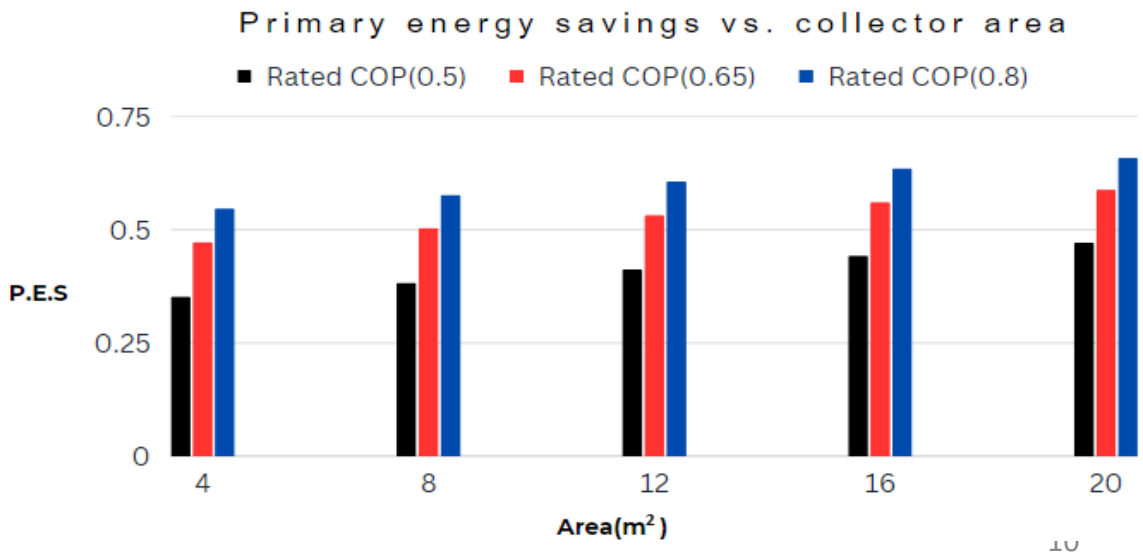
Solar Fraction (S.F): Fraction of energy requirement contributed by solar thermal energy

- Larger Collector Area => High SF
- High COP => High SF



Primary energy savings (P.E.S): Energy saved with reference to traditional source (Electricity)

- Larger Area => High PES
- High COP => High PES



Findings: *Economic Analysis (LCOE)*

Levelized cost of energy (LCOE): Cost of energy associated with the generation of solar energy for cooling

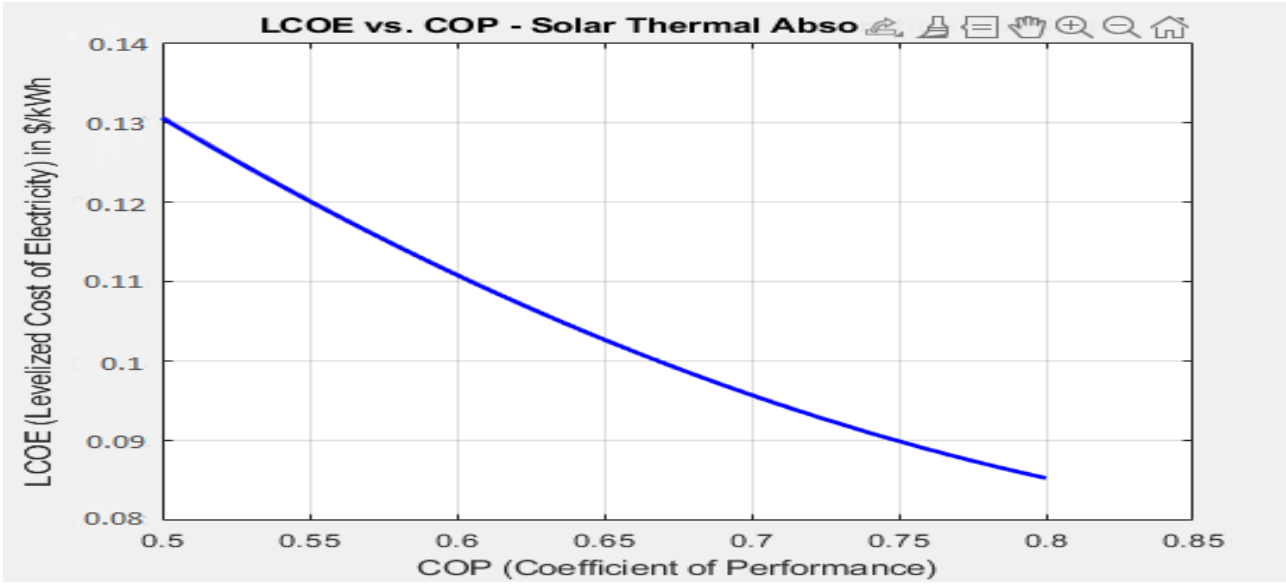
- Lowest LCOE (COP=0.8)

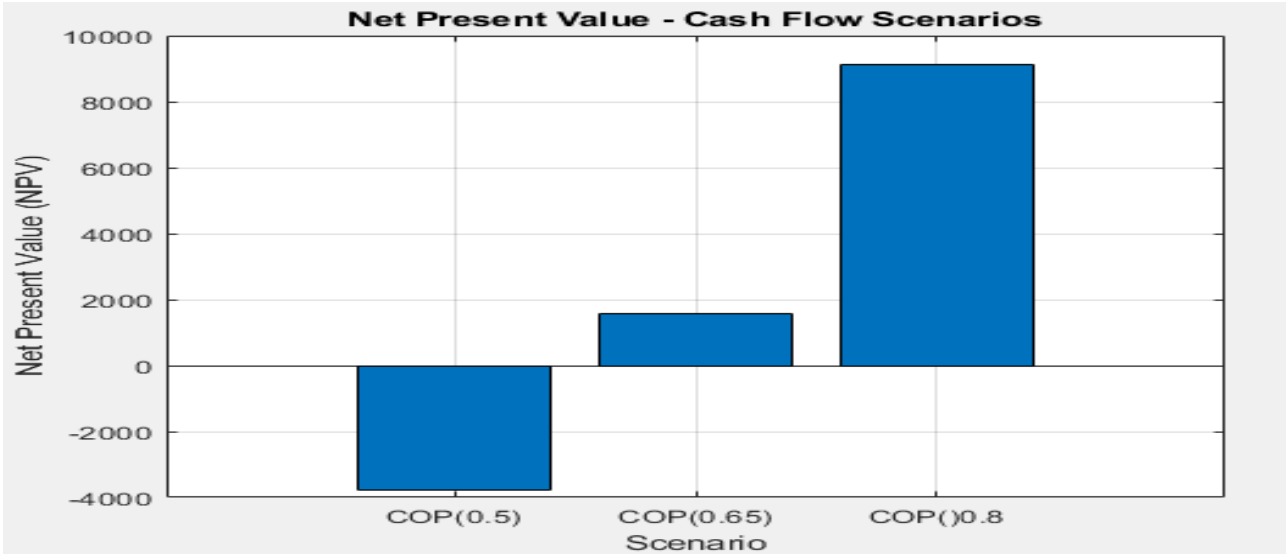
=$0.085/kWh

Net present value (NPV): Represents the present value of the system's future discounted cash flows

Highest NPV (COP=0.8)

=$9,200



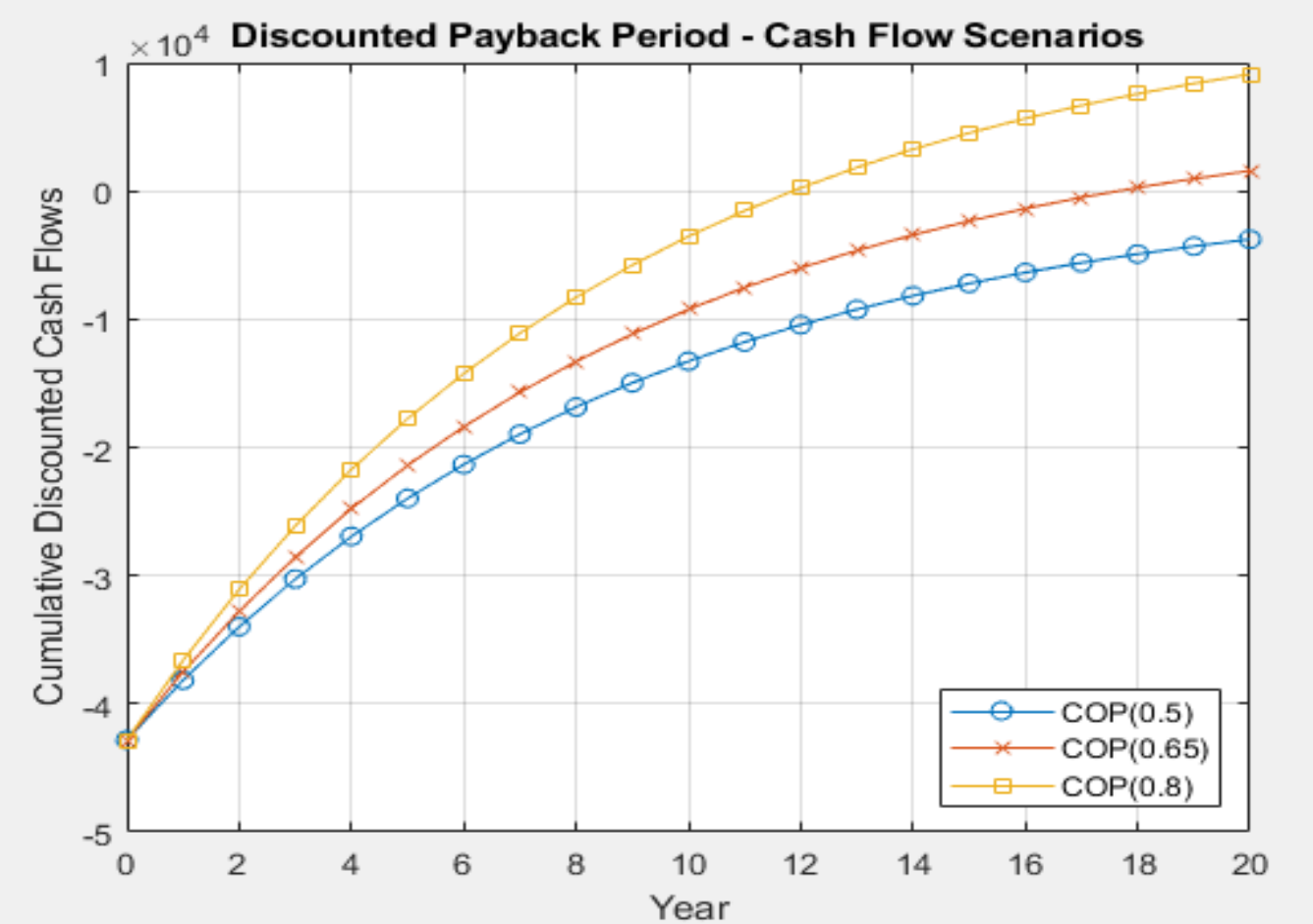


Findings: *Economic Analysis (DPP)*

Discounted pay-back period (DPP):

Gives the number of years it takes to break even

- Payback in 12 yrs (COP=0.8).



Conclusion, Future Work and Recommendations:

Optimal Configuration:

- COP = 0.8, collector area = 12 m^2, hot storage volume = 0.2 m^3.

Financial Feasibility:

- **LCOE:** Achieved $0.085/kWh .
- **NPV:** $9,200, Highest.
- **DPP:** Shortest DPP of 12 years.

Financial Viability: Potentially profitable investment for Lesotho cold-chain.

Cost-Effective Operation: Emphasis on lower LCOE & shorter DPP for early break-even.

Recommendations for cost effectiveness

- Scaling Up, Advanced Technologies, Local Manufacturing, Proactive Maintenance, Government Incentives

Future Research Direction

- Advanced Optimization Techniques, Dynamic Models, Thorough Market Analysis, Real-World Implementation

ISEC 3rd INTERNATIONAL SUSTAINABLE ENERGY CONFERENCE 2024

SOLTRAIN
Southern African Solar Thermal Training & Demonstration Initiative

THANK YOU

For Further Interest

email: mphoyengane@gmail.com

N U L
Energy Research Centre

'NETE KE THEBE